Institution: Loughborough University

Unit of Assessment: C25 Education

a. Overview

This submission describes the education research of the Mathematics Education Centre (MEC), a department within the School of Science at Loughborough University. The MEC engages in educational research, works closely with the Department of Mathematical Sciences for teaching purposes, and is the focus of several long-standing national and international externally-funded initiatives to drive policy and practice concerning university-wide mathematics teaching and support.

The MEC was instituted in 2002 as a Centre within the then Faculty of Science. Between 2002 and 2008 the MEC expanded its research quality and capacity in the run up to RAE 2008. Since 2008 the MEC has expanded substantially: six new staff have been appointed (Hernandez-Martinez, Goos, Lerman, Gilmore, Inglis, Jones), with the latter three holding prestigious externally-funded British Academy and Royal Society research fellowships. University funding has been secured to ensure that these colleagues remain at Loughborough as full time members of staff at the completion of their fellowships.

Following a review of research strategy in 2010, the MEC now has two research groups which form the basis of our research activity. The Culture, Pedagogy and Identity Group (CPIG: Croft, Goos, Hernandez-Martinez, Jaworski, Lerman) focuses on the analysis and design of teaching and support for mathematics students, primarily at the undergraduate level. The Mathematical Cognition Interest Group (MCIG: Alcock, Gilmore, Inglis, Jones) focuses on students' understanding of numerical concepts, and their logical and mathematical reasoning, across all stages of education. Colleagues collaborate both within and across the two interest groups, and we have a shared series of research workshops.

The MEC has a balance between senior, mid-career and early-career staff. The return includes four professors (Croft, Goos, Jaworski, Lerman), two senior lecturers (Alcock, Inglis), two senior research fellows (Gilmore, Jones) and one lecturer (Hernandez-Martinez).

b. Research strategy

In RAE 2008 the MEC defined its primary research aim as the generation of research related to the analysis and development of policies and practices that concern the teaching and learning of mathematics, within the higher education sector and beyond. Since 2008 the MEC has sought to meet this aim by pursuing four strategic goals:

1. Consolidating its position as the UK's largest research group on undergraduate-level mathematics education;
2. Increasing its research capacity by attracting and retaining talented researchers;
3. Enhancing its research infrastructure to strengthen research capacity, and to ensure the long-term sustainability of our research groups;
4. Consolidating and extending links with policymakers and practitioners.

These goals have been achieved by:

- Expanding our international reputation through the traditional channels of high-impact journal publications and conference presentations, and through academic exchanges. During the REF period we have hosted visiting researchers from countries including Australia, Belgium, Botswana, Canada, Greece, Iceland, Kenya, Lithuania, the Netherlands, New Zealand, Norway, the USA, Switzerland, and Turkey. (Goal 1).
- Attracting a cohort of externally-funded researchers at an early career stage to form a new research group focused on mathematical cognition. The Royal Society's only two Mathematics Education Research Fellowships (awarded in 2009 and 2010) are hosted by

the MEC (Inglis, Jones), and Gilmore holds a British Academy Postdoctoral Fellowship, which will be followed by a Royal Society Dorothy Hodgkin Research Fellowship in January 2014 (awarded in mid 2013). University funding has been secured to ensure that these researchers remain at Loughborough at the end of their fellowships. (Goal 2).

- Investing substantial sums into improving our research infrastructure. Since 2008 over £50,000 has been invested in laboratory facilities and state-of-the-art equipment (detailed in REF5d). (Goal 3).
- Expanding the number of research students in the MEC, across all our areas of interest. We now have 11 full-time research students (Goal 2).
- Appointing three Visiting Professors (Duncan Lawson, Yvette Solomon, and David Tall) who all actively contribute to our research environment by working with PhD students, collaborating with colleagues, and contributing to research events. (Goals 1 and 2).
- Developing and implementing strategies which ensure that we maximise the impact of our research. (Goal 4).
- Hosting influential workshops, conferences and seminar series designed to increase awareness of the MEC's research. Our monthly afternoon workshop series regularly attracts colleagues from across the region. A regional seminar network, the Midlands Mathematics Education Seminar Series, is organised within the MEC, an arrangement which deepens our collaborative links with colleagues across the M5 Group of Midlands Universities (Birmingham, Leicester, Loughborough, Nottingham and Warwick). (Goals 1 and 4)

To provide focus to our work, and to help foster productive collaborative research, the MEC has formed two research groups: the Mathematical Cognition Interest Group (MCIG) and the Culture, Pedagogy and Identity Group (CPIG). The groups function by encouraging collaborative research activity, and sharing methodological and analytical expertise. All staff and research students have a primary affiliation to one group, but where appropriate, staff work across the two research groups. The groups share a workshop series and there are many examples of collaborative projects and PhD supervision involving staff from both groups (for example, Roy's PhD involves a cognitive analysis of pedagogical resources, and she is supervised by Inglis and Jaworski).

Encouraging and supporting applications for research funding is also a responsibility devolved to the research groups, overseen by the MEC Research Committee. Both groups organise rigorous internal peer review prior to external submission of research proposals. This structure has been extremely successful: since 2008 we have attracted £2,744,041 of external research funding, a substantial increase from the £200,282 returned in our RAE 2008 submission.

Our aim for the next five years is to continue to develop and sustain research in mathematics education that achieves the highest levels of international excellence and recognition. Specific strategic objectives designed to ensure this are:

1. Maintain our position as an internationally-leading research group focused on mathematics education at HE level, and expand our growing international reputation for research in mathematical and numerical cognition.
2. Retain early career staff who have joined the Centre in recent years, and support their transition to become international research leaders.
3. Maintain a dynamic, well-supported research environment by continuing to invest in research infrastructure.
4. Expand the range of sources from which we derive research income.
5. Support the mathematics education community by hosting an increasing number of high-quality workshops and conferences which will attract international researchers.

In addition to these overarching goals, each research group has set specific research priorities for the next five years.

CPIG aims to expand its internationally-recognised work on the design of teaching, the implementation of design principles and practical approaches, and the study of teaching development (Goos, Lerman, Jaworski). The group will expand its work in mathematical support for students at all levels, particularly those having difficulties with mathematics, by focusing on the

contexts and cultures in which teaching and learning are embedded and how these relate to student identities (Croft, Hernandez-Martinez, Lerman).

MCIG aims to expand its growing international reputation for numerical cognition research, and in particular seeks to better understand the relationship between domain-general executive function skills, 'number sense', and mathematical achievement (Gilmore, Inglis). A second priority area for the group is to consolidate and expand its work on mathematical proof and reasoning across primary, secondary and tertiary education (Alcock, Jones, Inglis).

c. People, including:

i. Staffing strategy and staff development

During the assessment period the MEC has successfully followed its research strategy by recruiting several internationally-recognised researchers. Goos and Lerman have joined as professors, and Hernandez-Martinez and Inglis have joined as lecturers, with Inglis subsequently being awarded a Royal Society Educational Research Fellowship and being promoted to senior lecturer. Gilmore (funded by the British Academy and, from 2014, the Royal Society) and Jones (funded by the Royal Society) have joined as externally-funded senior research fellows, and have subsequently been awarded permanent posts (to commence when their fellowship funding ends). Early career academic staff undertake the New Lecturers' Course, which specifically involves units introducing the University's research culture and support available from the Research Office. During the three years of this course early career staff have a light teaching load (approximately 1/3, 1/2 and 2/3 of the norm in the first three years) and light administrative duties. Mentoring is available within the Centre for early career staff, and academic staff are encouraged to participate as mentors, which is beneficial to both parties. The Research Office provides bespoke one-to-one support for staff writing grant proposals, which further enhances our research culture.

In 2011/12 Gilmore successfully applied to participate in the Developing Future Research Leaders programme, an EPSRC-funded initiative that saw research staff and early career lecturers receive a leadership development grant, dedicated coaching, participation in Action Learning and 360° Feedback. Other early- and mid-career staff in the MEC have been actively encouraged to develop their leadership potential, both through training activities and by taking leadership positions within the Centre. For example, Alcock sits on the MEC Management Group, Inglis chairs the MEC Research Committee, Gilmore is the Director of Research Degree Programmes, and Hernandez-Martinez is Postgraduate Admissions Tutor.

Loughborough University undertook a comprehensive analysis of its alignment with the Concordat to support the Career Development of Researchers in 2009/10, and published an implementation plan in 2010, for which it received the European Commission's HR Excellence in Research Award. The plan was updated in 2012, as part of an internal review for the HR Excellence award. Specific outcomes from the plan included a continuing commitment to a University-wide Research Staff mentoring scheme, a revised Code of Practice for the Employment of Researchers, and establishment of the Loughborough University Research Staff Association. Monitoring takes place through participation in the Careers in Research Online Survey, and through the 2012 University-wide Staff Survey, which found that 100% of staff in the MEC (i) regarded the university as a "good place to work"; (ii) enjoyed their work; and (iii) felt valued by their colleagues.

Improvement of research performance across all disciplines has been a key University priority during the assessment period, and all academic staff complete an annual Personal Research Plan (PRP), which facilitates discussions and areas for development for individuals. This process embeds research in performance monitoring and reward systems and is monitored by the University's Research Performance Monitoring Committee, chaired by the Pro-Vice Chancellor for Research (PVC(R)). Research performance is facilitated by the award of study leave opportunities. During the assessment period Alcock (three months), Croft (twelve months) and Jaworski (three months) have been awarded study leave periods, in addition to the three staff who currently hold externally-funded fellowships (i.e. who have no teaching duties). Jaworski's study leave was the result of an invitation to take up the prestigious Donders Chair at Utrecht University.

In view of the number of relatively early career researchers in the MEC, during the assessment period we have appointed three Visiting Professors (Lawson, Newman; Solomon, Manchester Metropolitan University; Tall, Warwick) to provide additional mentoring for PhD students and early career academics. All three Visiting Professors actively engage with the MEC's research environment by, for example, co-supervising PhD students or attending workshops and providing feedback and advice on draft funding proposals and publications.

Loughborough is committed to achieving equality for all, including mandatory recruitment and selection training which embeds Equality and Diversity policy. The University is committed to Athena SWAN and the MEC is currently preparing an application for a silver award in a joint process with the Department of Mathematical Sciences.

The University has an Ethics Committee which serves to advise on ethical matters arising in the conduct of the University's business. It devolves ethical approval of research activity to the Ethics Approvals (Human Participants) Sub-Committee, upon which Inglis sits, which ensures that any work that involves human participants is conducted to required ethical standards. The University also has a Research Misconduct and Whistle-Blowing Policy that allows staff to feel comfortable in reporting issues of research misconduct without fear of recrimination, ensuring a culture where research integrity is maintained. This structure ensures that the research done at the University is ethically responsible.

ii. Research students

The Graduate School works alongside other University services and the MEC to enhance and support a vibrant graduate community of mathematics education scholars at Loughborough. PGR training and development is provided centrally by the Graduate School which works closely with other internal support services such as the Careers and Employability Centre and the Library. The Graduate School offers a comprehensive training programme that is mapped to the Researcher Development Framework, comprising face-to-face workshops, an annual research conference including poster competition (also open to academic and research staff) and the 'Café Academique' which is a forum where PhD students can debate the latest ideas from all areas of research. The Careers and Employability Centre have a dedicated careers advisor for researchers, to support research staff and research students.

The University is committed to achieving an education and work environment which provides equality of opportunity and freedom from discrimination. To this end recruitment of all students to the MEC is in accordance with the University's formal admissions policy which requires that research students should have a good first degree in a discipline relevant to their proposed area of research (typically education, mathematics or psychology), and that they can demonstrate they can undertake a sustained programme of independent research. Decisions on the admission of candidates are taken by two members of staff following an interview, often by telephone or Skype for international candidates. The Director of the MEC allocates supervisors to each student, taking account of research expertise, workload and supervisory experience. The student's supervisory team also includes a Director of Research Degree Programmes who takes an overview of the supervisory arrangements and can assist in the resolution of any issues.

Applicants with disabilities are invited to identify any special needs or support requirements they may initially have and they are supported in their programmes of study through the University's Counselling and Disability Service.

Within the School of Science, quality assurance of research degree programmes is provided by an Associate Dean for Research who is a member of the University's Research Committee (chaired by the PVC(R)). At the institutional level, quality assurance is provided by the Dean of the Graduate School, who is responsible for considering and approving a range of research student business from admissions to examinations, as well as, for example, chairing student appeals, thereby ensuring consistent and equitable treatment. The Dean of the Graduate School leads a cycle of regular research degree programme reviews as part of the University's quality assurance

mechanisms. The outcomes of these reviews are reported to the University's Research Committee. The University also participates in the UK wide Postgraduate Research Experience Survey (PRES) thereby gaining useful student experience feedback from its research student population which can be benchmarked nationally.

Research student progress is encouraged through regular supervisory meetings which are held at least on a monthly basis and normally once per week. Written records of these meetings are maintained within the MEC. In addition a major academic progress review, against published criteria, is held at the end of each year of registration and students are required to produce a significant piece of written work, as well as undertake an interview with an independent assessor before being permitted to progress to the next year of registration. Records of these meetings are entered on the University's central student record and re-registration is automatically blocked where an unsatisfactory review is entered. An overview of all students' progress is maintained by the MEC Research Committee.

Academic support for the student is provided by the research degree supervisors, though students are encouraged to contact other members of staff should they need additional guidance in a specific area. In addition the University offers a wide range of support facilities, including the Graduate School, the Student Advice Centre, the Research Student Office in the Registry which provides dedicated administrative support to research students, a Statistics Advisory Service and the English Language Support Unit.

The MEC provides specific research and research skills training through academic supervision, as well as a programme of PhD research methods workshops (six afternoon workshops per year). In addition, research students are required to attend the MEC's general workshop programme, and to present their work to the department at least twice during their registration period. MEC research students attend (and in some cases contribute to organising) the annual 'Science Matters' Conference, a research conference for the entire School of Science postgraduate community. Relevant students, notably those whose work focuses on dyscalculia and surrounding issues, also attend the annual Health & Life Sciences Research School PhD conference, which facilitates interdisciplinary work. Funding is provided on a competitive basis for student attendance at international conferences, and each student is guaranteed funding to attend Day Conferences of the British Society for Research for Research into Learning Mathematics. In addition, many students have successfully applied for external funding for conference attendance, with support from their supervisors. Since 2008 a total of £7430 has been awarded to MEC research students from external sources (such as the Institute of Mathematics and its Applications and the Higher Education Academy), an average of £585 per full time student. A further £1343 of conference funding has been awarded to our students from the Graduate School's annual competition. Typically, these awards are matched by the MEC Research Committee.

d. Income, infrastructure and facilities

The University Research and Enterprise Offices provide professional research support offering a complete service for the costing and pricing of research grants and contracts, facilitating interdisciplinary bids. It also actively targets funding opportunities, supports drafting of applications and negotiates legal agreements and provides financial support on an on-going basis. Within the MEC, research funding applications are supported by a rigorous review process coordinated by the two research groups. This structure has been highly successful: during the assessment period we have been awarded grants worth a total of £2,744,041 – a substantial increase from the £200,282 of research grant income returned to RAE 2008 – from bodies including Action Medical Research (1 award), AQA (1 award), the British Academy (1 award), the ESRC (3 awards), the HE STEM Programme (7 awards), JISC (2 awards), the Nuffield Foundation (3 awards), and the Royal Society (3 awards).

At a university level, Loughborough has significantly increased its research funding over the years since RAE 2008 (from £34.6m in 08/09 to £38.7m 11/12). Of the latter figure £22.6m was received from highly competitive peer reviewed research council sources which has in turn leveraged a

continued growth in our funding received from industry and commerce as part of our on-going development of relationships with strategic industrial and other partners.

As part of this overall strategy within the REF period, a further £7.4m of Research Capital Infrastructure Funding (RCIF) has been invested into renewing research infrastructure and equipment, supporting key research strengths across the campus. Over £4 million has been invested in the 'Transforming the Library' project to provide a wide range of improvements to the existing facility, increasing study space and improving the learning environment. Loughborough University's IT Services supports research, learning, teaching and administration, providing a variety of communications and information technology facilities which can be accessed by staff and students.

As part of this cross-campus investment, £55k has been spent providing research facilities designed to support the creation of the new Mathematical Cognition Interest Group. The MEC now has two suites of laboratories. The Eye-Movement Laboratory is equipped with state-of-the-art eye-tracking facilities, which have been used to investigate a variety of issues, most notably expert/novice differences in mathematical reading behaviour (e.g. Inglis & Alcock (2012, *Journal for Research in Mathematics Education*); Hodds PhD; Roy PhD). The quality of our eye-tracking laboratory has directly led to research collaborations with external colleagues (e.g. Hewitt, Birmingham; Mason & Watson, Oxford; Biza, UEA). The MEC Toddler Lab is a linked pair of child-friendly laboratories, joined by a two-way mirror, and equipped with high-spec recording equipment. The lab, completed in 2012, has substantially expanded the range of studies we are able to conduct, and is being heavily used by the ESRC-funded *Skills Underlying Mathematics* project. In 2014 further investment will be made, with a £3m refurbishment of the entire Schofield Building, the home of the MEC. This will involve the refurbishment and renovation of all existing offices, research facilities and seminar rooms, and represents a substantial investment in the future of the MEC.

e. Collaboration or contribution to the discipline or research base

All researchers in the MEC actively collaborate with national and international colleagues. During the assessment period, eight of the nine researchers being returned have co-authored journal papers with international collaborators (from countries including Australia, Belgium, Canada, China, Greece, France, Ireland, Israel, Norway, and the USA). For example, Gilmore was recently invited to co-author a review in *Trends in Neuroscience and Education* with the coordinators of the EARLI Neuroscience Special Interest Group, and Alcock and Inglis sit on advisory panels of NSF grants held by the Proof Comprehension Research Group at Rutgers University (USA). Notable examples of regional collaboration are the Mathematical Cognition Group, a network of colleagues from local education and psychology departments which organises monthly research meetings, and the Midlands Mathematics Education Seminar Series, discussed above.

The MEC actively contributes to the wider mathematics education research landscape. For example, Jaworski is currently the President of the International Group for the Psychology of Mathematics Education (PME), the largest and most prestigious international research organisation in the field. Until 2009 Jaworski served as the President of the European Society for Research in Mathematics Education, and Goos is currently the President of the Mathematics Education Research Group of Australasia. Other researchers also contribute to learned societies' activities: during the assessment period Hernandez-Martinez and Jones have served on the Committee of the British Society for Research into Learning Mathematics, and Jones sits on the Vision for Science and Mathematics Education Committee of the Royal Society.

Many members of the Centre edit and/or serve on editorial boards of internationally-leading mathematics education journals. Lerman is the Senior Editor of the *International Journal of Science and Mathematics Education* and the Associate Editor of *For the Learning of Mathematics,* Goos is the Associate Editor of *Educational Studies in Mathematics* (and will take over as Editor-in-Chief in January 2014), and Alcock edits the Current Reports section of *Research in Mathematics*

Education. Inglis sits on the International Advisory Board of the *Journal for Research in Mathematics Education*, the leading journal in the field, and other researchers sit on the editorial boards of *Educational Studies in Mathematics* (Lerman), *Research in Mathematics Education* (Alcock, Inglis, Jaworski), the *International Journal of Mathematical Education in Science and Technology* (Croft), the *Journal of Mathematics Teacher Education* (Goos, Jaworski), *Mathematics Teacher Education & Development* (Lerman), and the *Mathematics Education Research Journal* (Goos). Alcock, Gilmore and Inglis recently guest edited a special issue of *Research in Mathematics Education* on experimental research methods.

Staff also regularly review proposals for funding agencies. Gilmore and Hernandez-Martinez are members of the ESRC Peer Review College, and other colleagues have reviewed for the ESRC (Inglis, Jaworski, Jones), the Israeli Science Foundation (Goos, Inglis, Jaworski), Research Foundation Flanders (Gilmore, Inglis), the Natural Sciences and Engineering Research Council of Canada (Gilmore), the Nuffield Foundation (Croft, Jaworski), the Social Sciences and Humanities Research Council of Canada (Gilmore, Jaworski), and the Royal Society (Jones).

All colleagues collaborate nationally and internationally. As noted above, Alcock and Inglis collaborate with the Proof Comprehension Research Group at Rutgers, and serve on the advisory boards of NSF-funded projects. Gilmore has active externally-funded collaborations with psychology departments at Nottingham, Ulster, and Warwick, and health sciences departments at Bonn, Leicester, UCL and Warwick. Hernandez-Martinez has externally-funded collaborations with education departments in Manchester and Nottingham, Croft sat on the advisory board of ESRC-funded projects at Manchester, and Inglis is a member of the advisory board of an AHRC-funded research network involving colleagues from Amsterdam, Edinburgh, Hertfordshire, and the OU. Hernandez-Martinez and Inglis hold honorary research fellowships at the School of Education in Manchester and the Learning Sciences Research Institute in Nottingham respectively, and in 2011 Jaworski took up the prestigious Donders Chair (a visiting position) at Utrecht University.

During the assessment period colleagues have given a total of 23 keynote addresses at international conferences (Alcock 2, Croft 3, Goos 5, Inglis 1, Jaworski 12), and have regularly contributed talks and posters to international mathematics education, general education and educational/developmental psychology conferences.