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Thank you for offering us the opportunity to contribute to the review into post-16 mathematics provision in England. Our submission begins by outlining the background to our 'art school' mathematics initiative before responding to the formal review questions.

FAMC background

Fine Art Maths Centre was established at Central Saint Martins (CSM) in October 2014 after a pilot in the previous academic year.

CSM is a specialist art and design college, part of University of the Arts London. FAMC was the first centre in such a setting to be part-funded by Sigma, the network for excellence in mathematics and statistical support. (Sigma is funded by HEFCE and usually supports engineering, economics, business and social science undergraduate students with quantitative skills).

FAMC has pioneered innovative, 'practice-led', 'no-prerequisite' study in mathematics open to all undergraduates and postgraduates on courses in the School of Art at CSM. Our offering currently comprises one-to-one tutorial support and the following short courses (each taking up a total of at least 12 hours' classroom time):

- Euclidean Geometry
- Perspective and Projective Geometry
- Non-Euclidean Geometry & Topology
- Introduction to Computer Programming
- Infinity

Our orienting idea is that artists increasingly look to mathematics to help them produce artworks, particularly given the prevalence of digitally-oriented art practice, but find themselves thwarted by decisions made when younger. Most of our 'home' students abandoned mathematics as soon as possible and chose post-16 options suited to applying for art and design courses. In a 'monotechnic' like CSM, where no academic staff from quantitative disciplines are employed, it would be otherwise next to impossible to return to the study of mathematics or quantitative skills.

FAMC's primary aim is to create mathematics provision that sits naturally within the students' disciplines and practices and as far as possible aims to offer a 'no prerequisites' entry. Our approach exposes them to challenging and unexpected ideas, but also provides technical grounding when appropriate. Ideally, artworks are then produced which would otherwise not get past initial ideas.

Sigma-funded centres are normally based on an academic support model, helping students who encounter difficulties with the mathematics and statistics embedded in their degree programmes. Most centres are based on offering provision to Business, Economics and Engineering students, where mathematics components are a compulsory part of their degree course.

FAMC was the first centre funded by Sigma in the Arts or Humanities. But, more importantly, FAMC is the first centre not to work with a 'deficit' model for mathematics support. Our students have no compulsory mathematical or quantitative components in their studies, and so do not come to us because they are failing or struggling with their curriculum.

In fact, CSM students do not have a curriculum in the way that other academic disciplines do - they are encouraged to develop their own art practice over the course of their studies and in effect 'set the test they undergo' (BA Fine Art students receive their degree classification based on their final degree show and a dissertation on a topic of their choosing).

Our provision at present is therefore oriented in two practical ways:

(i) Supporting students who have specific questions and demands through one-to-one tutorials;

(ii) Running short, extra-curricular workshops covering technical areas where unsupported self-study is difficult or to expose students to mathematics that would otherwise pass them by.

We believe our workshop courses are popular because they offer some structure in a degree course that tends to leave students to work independently and because we have responded to authentic needs and interests rather than imposing a preconceived set of topics.

FAMC's courses are not assessed and fall outside the formal curricula. This has allowed us to be flexible and agile in response to student demand. Students participate for no other reason than that the courses are engaging and always directed to encouraging art practice. In each year so far, at least 1 in 7 of the 400-strong Fine Art cohort has been to a tutorial or one workshop session. We believe this is a surprising and encouraging participation outcome in itself.

Questions

1.What is your view of the mathematics and quantitative skills young people have when they enter employment or higher education?

Students have not been exposed to a sufficiently broad range of mathematics and have a too narrow conception of the subject and, crucially, what it means to be 'good at' mathematics (which can mean a mastery of a broad range of calculation-based techniques with very shallow understanding). Almost all of school mathematics material is at least three centuries old, which often becomes an issue when dealing with issues and ideas thrown up by the contemporary world and, of course, when attempting to work critically and creatively with modern technology.

In particular, Art students lack familiarity with geometry and logic. Many would have benefited from being exposed to some ideas associated with modern mathematics; many find axiomatic systems and foundational questions appealing. A systematic study of geometry provides a foundation for

thinking about and working with space that the disconnected fragments that remain on the GCSE syllabus do not provide. We note that students who have gone through school systems outside the UK often (though not always) have much stronger knowledge in this area and are familiar with relevant computing packages (for instance, French students are now using geogebra routinely in their final two years).

We believe that more exposure to logic, broadly conceived, and its place in programming, deduction and practical reasoning would benefit most HE students, especially (but not only) across the arts and humanities.

2.What basic level of mathematics and quantitative skills do businesses and higher education need school leavers to possess? Do leavers meet those levels now?

3.Are there sufficient school leavers with advanced mathematics and quantitative skills for the needs of business and higher education?

4.Does post-16 maths provision need to change to better meet current requirements? How?

The problem of “two cultures” is familiar, and participation in maths education by arts and humanities students in the UK is low. Given the options available, this is hardly surprising: maths as it is presented at 16-19 is oriented towards either mundane functional skills or preparation for STEM study, dominated by algebra and calculus. While functional skills are important for everyday life, arts and humanities students who have attained a C at GSCE currently have little inclination or incentive to continue with mathematics as a subject. Curricula appear uninspiring and largely irrelevant to students' other studies, interests and future ambitions.

There is very little choice on offer and for many students post-16 initiatives will be 'more of the same' and perhaps even less appealing than what they studied pre-16. There are over 150 000 Art & Design students studying in Higher Education in the UK – our experience suggests there are large areas of mathematics that would be useful, relevant and appealing to them if only they could encounter them at the appropriate level.

One could even say that the traditional post-16 maths syllabuses that dominate pre-university study appear irrelevant to creative practices and industries. They emphasise calculation and algorithmic procedures that provide correct solutions to problems that rarely present themselves in creatve contexts. To achieve this in a reasonable time, they generally forego understanding or explorative and creative problem-solving. Even if the mechanical approach is still appropriate for some learners, it is surely not the only one we need in the twenty-first century.

If more students are to engage with mathematics beyond GCSE, there will have to be an offering that is relevant and appealing to them. This will require an ambitious vision that seeks inspiration from them whole breadth of mathematics without being bound by what has been done before.

Our work at FAMC has a focus on drawing-led and visual methods of engaging with mathematics. We focus on twentieth century mathematics that lies far outside numeracy and functional skills; yet our students have no prior mathematical expertise.

Topics we believe are relevant for many creative practitioners and industries in the twenty-first century include geometry, programming, group theory and symmetry, abstract algebra more broadly, graph theory, probability and game theory, linear algebra, topology and set theory. It is possible to teach these traditionally 'advanced' subjects at a suitable level, but there has to be a will to do so; devising and testing curricula of this kind requires investment.

5.How do you see those requirements changing in the next 5-10 years?

In the next decade, university Art courses are going to have to come to terms with the revolution in computing power and digital technology - they won't be able to shunt students interested in these developments off to other courses such as Animation and Game Design. The same effect is already being felt in other creative fields, especially music. The creative industries will need and value graduates who have the abstract thinking, modelling and problem-solving skills that an ongoing engagement with maths fosters, as well as specific mathematical skills and understanding relevant to their field.

6.How should post-16 maths provision change to meet those future requirements?

At the very least, students will need to develop basic competence in programming and the manipulation of virtual environments. Mathematics and logic underpin these competences, but a wide variety of other mathematical subjects feed into them as well: networks, algorithms and coordinate geometry are a few obvious examples.

GCSE students today study almost none of this material, but they *are* required to demonstrate how to express bearings when sailing a boat and how to perform arithmetic operations that, in reality, everybody does with a calculator (or, more often, the phone in their pocket). If the UK wishes to produce 16-year-olds who are in any way prepared for the twenty-first century, this will have to change.

7.Is there a case for more (or all) students to study maths after the age of 16? To what level?

Yes, but the current picture of a compulsory 'core mathematics' course that sits to the side of their main studies and repeats in more detail with practical applications what they have seen at GCSE will not do. 16-19 maths must be relevant to the students' studies, their ambitions for the future and their interests; it must also reflect something of modern maths and the technological world it has helped create.

We have found that, despite their absence from traditional curricula, the topics most relevant to art students often lie at the core of modern mathematics. Incorporating these topics in their study can bring multiple benefits: alongside domain-specific knowledge and technical skills, students learn transferrable skills in reasoning, problem-solving and abstract thought. They also learn what GCSE

maths might not have taught them: that maths can be interesting and intellectually exciting, and is open to anyone.

For arts and humanities students, we recommend a focus on geometry, logic, reasoning and mathematical ideas (e.g. infinity and the nature of the real numbers). These may not normally be considered under notions of numeracy and 'quantitative skills' but the general relevance of logic and forms of reasoning and axiomatics represent a very suitable compromise for post-16 study.

We also note that such students often find the historical and philosophical background to some mathematical ideas helps them contextualise them and relate them to their other studies. This kind of material is usually conspicuously absent from existing pedagogical practice. Indeed, would-be artists and designers are currently being deprived of the intellectual underpinnings of important components of the history and culture of art and design. Euclidean geometry is central to Islamic design and Gothic architecture; projective geometry is intimately connected to linear perspective. No Home students appear familiar with these mathematical dimensions. Straightedge and compass constructions are touched on in GCSE mathematics but in deracinated and emaciated form. We also find that students who have been taught some 'perspective' only have a smattering of foreshortening techniques and no familiarity with the geometric principles underpinning Renaissance innovations in depiction. This is not always the case with international students.

8.Please add any other comments or evidence you would like us to consider.

In addition to our work at CSM we have also devised a year-long programme based in the Humanities department at London's City Literary Institute. This comprises three 12-week courses: Philosophy of Mathematics, History & Philosophy of Calculus and Philosophy of Infinity. There are no prerequisites for these adult education courses, though we do offer an introductory course for those new to philosophy and a number of very short ‘taster’ courses:

http://www.citylit.ac.uk/courses/philosophy-of-mathematics-and-logic
http://www.citylit.ac.uk/courses/philosophy-and-history-of-calculus
http://www.citylit.ac.uk/courses/philosophy-of-infinity

The courses are very popular and are frequently sold out; formal feedback suggests that many students rediscover an interest in maths after dropping it at 16 and following an arts or humanities route; that decision effectively cut them off from the subject, a situation we believe is extremely undesirable.

These courses have taken topics normally considered suitable only for advanced undergraduates. We aim to make the ideas and consequences of them accessible to a general audience without the need for long, technical apprenticeships.

We feel that this material would also be suitable for a post-16 qualification designed to for arts and humanities students, who are interested in the ideas associated with contemporary mathematics but who don't wish to devote themselves to calculus.

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