Institution: University of Lincoln.

Unit of Assessment: UOA10 Mathematical Sciences

1. Unit context and structure, research and impact strategy

A) Overview. The Mathematics UoA of the School of Mathematics and Physics is part of the College of Science at the University of Lincoln. The UoA has 4 members: Prof. Evgeny Khukhro, Dr Sandro Mattarei, Dr Simon Smith and Dr Anitha Thillaisundaram. The School of Mathematics and Physics was opened in 2014, and in 2015 the Algebra Research Group was formed, consisting initially of Prof. Khukhro and Dr Mattarei. It was a strategic decision to focus on algebra, and to build up this small but excellent group. The choice of algebra as the first mathematical direction in the newly opened school was largely due to two factors: 1) this direction could make a substantial contribution to mathematics even being a naturally small group in a new school, and 2) historical connection of the city of Lincoln to algebraic research via first works by George Boole. The School of Mathematics and Physics also has two applied mathematicians, employed in late 2019, who make up part of the Physics UoA. In 2018, the Algebra Research Group was transformed into the Charlotte Scott Algebra Research Centre, which focusses on group theory and closely related topics, such as Lie algebras and number theory. The Algebra Research Centre members have unique expertise in nilpotent groups, automorphism groups, profinite groups, totally disconnected locally compact (tdlc) groups, permutation groups, branch groups, and thin Lie algebras; all of which are of fundamental importance for the development of algebraic studies. Our researchers are regularly invited to speak at prestigious international conferences, and our researchers are members of professional bodies, editorial boards, grant committees, and organising committees of conferences.

B) Research and Impact Strategy. This is the first REF submission of the Mathematics UoA in Lincoln; therefore, in this section we describe the strategy that has been followed during the current census period. Our research mission is to conduct cutting-edge research in algebra and its related areas at a leading international level, to disseminate the results in leading international journals at national and international conferences, to provide a highly invigorating local research environment, exemplified by top quality staff, PhD students, visitors, international collaborations, and to strive to attract a diverse portfolio of research grants. Our impact strategy consists of two parts: firstly, to engage with the public and to raise awareness of the importance of mathematics via outreach activities, such as public lectures and activities for school children, and secondly, to contribute to postgraduate-level education by transferring our research into educational material such as textbooks.

With regards to our research strategy, the UoA's aims are to concentrate research within important areas of algebra (specifically group theory, the theory of Lie algebras, and polynomial algebra), to support the research in these areas and to ensure that the UoA will develop further its international reputation and leading position in these knowledge areas as these subjects advance. The UoA aims to make use of the synergies between areas that promise fruitful interactions, as between groups and Lie algebras, and locally compact groups and permutation groups, and furthermore concerning applications of group theory such as cryptography.

A core part of our strategy is to work collaboratively with expert international algebra groups, such as the groups in Brasilia (Brazil), Bilbao (Spain), Düsseldorf (Germany), Milan (Italy), and Newcastle (Australia). Such synergies, interactions and collaborations have recently produced important contributions to the theory of algebra. Examples include further development and application of Khukhro's method of generalised centralisers in groups and Lie rings, which made it possible to obtain, in collaboration with Makarenko (Mulhouse, France) and Shumyatsky (Brasilia), new results on almost fixed-point-free automorphisms, as well as on groups with Frobenius groups of automorphisms. Smith discovered a new type of product of infinite permutation groups, which enabled him to solve a high-profile problem on tdlc groups. This product led to the development of a deep structure theory for infinite primitive permutation groups with various finiteness properties which has further consequences for topological groups

and for graph theory. Thillaisundaram's collaboration with Klopsch (Düsseldorf) enabled them to obtain results on maximal subgroups of multi-edge spinal groups generalising the famous Gupta–Sidki groups, and recently a new collaboration has produced results concerning the Hausdorff dimension of pro-*p* groups which has answered long-standing open questions. Mattarei carries on fruitful collaborations with Italian mathematicians on diverse topics: Lie algebras with Avitabile (Milan), special polynomials in finite fields with Pizzato (Trento), and congruences for combinatorial sums with Tauraso (Rome). Of the total outputs produced during the current census period, 87% of the publications are with international collaborators. For instance, Khukhro has 18 publications with his Brazilian and French collaborators, Mattarei has 6 publications with his Italian collaborators, Smith has 4 publications with his international collaborators, and Thillaisundaram has 5 publications on joint work with the Düsseldorf group and 3 publications with the Bilbao group.

All of the unit's research outputs are disseminated in high-ranking journals, such as the Journal of Algebra, the Journal of Group Theory, Proceedings of the American Mathematical Society, the Israel Journal of Mathematics and the Duke Mathematical Journal. As mentioned in the overview, the members of the unit have been invited to give research talks at prestigious conferences. For instance, Smith was a morning speaker at the British Mathematical Colloquium 2018, Mattarei was invited to speak at the algebra workshop at the British Mathematical Colloquium 2019, Khukhro was an invited speaker at the Ischia Group Theory Conference 2018, and Thillaisundaram was invited to speak at the Ischia Online Group Theory Conference 2020.

We strive to provide an invigorating research environment, to attract PhD students and postdoctoral researchers, by conducting fortnightly Algebra Research Seminars, as well as hosting reading groups and informal seminars, and by inviting external academics to Lincoln for research collaborations. More details of our seminars are given in Section 4. These seminars are also open to our undergraduate and postgraduate students. In addition to seminar speakers, over the past four years we have had ten academic research visits, ranging from a week to a month. Half of these visits were supported by London Mathematical Society (LMS) research grants.

The School of Mathematics and Physics and the University of Lincoln provide a very supportive environment for encouraging high-quality grant applications. The University's Research and Enterprise Office regularly hosts grant-writing workshops and grant panel discussions, and the School of Mathematics and Physics has a grant assistance funding scheme for our members to undertake research visits and to attend conferences, in order to boost our research collaborations and to expand on our research ideas and pursuits. As well as making more than thirty bids over the past 4 years, the unit has successfully obtained many conference grants (such as the LMS Celebrating New Appointments Grant and the LMS Regional Meeting Grant) and other research grants (such as the EPSRC Overseas Travel Grant and the Düsseldorf University Alumni Research Grant).

Regarding our impact strategy, all members of the unit are part of extensive outreach activities such as mathematical challenges and masterclasses for school children, the Newton Academy mathematics events for schoolgirls and the Engineering Development Trust Headstart event for 16-17 year-old school pupils. All of these events have been well received and positive feedback has been obtained. More information on our outreach activities is given in Section 4. In addition to public engagement, postgraduate courses on totally disconnected locally compact groups, which include Smith's work, have taken place at the University of Binghamton, USA in 2017 and at the University of Oxford in 2018, a postgraduate course on Lie ring methods in group theory, which includes Khukhro's work, was held at the University of Brasilia in 2018. More details on these, and on the book "New directions in Locally Compact Groups" which was published in 2018 and includes an entire chapter on Smith's work, are given in our Impact Case Studies.

C). Research and Impact Strategy for the Future. The development of mathematics research in Lincoln is based on the current strengths of the existing staff, and the increase in staff numbers depends on prospective increases in undergraduate intake and research funding.

Planning for the directions of research and its organization is conducted with the help of consultations with the School's External Advisory Board, which includes 16 leading figures both in pure mathematics (such as a Fields laureate Efim Zelmanov) and applied mathematics (for example, Prof. Natasha Maurits), as well as from industry, from the UK, the USA, the Netherlands, Brazil, Spain, Japan and Norway.

Our research strategy for the immediate future is to further develop our UoA into a small but internationally distinct and well-recognised centre of research excellence in Algebra. Further research is planned, individually and in collaboration, to advance the methods and approaches in the above areas of algebra and number theory, as well as exploring other possible applications. Already there have been recent new collaborations in group theory with the University of Cambridge, University of Valencia, University of Kurdistan, École Normale Supérieure de Lyon, Ohio State University and City University of New York; and there is an interdisciplinary collaboration in cryptography in the pipeline. The highly topical area of tdlc groups attracts collaborations for Smith with researchers in the UK, Austria, USA and Australia, as exemplified by the recent mini-conferences in Lincoln in 2017 and 2018. The joint work of Khukhro with the Brazilian researchers aims at generalizations of the Wilson–Zelmanov theorem on Engel groups. The study of profinite groups from various viewpoints is one of the current trends in group theory, which is pursued in the work of Thillaisundaram and her collaborators, as well as of Khukhro. The research of the members of the UoA is also a basis for posing challenging problems to PhD students. Another research aim is to produce over 30 research outputs in highly-ranked international journals over the next 5 years, and where possible, we aim to disseminate our results in open access journals.

Organisationally, the development of the UoA is to be achieved through the following three aims. Firstly, we aim to recruit 2 more academics, 4 more postdoctoral researchers active in algebraic or algebraic-related research and 2 more PhD students over the next five years. The new academics will include applied mathematicians or statisticians, which will increase the diversity of our research portfolio. Our approach to attracting postdoctoral researchers and PhD students is via networking at conferences and ensuring that Lincoln provides an active, appealing and supportive research environment. For attracting PhD students from amongst the Lincoln graduates, the third- and fourth-year individual projects, the Lincoln Undergraduate Research Opportunities Scheme, provide an excellent opportunity for keen students to get involved in research, and especially in the research closely linked to the members of the UoA. Secondly, we aim to secure at least £500k of research income over the next REF census period by applying for EPSRC, London Mathematical Society, Royal Society, and Leverhulme research grants. Certainly, this research income, and the addition of postdoctoral researchers and PhD students, will enable more cutting-edge research to be conducted. The School of Mathematics and Physics has an internal peer review process for every grant application, which will help to increase the number of successful bids. Our strategy for securing larger research grants also include continuing to build a track record of smaller research grants, which enables new collaborations to be formed with other excellent mathematicians, which will thus strengthen the research proposals for larger grant applications. Thirdly, we aim to continue organising and attending national and international conferences, as well as further disseminating research outputs in leading international open access journals and at conferences. Organising and attending conferences will also aid us towards our goal of recruiting more postdoctoral researchers and PhD students, and towards our goal of increasing the number of our national and international collaborations, which will also help to increase our research income.

Our impact strategy for the future is to expand our outreach activities and continue to promote the transfer of our research into educational material. Impact through public engagement is not easy for pure mathematics, since our research is very abstract and technical. However, much of our research has a geometric aspect to it and can be depicted pictorially (such as with tree diagrams and fractals), which is an excellent way of conveying our research ideas to the public. For the aspects of our research that is less geometric, simpler examples and analogies can be used equally successfully. We will continue to maintain contact with local schools in Lincolnshire, and to organise algebra public lectures at the University of Lincoln and wider afield. Our strategy

has been to focus on local public engagement. We are very pleased to receive compliments from the public for our outreach work. A strategy for the future is to broaden our public engagement activities outside Lincolnshire to a more international level. This has already been done by Khukhro, in his public lectures in Brazil and Russia, in 2016 and 2017 respectively. Further details of these lectures are given in the Impact Case Study on outreach.

2. People

Strategy and development. Our strategy is to recruit staff active in algebraic research, whose expertise complement and diversify the existing areas of the UoA's research. Khukhro, an experienced expert in nilpotent groups and profinite groups, was the founding member of the UoA, and he was strategically appointed in 2014 to attract other high-profile algebraists to Lincoln. Mattarei, a long-established expert in thin Lie algebras with a broad expertise ranging from pro-*p* groups to number theory, was appointed in 2015. Smith and Thillaisundaram were simultaneously appointed in 2016, bringing in expertise in permutation groups and branch groups, respectively. Each appointment was due to the expertise and diversity in algebra of that member, which harmonised well with the existing group members. Khukhro was promoted to a professorship in pure mathematics in 2018 and Smith became a senior lecturer in 2017.

With the future growth of the school and its research income we envision future academic recruitment in the emerging areas linked to our current strengths, such as the subject of analytic groups, combinatorics of non-abelian groups and more applied areas. Our growth directions are always discussed with the aforementioned External Advisory Board, which helps us to be at the forefront of mathematics developments in the world. Additionally, new recruitment is planned also by recruiting more members of staff active in algebraic-related research via postdoctoral grants, such as EPSRC, Royal Society, and Leverhulme grants. In terms of development for existing staff, members of the UoA also have the opportunity to apply for academic leave to enhance and promote their research. The School's research assistance fund also enables staff members to attend conferences and undertake collaborative research visits. In addition, the Lincoln Institute of Advanced Studies regularly awards mobility grants to academic staff; Thillaisundaram obtained mobility grants to undertake a research visit to the University of the Basque Country and to invite a postdoctoral researcher from École Normale Supérieure de Lyon to Lincoln. Both research visits were on topics in branch groups and altogether resulted in 6 papers.

Equality, Diversity, and Inclusion. The name of the research centre was chosen to highlight an important role model: Charlotte Scott was a highly regarded mathematician who was born in Lincoln and was the first British woman to receive a doctorate. She was influential in developing the mathematical education of women and their participation in mathematical research.

The Algebra Research Centre has a diverse background, with origins from Italy, Malaysia, Russia, and the UK. One of our staff is female and of a minority ethnic origin. The School and the University have many support schemes in place, such as childcare schemes and regular female and BAME scientists networking events.

Special attention is given to inviting female researchers, as well as early career researchers, to conferences and seminars conducted by Algebra Research Centre. The proportion of female speakers at the algebra research seminar in Lincoln is 30%, and the proportion of early career speakers is 43%. Our algebra research seminar usually takes place at 2-3pm, which is compatible with scientists with childcare responsibilities.

In addition the School and Algebra Centre supported Thillaisundaram in giving a talk “Hausdorff dimension of pro-*p* groups – history and open problems” at the “Women in Mathematics” conference at the Isaac Newton Institute, University of Cambridge in 2018, and her presentation on the same topic at “STEM for Britain 2019” in the House of Commons. One of the UoA's PhD students is female, Valentina Iusa (at that time 50% of our PhD cohort), who has successfully obtained her PhD in 2019, with the full support of the Algebra group in her studies and research,

having also published a research paper in *Monatshefte für Mathematik*. Another completed PhD was in applied mathematics in 2016 by Roberta Dessi, who was supervised by members of staff from the physics UoA.

Post-graduate support. Currently our PhD student is in year 4 of his part-time studies, while our former PhD student successfully completed her thesis and prepared two research papers containing interesting results on groups and Lie algebras admitting Frobenius groups of automorphisms, which, in particular, solve a problem posed by Khukhro et al. in 2010. There are currently 3 more PhD students in applied mathematics, who are supervised by members of staff from the physics UoA. Whilst we support pure mathematics students in our UoA, there is also support to applied mathematics students, and we view this as a positive role the UoA and its staff play for the benefit of research and studies in the School. The PhD students benefit from regular research seminars and LARA (Lincoln Algebra Research Afternoons) study group meetings, as well as from conferences conducted in Lincoln. Being such a small group, the students receive a more personalised experience as they are fully integrated with the UoA. The PhD students also take part in conferences both in the UK and abroad, with the partial financial support from the School. The School also provides opportunities for PhD students to become teaching assistants for undergraduate students providing valuable work experience. Furthermore, the School invites PhD students to present their research to third-year undergraduate mathematics students in a seminar series as part of the Advanced Topics of Mathematics module. The University's Doctoral School offers lots of support and transferable skills training, and every PhD student has two supervisors plus an academic mentor. All supervisors and academic mentors in the Algebra Research Centre have undergone PGR supervisor training.

3. Income, infrastructure and facilities

Current research income. The UoA has benefited from London Mathematical Society (LMS) grants (£1000) secured by Thillaisundaram to support one-day algebraic research meetings at University of Lincoln in 2017 and in 2018. These meetings were attended by academics from overseas as well as leading UK institutions (Cambridge, Oxford, Leeds). Thillaisundaram, jointly with algebraists from Lancaster, Royal Holloway and Cambridge, secured a further LMS grant (£3000) to support research visitors to the University of Lincoln, and to organise a research meeting on Words in Finite and Profinite Groups at the University of Lincoln in 2019, and a meeting on Linear Groups in 2020. In 2019, Thillaisundaram obtained an EPSRC grant (£10 610) for a research project on “Hausdorff dimensions of p-adic analytic groups”. Several overseas research visiting grants supported collaborative research of members of the Algebra Centre with researchers in Brazil (Khukhro in 2014–2016, 2018, 2019), Germany (Thillaisundaram, 2018; ca. £1800), Russia (Khukhro, 2014–18; ca. £5400), and USA (Smith, 2017). An LMS grant (£1400) secured by Smith in 2017 supported a research visit to Lincoln by a leading US-based researcher Wesolek to give a series of lectures in the UK on his research at the University of Lincoln, the University of Leeds and the University of St Andrews, as well as to collaborate with Lincoln researchers on totally disconnected locally compact groups and related topics. Another LMS grant (£1200) secured by Smith supported a research visit by a leading Australia-based researcher, Reid, to work collaboratively with members of the Algebra Research Centre. Similarly, Thillaisundaram obtained an LMS grant (£1500) in 2019 to support the visit of US-based mathematician Skipper to deliver a series of talks at the Universities of St. Andrews, Oxford, Lincoln and Cambridge. In 2019 and 2020, Thillaisundaram was awarded LMS grants (£2000) to support the visit of a promising new mathematician Francoeur, to work collaboratively with members of the Algebra Research Centre. Furthermore, the Algebra Research Centre has been awarded an LMS Regional Meeting and Workshop grant (£5000) to host a 3-day meeting in Lincoln in 2021, on topics including profinite groups and their related aspects, as well as broader topics such as cryptography and mathematics in education.

Future research income. The Algebra Centre is always striving to attract a diverse portfolio of research grants from the EPSRC, the LMS, the Royal Society, and the Leverhulme Foundation. For example, last year Smith has submitted an EPSRC Standard Grant proposal on permutation

groups, totally disconnected locally compact groups and the local isomorphism relation; Khukhro has recently submitted a Heilbronn Focused Research Grant; Mattarei will soon be submitting an EPSRC Standard Grant proposal on classifying thin Lie algebras; and likewise Thillaisundaram is in the process of submitting an EPSRC New Investigator Award proposal on maximal subgroups of branch groups. As mentioned in Section 1, the School of Mathematics and Physics also has an internal peer reviewing process for grant proposals, to maximise the quality of grant applications. In the current REF census period, over forty grant bids have been made with a 38% success rate, and this high level is expected to be sustained in the future.

Infrastructure and facilities. As part of the School of Mathematics and Physics, the Algebra Centre is housed in the new Isaac Newton Building (since 2017), with excellent environment for research in pure mathematics. All members of staff have individual offices, which provide the essential quiet and undisturbed atmosphere for academics to conduct research in pure mathematics. The PhD students have a shared office, which promotes friendly informal discussions, and a supportive environment, which is key for postgraduate research in mathematics. The mathematics research room is well-equipped for supporting seminars, small conferences, and other activities. All staff are provided with computers, printing facilities and university-supported software. The Library is well stocked with algebraic monographs, and an unlimited university allowance for inter-library loans allows access to journal papers.

Given the nature of algebraic research, the infrastructure required is relatively modest, however time is an important research aid. The Algebra Centre is very supportive towards its members, making sure that the members meet regularly at seminars or more informally, to enable and encourage the exchange of research ideas and to discuss research problems.

4. Collaboration and contribution to the research base, economy and society

Algebra Research Seminar attracts visitors both from the UK and overseas. Over the last four years more than 50 external speakers visited Lincoln with talks at the seminar on topical issues of algebraic research, including 15 overseas speakers. Some of the most prestigious speakers include Prof. George Willis, Prof. Dan Segal and the Fields Medallist Prof. Efim Zelmanov. As mentioned before, special attention is given to inviting early career researchers to speak at our seminar. This opportunity and experience are valuable for the career progression of young researchers.

Interdisciplinary research for the algebra group means primarily interactions between various parts of mathematics. One of the strong points is development and application of Lie ring methods for solving group-theoretic problems. An important development in the theory of totally disconnected locally compact groups has arisen in connection with the theory of permutation groups. Furthermore, interactions between various parts of algebra play significant role in the study of Hausdorff dimensions of pro-*p* groups.

National and international collaboration**.** The Algebra Centre fosters and encourages a range of collaborations, which are supported by grants or School funding:

- Khukhro collaborates with Brazilian mathematicians (Shumyatsky and Acciarri) on the study of profinite and compact groups, as well as of length parameters of finite groups; this collaboration also involves Traustason (Bath, UK).
- Khukhro was a member of a research team (of 25 researchers) at Sobolev Inst. of Mathematics, Novosibirsk, Russia, in the project 14-21-00065 "*Study of the structure of groups and algebras; algorithmic problems in groups and algebras and their applications"* supported by a ca. £1,400,000 grant of the Russian Science Foundation in 2014–19.
- Khukhro was a member of a research team (of ca. 50 researchers) at the Sobolev Institute of Mathematics, Novosibirsk, Russia, in the newly formed “Mathematical Centre in Akademgorodok” supported by a ca. £4,000,000 grant of the Russian Government in 2019–20.
- Khukhro is one of the organisers of the international online seminar "Kourovka Forum" devoted to current trends and unsolved problems in group theory.

- Mattarei collaborates with Italian mathematicians (Avitabile, Pizzato and Tauraso) on topics in Lie algebras, on special polynomial in finite fields, and on congruences for combinatorial sums.
- Smith collaborates with mathematicians in Australia (Praeger, Reid and Giudici), Iceland (Möller), Austria (Imrich), USA (Wesolek) and the UK (Macpherson) on the study of permutations groups and totally disconnected locally compact groups.
- Thillaisundaram collaborates with German mathematician (Klopsch), Spanish mathematician (Fernández-Alcober), and Italian mathematicians (Noce and Di Domenico) on the study of generalisations of Grigorchuk–Gupta–Sidki groups and Hausdorff dimensions of pro-*p* groups.

Esteem indicators. All members of the UoA regularly peer-review articles for many highly ranked mathematical journals. Below is a more detailed account of esteem indicators for each member of the Algebra Centre.

Khukhro is a managing editor of *Journal of Group Theory* (de Gruyter), and of the *Kourovka Notebook,* which is the world-famous collection of unsolved problems in group theory. Khukhro is a member of the editorial board of *Journal of Algebra* (Elsevier). A conference was organised and conducted in Lincoln in 2016 in honour of Khukhro's 60th birthday, which attracted participants from 10 countries. Furthermore, Khukhro was bestowed the title of *Professor Honoris Causa* by the University of Brasilia in 2017.

Mattarei is a full member of the EPSRC Peer Review College. In April 2017, Mattarei was invited as a Visiting Professor by the University of Milano-Bicocca. Additionally, Mattarei was an invited speaker at the British Mathematics Colloquium in 2019, the largest pure mathematics conference held annually in the UK.

Smith was invited in 2018 to be a prestigious Morning Speaker at the British Mathematics Colloquium, the largest pure mathematics conference to be held annually in the UK. In 2019 two textbooks were published that prominently featured results of Smith. The first, *Permutation groups and Cartesian decompositions* by Praeger and Schneider (London Lecture Notes Series, vol. 449), featured Smith's work on infinite primitive permutation groups, while the second, *New Directions on locally compact groups* (London Lecture Notes Series, vol. 447), has a whole chapter devoted to Smith's work on totally disconnected locally compact groups.

Thillaisundaram is a member of the London Mathematical Society Early Career Research Committee and is a reviewer for the University of Lincoln's Undergraduate Research Opportunity Scheme. Additionally, Thillaisundaram was a STEM for Britain 2019 finalist in the House of Commons.

Invited lectures at conferences. All staff of the Algebra Centre regularly give plenary lectures at seminars and colloquia in the UK and abroad, as well as at international and national conferences. These include:

- Khukhro gave invited plenary lectures at international conferences in Belgium (2017), France (2015), Germany (2018), Italy (2014, 2016, 2018, 2021), Russia (2014), Spain (2020), Turkey (2016), UK (2016, 2019).
- Mattarei gave an invited talk at a conference Topics on Groups and Their Representations in Italy in 2017, and in 2018 at a Workshop Non-Associative Algebras and Applications in Lancaster; he was an invited speaker at the British Mathematics Colloquium in 2019.
- Smith gave invited plenary lectures at the ICMS in Edinburgh (2018) and the BIRS in Canada (2016), as well as at international conferences in Germany (2018), Lincoln (2017, 2018), Paris (2016) and Australia (2014). He was a Morning Speaker at the British Mathematics Colloquium in 2018.
- Thillaisundaram gave an invited talk at the 4th Biennial International Group Theory Conference in Malaysia (2017), and at NordDeutsches Mathematisches Kolloquium in Germany (2017). She spoke at the Women in Mathematics meeting in Cambridge

(2018); she gave an invited talk at the Functor Categories for Groups meeting on Hausdorff dimension in London (2018). She was an invited speaker at the LMS Prospects in Mathematics Conference in Lancaster (2019), at the Group Algebras, Representations and Computations conference in Bangalore, India (2019), at Groups in Galway (2020) and at the Ischia Online Group Theory Conference (2020).

***Outreach activities*.** Staff of the Algebra Centre are involved in extensive outreach activities aimed at raising the public awareness of the importance and beauty of mathematics, attracting school children to studying mathematics at all levels, changing the perception of mathematics and mathematicians in the society. These activities include:

- *Mathematics Challenges* for school children are conducted every year by staff of the Algebra Centre. The challenges attract school children of ages 15–17 with a wide geographic distribution, although with participants from the neighbouring counties. The winners attend prize-giving ceremonies in Lincoln, greeted by the leading academics, including visitors-lecturers in the Distinguished Mathematics and Physics Public Lectures series.
- *Public lectures* for the general public are organised by members of the Algebra Centre. For example, Khukhro's lectures on George Boole in Lincoln (2015), in Russia (2016), and in Brazil (2017) included references to recent research outputs as examples of applications of Mathematical Logic in "normal" mathematics. These lectures are documented on websites and are currently being re-worked into a paper in *De Morgan Journal* in collaboration with Borovik. Another example is Khukhro's inaugural professorial lecture in 2018.

There are established annual mathematics public lecture series: George Boole public lectures in mathematics, and Charlotte Scott public lectures in mathematics. The lecturers in these series are given by distinguished mathematicians such as presidents of the learned societies (London Maths Soc., Edinburgh Maths Soc., Operational Research Soc.) and attract enthusiastic audiences from various walks of life, including young people, university lecturers, school teachers and pensioners.

- *Lectures/workshops for school children* are organised and conducted by members of the Algebra Centre. For example, the masterclass lectures of Khukhro in 2015 for school children attracted very positive feedback, which was documented by means of a questionnaire. These lectures on group theory were written to inspire school children to see mathematics as a vibrant and dynamic subject. This was achieved by including in the lecture recent results published by members of the Charlotte Scott Algebra Research Centre. Another example is the Engineering Development Trust (EDT) Headstart workshops in 2017, 2018, and 2019 with similar lectures, documented with very positive feedback in questionnaires. Thillaisundaram also spoke on "Hausdorff dimensions in group theory" at the Girls in Mathematics Day at the Bishop Grosseteste University in 2019.

Impact of research on teaching and learning. The research of the members of Algebra Centre influenced the design and delivery of curriculums at universities in the UK, USA and Brazil. For instance, recent research by Khukhro has been incorporated into the syllabus of an advanced course on group theory in University of Brasilia (Brazil), and recent research by Smith has been incorporated into the syllabus of advanced courses on group theory at several universities, including Binghamton University (USA) and the University of Oxford (UK). Smith's research also features prominently in an LMS Lecture Note Series textbook that has been used as an integral part of a course on totally disconnected locally compact groups at ETH Zürich. Furthermore, Smith's research has also been incorporated into the undergraduate course at the University of Lincoln.