PROPOSAL FOR NEW ADDITIONAL FUNDING OF UK MATHEMATICS

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Foreword. Mathematics is a fundamental human activity which is at least 5000 years old and thriving and most impactful as never before. Mathematical achievements are among the longest to be kept in the memory of civilisations. School children learn the names of Pythagoras, Euclid and Diophantus. Some of new maths discoveries are so groundbreaking as if they come from the future of many years ahead.

Mathematics includes pure mathematics, statistics and applied mathematics. It plays increasingly fundamental role in optimisation, financial markets, banking system, cryptographic methods, traffic flow control, quantum computing, defence and security, cybersecurity, transmitting internet data, weather forecasting, computational modelling, machine learning, artificial intelligence, advanced algorithms, decision-making under uncertainty. Demand for the mathematical sciences is growing.

Mathematical mindfulness is one of strategic aspects of successful modern society. It is remarkable that mathematics for these applications resulted from merely curiosity driven fundamental research, with the actual applications (as well as enormous economic and societal impact) emerging only many years later. However, all those future applications were typically not original motivations behind important mathematical developments.

New fundamental societal changes related to the ongoing technological revolution and increasing use of AI are coming, and only those countries which invest now more in mathematics can continue to be prosperous and successful. Many leaders mention that without increasing mathematical mindfulness of the population inevitable problems with employment in sectors where AI replaces humans may lead to drastic consequences.

To make ourselves the leading country for education and science, we must start with mathematics. Its research does not require huge laboratory and equipment costs typical for other natural sciences. With relatively small new investment we can fundamentally revitalise our maths research and get a huge return. A rate of return on investment as benefit-to-cost ratio may be estimated as follows: Engineering 88, Physics 31, Chemistry 246, and Mathematical Sciences 588[1].

To reach to new fundamental discoveries and theories one cannot proceed via incremental and technical improvements of existing results or in a linear way. One has to engage in a courageous and highly risky exploration needed for genuine breakthroughs. Greatest maths achievements can be compared, in terms of their impact on our knowledge, with a Moon landing, but, unlike space exploration or artistic achievements whose significance can be recognised and appreciated by millions, top achievements in mathematics can be comprehended by smaller numbers.

The main resource, our national treasure, people, are already here. The UK is incredibly rich in potential maths talents. Future maths talents are among our children and grandchildren. Our task is to help them develop,

Date: July 2019–January 2020, see also https://ivanfesenko.org/wp-content/uploads/2021/10/ct-1.pdf.

[1] Ph. Bond. An Independent Review of Knowledge Exchange in the Mathematical Sciences, 2018, EPSRC, https://admin.ktn-uk.co.uk/app/uploads/2018/04/KE-booklet-for-web.pdf

support and encourage in their study of mathematics and its applications. And then we will get new 'Newton's, 'Ramanujan's, 'Turing's.

However, *UK maths has been hugely underfunded*[2]. We must invest in our future to support young maths talents now. We are experiencing the lack of well educated mathematicians[3], to work in our high tech companies, to successfully develop UK unicorn start-ups. *By increasing and modernising its funding of mathematics, the UK has the greatest opportunity to stimulate and support stunning revolutionary discoveries, fundamental research that will matter for centuries.* Unlike many other areas, in maths one can move from investment to productive phase quickly as we do not need to build something first.

We must modernise how and where we invest in UK maths. This requires an appropriate scale of investment and financial support made available, and dedicated people to conduct required activities in a novel and flexible way to successfully deal with the modern challenges. This includes proposed below changes in the length and type of PhD studentships and postdoctoral positions, to make them not only internationally competitive but truly internationally leading, to attract best talents. This includes nurturing and properly supporting pioneers in mathematics in their fundamental breakthrough work. This includes helping mathematicians to constantly extend their range of expertise and work intra-disciplinary. This includes building a new architecture of maths research, with many horizontal links between research groups in different universities, unifying all of UK mathematics in a productively operating system which is stronger than the sum of its component.

This includes fundamental changes in the way the maths programme of EPSRC operates and fundamental improvements in processing maths grant proposals by EPSRC[4]. If such changes are not implemented, the new additional funding for UK mathematics may be wasted. For many years EPSRC has been failing to properly support British mathematical research. Unlike all other R&D countries, EPSRC is the only research council which does not involve scientists as its members.

This proposal, following a request from No 10, asks for new additional investment in

- 150 or more PhD studentships of new type annually, each 4-5 years long
- 100 postdoc fellowships of new type annually, each 3-4 years long
- 4 advanced fellowships annually for future 'Newtons', each 8 years long
- doubling the volume of EPSRC grants for UK mathematicians, increasing the number of longer-term grants of programme grant type and the number of small grants

The budget of the new additional funding of advanced UK maths is £60m per annum.

With the growth of UK maths, other UK sciences and ultra-modern industries will grow too, in particular because they will be getting researchers that are much better educated in modern maths, including their pioneering insightful skills. Mathematics is intensively used by all other natural sciences, and the new investment in the UK maths will positively improve research in other natural sciences. Taking our maths to new heights will also fundamentally increase the influence of our higher education and this country worldwide.

Parts of this proposal have been discussed with many mathematicians, in the UK and overseas, on numerous occasions for a number of years and they take into account their constructive remarks. The author of this

[2] The Bond report asks to triple the funding of UK maths, see footnote 1

[3] 'Skilled mathematicians of a high calibre are needed and they are in short supply', from the Bond report cited in footnote 1

[4] Various problems are listed in the Bond report, see footnote 1

proposal also relies on his intensive international research contacts and knowledge of mathematical environment in many other countries.

1. Supporting maths PhD students. Key problems here are well known. No other mathematically leading country has such a small period of funded PhD studentships, 3-4 years, as the UK. The length of PhD studentships in the USA is 5 and even 6 years. Modern maths requires at least 4-5 years of PhD study, and it is most fundamental for us to have 4-5 year long funded PhD courses. In most other countries PhD students are actively involved in moderate teaching, thus becoming genuine members of academic community and acquiring the most valuable experience of teaching during their PhD years. Typical US PhD students teaching duty is 6 hours of teaching per week in each semester starting from their 2nd PhD year. The current UK system of PhD studentships does not properly support young talents, does not give them enough time to develop, forcing them to be internationally non-competitive. We should feel guilty that most recipients of PhD maths degree in this country know so much less than recipients of PhD degree in other countries. We also experience the shortage of PhD students.[5] The size of living costs on PhD studentships deteriorates in real terms. Most UK universities do not count teaching of PhD level courses, including running study groups, as part of teaching duty of their staff, so it remains a purely voluntary unpaid activity.[6] As the aftermaths, our PhD students in most universities get a very small amount of education (attending lecture courses) at the PhD level. Some universities teach to each other some small PhD level courses online, but this is very little. We can use the best tested with time features of the US academic system to run PhD studentships more successfully.

Proposal 1. *Provide new funds to EPSRC to run new maths PhD studentships*. They will be awarded to 150 or more top applicants each year. Their annual allocation to maths departments (and then maths departments deciding which applicant to award) will be decided by a special panel including most successful supervisors of PhD maths students. The panel will take into account various factors such as the total size of EPSRC maths grants during a certain previous period to a maths department, the observed quality of work with PhD students, the current numbers of PhD students, other existing sources of PhD studentships such as local CDT, etc. New maths PhD students will be encouraged to conduct some teaching (up to 3 hours a week) in the last three years of their PhD course.

With the extended period of 4-5 years for PhD studentships, it is even more important that teaching at PhD level becomes official part of academic duties. *Suggest that all UK maths departments start to count as part of teaching duties such crucial activities as teaching PhD level courses, including running study groups.* Since PhD students will be teaching in their last three years, teaching PhD courses by permanent staff as part of their teaching duties is not expected to create significant problems in terms of overall teaching duties of staff.

Improving the quality and length of PhD maths studentships in the UK will attract more international students coming to study in the UK with fully funded studentships from their countries. The UK PhD maths courses can, if the proposed reforms are implemented now, attract best candidates worldwide to come to study here.

2. Supporting maths postdoctoral researchers. Problems here are also well known. No other mathematically leading country has such a small supply of postdoctoral fellowships or their replacements. Not having

[5] EPSRC Mathematical Sciences Strategy Workshop, Report on outputs and next steps, March 2019, `https://epsrc.ukri.org/files/newsevents/ms-strategy-workshop-report-mar19-pdf/`

[6] In the last 20 years the author of this text has taught and organised 20 PhD level courses and study groups, none of which was counted as part of official teaching duty.

enough postdoctoral positions means destroying and wasting outcomes of our work with PhD students. In most other countries postdocs are actively involved in moderate teaching, thus becoming genuine members of academic community and acquiring the valuable experience of teaching. When those overseas postdocs apply for tenure track/permanent jobs, they are in a much more advantaged position in relation to their teaching skills than UK postdocs. The current UK system of postdoctoral fellowships does not properly support young talents, does not give them enough time to develop, making them internationally non-competitive. In addition, the UK is lagging behind many other countries in terms of female maths postdocs.

In 2017, 34% of maths postdocs were supported by EPSRC funding, 16% of postdocs were supported by EU funding.[7] UK departments have a small number of their own postdoc fellowships in comparison to countries such as the US, while in Germany the standard way to fund a postdoc for the period of 3+3 years is to hire them as temporary teaching assistants. Compare 6 years in Germany with 2 years in the UK. We should do so much better for our young mathematicians. And UK postdocs are paid less and less in comparison to other countries.

Proposal 2. *Provide new funds to EPSRC to establish new special international postdoc fellowships*. They will be awarded to 100 top applicants each year, each fellowship is 3-4 years long. They will have some teaching duties (seminars or lecture courses, up to 4 hours a week). This agrees, as far as the EPSRC share is concerned, with the proposal 'Government and universities should create, at a minimum, 100 additional PhD places per year dedicated to training mathematical scientists looking to generate impact with their work. These PhDs should have a greater emphasis on breadth in training, with business and computer coding skills included in addition to deep mathematical expertise' in the Bond review, see footnote 1. Their annual selection will be the responsibility of a special panel including most successful supervisors of postdocs in the previous 10-15 years in terms of their postdocs maths contributions and further academic career.

3. Supporting promising young researchers. Research developments in mathematics can be approximately compared with a large tree. There are fundamental developments that have already become wide branches of the tree or will become wide branches in due course. Secondary (in the long run) developments will never become wide branches or many won't stay long as living branches. Some of the secondary developments may be and often are mistakenly perceived by contemporaries as primary developments. Too many efforts of UK mathematicians are spent on secondary developments. Larger numbers of modern researchers work more or more narrowly. This typically means to concentrate and reach a high level of technical expertise in a small area, at the same time having little understanding about what is going on other branches, including primary branches. This means losing the overall perspective of the place of one's research work in the tree of mathematics. Some roots of the decline of support to long-term fundamental work, such as the shortsighted race to higher number of publications and higher citation index, which often results in pressure to produce short-term work that consists essentially of minor improvements to known results, originate from causes external to the mathematical community. Younger mathematicians bear the brunt of this short-sighted race and other related aspects. People are losing the enthusiasm and passion for long-term research and exhibit most pragmatic attitude to what and when to study in mathematics. They are forced to specialise quite narrowly, which leads to the emphasis on technical perfection as opposite to innovation and on presentation rather than substance of work. Associated issues are lack of inventiveness, fear to look too far away or think non-linearly, more widely

[7] London Maths Society Survey `https://www.lms.ac.uk/sites/lms.ac.uk/files/files/2017%20survey%20of%20postdoctoral%20researchers.pdf`. It is difficult to know how many postdocs are hired as teaching fellows.

spread imitation, fear to stand alone in scientific endeavour and the implied need to belong to some group and hence to be too dependent on other people opinions.

Proposal 3. *Establish 4 annually awarded new fellowships in mathematics, each 8 years long.* These flagship fellowships will inspire, flexibly support, disseminate and promote long-term (8 years = 5 years and if goes well another 3 years) fundamental work of its fellows on pioneering groundbreaking achievements. Such fellowships could serve as a great attraction to bring the world best researchers to the UK annually, starting from their UK PhD course. In order to operate to maximal benefit, there should be a well-structured flexibility of these fellowships, recognising the diverse ways in which the best outcome can be effective.

4. Improving the way grant proposals are produced and processed. A research grant proposal in a narrow technical area can often attract higher level of support from peers working in the same secondary development who are keen to help to sustain it. A research grant proposal on a visionary work on fundamental problems or a long-term program of fundamental investigations in a new emerging fundamental area or an intra-disciplinary programme, can easily receive short-sighted referee comments and not get funded. New discoveries and academic theories that never existed in earlier studies always appear on stage in the form of a minority view. We need to encourage more fundamental, longer-term intra-disciplinary work and reduce support to narrowly specialised short-term technical work which is not internationally leading. When evaluating research proposals, it is most fundamental to prioritise excellence and depth of the science, and contribution to fundamentally important developments. It is not rare that research grant proposals are evaluated superficially, without taking into account their depth and vision. For example, counting numbers of publications may lead to absurd outcomes.

Proposal 4. *Reduce the length of maths grant proposal form to 6 pages in total, remove the requirement to provide annual plans of work. Improve the work of EPSRC maths panels. Provide more grants support for longer-term work.*

5. Small grants. The situation with small UK maths grants is very unsatisfactory.[8]

Proposal 5. *Allocate to the EPSRC additional resources to enable their support of small maths grants. Such small grant proposals should be processed in a faster simplified way and by smaller panels, separately from other grants. New small maths grants can include maths engagement grants, to support work on presenting fundamental maths discoveries to the general audience.*

6. Fundamentally improving the way maths programme of EPSRC operates.

Being under pressure from UKRI to save costs and be efficient, EPSRC has to treat grant proposals uniformly across all their science areas, in particular, using the same application forms and peer review forms. It is important to start to pay individual attention to different science areas and the considerations of saving costs should only play a decisive role when such savings do not dramatically sacrifice the quality of work. *It is crucial to tune EPSRC maths programme mechanisms to address modern mathematics issues more effectively*, by creating better and more suitable for mathematics research forms, criteria, rules of work, grant proposals structure and peer reviews code of behaviour.

[8] EPSRC Mathematical Sciences Strategy Workshop, Report on outputs and next steps, March 2019, `https://epsrc.ukri.org/files/newsevents/ms-strategy-workshop-report-mar19-pdf/`

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It is not rare that EPSRC research grant proposals are evaluated superficially, without taking into account their depth and vision.[9] To be able to evaluate as the deeper level, a peer reviewer needs to have her/his own experience of working on visionary mathematics, the number of such mathematicians is small. The existing peer review mechanism and fellowships and grants are struggling to address these issues. One aspect of the problem is the intuitive but wrong strive to be democratic in choosing members of panels, this results in situations when such panels include no visionary and leading mathematicians able to see various aspects of each ranked proposal and produce an expert judgement, but rather good but not outstanding scientists who prefer to support average grant applications and do not have enough expertise to see the real value of proposals. Another well known damaging aspect is using, in the absence of a profound professional advice, non-expert reviewers, which leads to ignorant opinions expressed with a high level of confidence and not challenged by panels even in presence of applicants response letter. We know that it is very difficult to optimise a process designed for everyday events to capture rare ones too, but we should try.

Proposal 6. *Improve and modernise the operation of EPSRC maths programme which has been failing UK mathematics for years. Urgently switch to the most efficient system of distributing maths grants, using the best experience of EU (ERC) and USA (NSF, Simons Foundation, DARPA) in many important aspects of processing grant proposals and peer review mechanisms. Maths programmes of NSF, DARPA and Simons Foundation are run by professional mathematicians for many decades, while the EPSRC is not run by professional scientists. It is time to fix this issue, it is time for mathematicians to take back control.*

To address the key issue of fundamental modernisation of EPSRC maths theme and the quality of its grant distribution, as well as to make sure that all this proposals, when funded, is well implemented, it is suggested to appoint three professional senior mathematicians (pure, applied, statistics) as co-chairs of EPSRC maths programme. The new chairs will in particular study the successful features of distributing maths grants in Europe and USA, run discussion forums, produce a proposal of fundamental reform of EPSRC maths theme and contribute to its implementation when approved.

[9] EPSRC provided no support in the last 20 years for two UK Fields Medallists working in the UK in 2020.