"WHAT HAVE RESEARCHERS EVER DONE FOR US?": A SUBMISSION FROM THE BSRLM[1] TO THE '14+ MATHEMATICS INQUIRY'

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BSRLM is occasionally, through its Executive, able to respond to inquiries such as this, although its constitution has only just changed to allow it to express opinions on behalf of the membership. This submission was compiled by Julian (Chair of BSRLM) on behalf of the executive and members of the society who attended the discussion at the Sheffield Hallam conference[2].

Introduction

The aim of the inquiry is to elucidate the causes of and possible solutions to shortages of well-qualified mathematicians entering Further and Higher Education and industry. The inquiry begins with the assumption (from the Roberts' report) that the UK economy is short of mathematical knowledge at many levels, from technicians to senior engineers and scientists.

We take the broader view that mathematics, as a rational, numerate and literate way of thinking about the world, should help provide the population with better understanding for citizenship as well as provide industry with more thoughtful, critical and useful employees.[3]

Within this context, there may be particular work-related emphases and skills[4], and particular work-related interests in terms of curriculum, assessment and pedagogy, but these must always be considered in the context of the broader perspective of students' interests and the broader social interest in a mathematically educated citizenry.

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[1] The British Society for Research into Learning Mathematics prepared this submission through its executive discussion, a working group meeting called especially to discuss the inquiry, and executive editing of a draft submission circulated to the membership for comment.

[2] This abstract is based on an appendix to the original submission which included details of BSRLM.

[3] We are aware of some potential contradictions inherent in this position, for instance that some hierarchical, possibly backward or outdated industries may have an interest in instrumental understandings, and may fear critical thinkers, and even the over-education of its workforce to the point where they ask too many questions, or simply leave for better employment elsewhere. For the sake of this paper we will conflate the interest of the general population with the interests of industry.

[4] Recent work by Wake & Williams in BSRLM publications has shown how useful workplace mathematics research can be in shedding light on students understandings and the way academic mathematics is encapsulated in College curricula.

The arguments against a predominantly work-related focus are:

- That many people feel they work to live, rather than live to work; and
- Students are already perhaps too alienated from mathematics: if mathematics is motivated predominantly as a workplace requirement then this could paradoxically serve to make the subject even less attractive compared to, for example, the arts, sociology, media.

However, there is another problem with focusing too narrowly on the apparent needs of employment. The perceived and stated needs of employers may bear little relation to the practical needs of their employees' actual work. In addition, employment in ten to forty years, when most of today's 14 year olds will be in their most productive years, may look very different and demand very different employees from those of today. Finally, employers may not always be the most critical judges of what their industry really needs if it is to improve and survive.

We consider therefore that the need is for the most thoughtful, highly competent and critical mathematician-citizens and employees possible: for a people who can see the world as a whole through mathematics and thereby understand it better, and who can also engage with, use and enjoy mathematics for its own sake.

Towards a Professional 'Learning Culture' in Mathematics Education

Our view is that a mathematically rich, knowledgeable society must be based on an ongoing commitment to developing a professional culture of mathematics education. This should include a combination of three commitments to:

1. high quality mathematics education for all;
2. research-and-development (R&D) *and* continuous, integrated evaluation of mathematics curriculum, pedagogical and professional development projects, and
3. 'fundamental', academic and applied research in mathematics education.

High quality mathematics education for all

A commitment to *a high quality mathematics education for all* post-14 is based on the broad aim of numerate, 'mathematically literate', educated citizenship, whether or not all industry feels the need for such a highly educated workforce as such. Several high profile cases in recent weeks illustrate the implications of innumeracy (or mathematical illiteracy) among the general population. One example involved the case of a medical researcher who did not understand independent events and probabilities[5] and the lawyers and jury who were unable to put him right, with tragic consequences for the victim.

Such a commitment to mathematics for all implies that mathematics must be considered whenever educational initiatives are planned. For instance:

- The National Centre for Excellence in Science Teaching initiative should give due emphasis and concern to mathematics. Mathematics has been called the 'queen' of sciences, and is the key to opening doors for youngsters' access to science and engineering in HE.
- Educational research initiatives such as the Teaching and Learning Research Programme (TLRP) should consider particularly strengthening research in mathematics education[6].
- An equal concern for developing subject-based professional capacity should be shown as is currently given to school improvement, i.e. a concern for the mathematics teaching profession as a unit for capacity building in contrast to schools as the predominant unit of development[7]. This kind of professional capacity building might be done through postgraduate provision in HEIs, subject associations and LEAs.
- Public understanding of science demands its counterpart – the public understanding of mathematics, with organisations that

[5] The research of Kahnemann, Slovic and Tversky, well-known to the mathematics educational research community, reveals many such misconceptions. These are not trivial misconceptions, but demand serious consideration in education at all levels of education post-14 from school through to university and postgraduate training. See vignette below.

[6] In fact we believe so far only one programme focuses on mathematics, and that is actually a joint project examining numeracy and literacy; in addition, other may relate partly to mathematics but focus on other cross curricular questions such as use of IT.

[7] We note that it is not in many schools interests to further educate their teachers, as this (a) may require good teachers to spend extended time away from the school, and so damage the schools provision, and (b) it may make teachers more marketable, cf. note 3 above. Thus the interest of the professional culture as a whole may sometimes conflict with that of the school: similar issues can arise in Initial Teacher Education. Thus we argue there is a place for seriously resourcing teachers at the level of the profession (nationally or at LEA level) and not just the school, where most funds have devolved in recent years.

continually raise public awareness as a complement to formal lifelong learning opportunities.

Research-and-development and evaluation

A commitment to *R&D and evaluation* in mathematics education implies that whenever reform or development initiatives are planned then evaluation and research should be integrated into the plan, so that reform is well-founded, and so that opportunities to develop robust knowledge from reforms and innovations is not lost.

Thus, for instance, one would expect to see in a professional culture committed to such learning:

- Independent and rigorous evaluation of the introduction of reforms such as the National Curriculum, the National Numeracy Strategy/Framework, or the recent Curriculum 2000. Such evaluations might threaten cosy assumptions that any reform initiative ‘has to work’ of political necessity. The key is to ensure that such evaluations continually feed into the system as fast as possible so that policy and practice can continuously be steered by emerging findings.[8]
- Teachers would come to see their role as evaluators and researchers as well as classroom practitioners: recent initiatives to develop teacher-researcher capacity through professional learning communities and evidence-based practice (TLRP, Networked Learning Communities, Best Practice Research Scholarships - BPRS etc) should be strengthened and embedded into professional development from ITE to rolling CPD.
- Data collection and analysis and the formation of evidence collected by agencies such as Ofsted, QCA, TTA would be transparent and rigorous, and would belong to and be shared by the profession in a collective endeavour to research and improve practice. The era of Ofsted holding teachers to ‘account’, scoring them in market league tables, hierarchical management and so on would be replaced by an era of partnership, collaboration and practitioner engagement in profession building and excellence. This would involve a new model of ‘flat management’, local R&D teams and networks, and so on.

[8] Latour, (Bruno, 1999: Pandura’s hope, Harvard UP) has argued the need for social science to develop research just in time, because the best social science interacts with and develops social practice rather than accumulates as in natural science. He cites feminist research as an ideal example.

A commitment to academic research

A commitment to academic research in mathematics education would aim in the long term to strengthen theory, develop ever more powerful capacity and methodologies, and ensure that mathematics education benefits from the world’s best work in the social sciences and other relevant academic fields. This cannot happen without well-funded research institutes, HEIs etc., and must take place with the active support and partnership of the profession at large.

In our view this could involve, for instance, the following measures.

- The best teachers and teacher-researchers would be recruited to join research teams and networks, undertake higher degrees by research etc. with HEIs on a seconded basis, helping to ensure a flow of skills and knowledge into academia and back to schools, and the continuing relevance of academic work to practice. This could be done by strengthening existing initiatives by GTCs, TTA etc., and by a commitment to secondment for the best teachers to develop research and leadership.
- A significant percentage[9] of educational spending would be reserved for ‘research’ in education, promoting the best and most effective research, in order to establish a vigorous British culture, and so that universities might recruit from the best academics world-wide, or at least nationally.

This will only happen if there is a belief that independent research capacity in educational research can be efficacious and is an essential part of a broader learning culture. In education we have a particular responsibility to ensure that excellent research supports the development of the profession as well as develops its own community.

The government policy of concentration of research resources in a few centres of excellence will hit educational research very hard, as much good educational research is currently distributed throughout the HEIs. If the bulk of research were concentrated in a few 5-star and 6-star university departments, this would terminate the bulk of mathematics education research in particular.[10]

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[9] We believe that the current percentage of education budgets devoted to educational research, to the nearest 1% , is in fact zero.

[10] In our view there is much "5-star" quality mathematics education research taking place in HEI departments of education that are currently rated, overall, at less than 5-star. In the 2001 RAE there were only two 5-star departments of education in the UK, and only one of these does significant work in Mathematics Education

What Can Research Offer to Mathematics Education?

We have suggested that good research in mathematics education can have a significant impact on our understanding of and the quality of education in the short, medium and long term. Indeed, when considered in comparison to the cost of ignorance, we suggest that investment in research is a wise investment.

On the one hand, research for policy makers can help avoid re-invention of the wheel, making the same mistakes twice and so on, and suggest where energy and resource might make worthwhile impacts. On the other hand, research into practice and research partnerships involving practitioners can provide a means of developing a thoughtful, reflective and critical teaching profession.

Both these endeavours depend on an infrastructure of centres of academic research excellence, where rigour and method are continuously re-examined in theory and practice by academics who tap into the international community of educational scholarship and research. But they also involve a partnership between research and the profession either in (i) determining research focus, or (ii) the conducting of the research itself.

Examples of Significant Research in Mathematics Education

In the following illustrative examples we highlight a few recent research or research-based projects of significance to mathematics education by British researchers.

1. Pupil autonomy and 'enquiry'

Academic, 'theoretically-based' research in education is often seen as disconnected from reality, 'boffin-like' by practising professionals. Yet, we believe, there is nothing so practical as a good theory. And there is nothing like academic work for disassembling our most cherished 'common sense'.

A good example of this is the well-known research of Denvir and Brown and others in the 1970s and 1980s. Denvir and Brown[11] showed that, even in the most favourable teaching conditions (one-to-one and carefully focussed and precisely designed), children's learning did not 'follow' teaching. That is, children persisted in failing to learn the behaviours and connections that were being taught, yet were learning or achieving 'objectives' which were *not* being taught.

[11] Denvir, B. and Brown, M. (1986a). Understanding of number concepts in low attaining 7-9 year olds: Part II - development of descriptive framework and diagnostic instrument. *Educational Studies in mathematics* **17**(1): 15-36.
Denvir, B. and Brown, M. (1986b). Understanding of number concepts in low attaining 7-9 year olds: Part II - the teaching studies. *Educational Studies in mathematics* **1**(2): 143-164.

Another, more contemporary example relates to transmission versus 'enquiry' styles of teaching and learning. For example, Leone Burton[12] interviewed mathematicians about their research practices. She showed that they adopted an enquiry approach in their own work, but often pursued traditional, 'transmission' strategies in their teaching. In secondary classrooms, Jo Boaler[13] compared the outcomes for pupils of learning mathematics in a conventional, traditional classroom and in a classroom in which all the work was focussed on pupil enquiry. The school which developed pupil enquiry had pupils who gained more in conventional terms, on GCSE assessments, but also gained more in the ways in which they related to mathematics outside of school[14].

Boaler described how in the enquiry case, pupils spent quite a bit of time in control of their own work, sometimes apparently off-task, whereas in the traditional classroom, activity was typically teacher driven. Yet, perhaps paradoxically, the 'enquiry' pupils learnt more and better.

These studies raise timely and thought-provoking questions about models of teaching and learning, and the complexity of the relationship between them. This kind of questioning is, we believe, important for a critical profession, in challenging 'common sense' assumptions about practice.

2. Intuitive fallacies and the mathematics curriculum

The research of psychologists of decision-making, such as Kahnemann, Slovic and Tversky[15], reveals that many misconceptions such as the gambler's fallacy and base-rate fallacy are based on decision-making heuristics such as 'availability' (the tendency to believe that what is most available to memory is more commonly occurring) and 'representativeness' (the tendency to believe that a sample should be representative of its parent population). These have been shown to be endemic in professions such as medicine, and can lead to dangerously flawed reasoning.

[12] Burton, L. (2001) Research Mathematicians as Learners - and what mathematics education can learn from them, *British Educational Research Journal 27* (5) 589-599.

[13] Boaler, J. (2002). *Experiencing school mathematics*. Mahway, New Jersey, Lawrence Erlbaum Associates.

[14] This case study research is also consistent with the large scale research by CASE, which showed significant GCSE gains for students who engaged in an enquiry-type curriculum several years after the intervention.

[15] Kahneman, D., Slovic, P. and Tversky, A. (1982). *Judgement under uncertainty: heuristics and biases*. Cambridge, Cambridge University Press.

Amir and Williams[16] and Afantiti and Williams[17] have recently shown how these heuristics and associated misconceptions affect children's thinking in school mathematics when they deal with chance and probability and infer that these might be addressed in the curriculum as early as age 11.

Such misconceptions demand serious consideration in the mathematics and other curricula at all levels of education from school through to university and postgraduate training (see for example Gorard[18]).

Other British research on learning and misconceptions relevant to the teaching of mathematical topics is regularly reported in BSRLM proceedings and at international conferences and journals, and curriculum developments should be routinely (and sometimes are) informed by these researches.

3. Teacher education and continuing professional development

BSRLM has recently undertaken some work with the Conference of Professors In Mathematics Education (CoPRIME) to review research and identify a research agenda in mathematics education. One study focused on Continuing Professional Development in particular. Typically, reviews of research in teacher education begin with statements such as "The paucity and fragmentary nature of the evidence from British studies which have a specific focus on mathematics teacher development makes it difficult to make definitive research claims" (Brown and McNamara[19]). "The fragility of the evidence base relating to CPD programmes, and particularly those relating specifically to mathematics, is even more acute". (Wilson et al.[20]).

Recent government CPD policies aimed at raising standards have been experienced, certainly in the primary phase in terms of prescription and initiative overload. In the longer term embedding policy has not

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16 Amir, G. and Williams, J.: 1999, 'Cultural Influences on Children's Probabilistic Thinking.' Journal of Mathematical Behaviour, 18(1), 85-107.

17 Afantiti-Lamprianou, T. and Williams, J.: 2002, 'A scale for assessing probabilistic thinking and the representativeness tendency'. In A. D. Cockburn and E. Nardi (eds.), Proceedings of the 26th Conference of the International Group for the Psychology of Mathematics Education (PME) (pp. 9-16). England: Norwich, and Afantiti, T. & Williams, J. (under review). A scale for assessing probabilistic thinking and the representativeness tendency *Research in Mathematics Education.*

18 Gorard, S. (1999). Keeping a sense of proportion: the 'politician's error' in analysing school outcomes. *British Journal of Educational Studies* **47**(3): 235-246.

19 Brown, T. and McNamara, O. (2001). Initial and continuing professional development of teachers. In: M. Askew and M. Brown, Eds. *Teaching and Learning Primary Numeracy: a review of British research for BERA in conjunction with BSRLM.* Southwell, BERA**:** 50-56.

20 Wilson et al. (2001).

always been understood in the terms in which it was presented nor has it always been fully implemented before the next policy was devised. Funded evaluation of long-term CPD programmes has usefully, but sometimes exclusively, been directed at the initial stages of such initiatives (Melrose[21], Harland and Kinder[22]), whereas it would seem reasonable to expect a degree of 'bedding in' so that a mid-term evaluation would be more indicative of the success of the programme.

Nevertheless, a number of messages come across very clearly. First, the need to allocate sufficient quality time to CPD, and to involve teachers themselves in the management of their professional development, e.g. 20-day courses (Askew et al.[23]). In reality, however, primary schools still retain an individualistic notion of development and one-day courses still predominate by virtue of time and cost constraints and perceived needs (Bottery and Wright[24]). Secondly, the cascade training so favoured by a number of these models is persistently identified as the 'weak link' in the process (Harland and Kinder, ibid. p.6). Finally, deep 'whole school' change and dissemination of good practice must be firmly rooted in teacher experience and depend upon cellular growth of working groups – a 'diffusion' rather than 'dissemination' model (e.g. the NNS: Earl et al.[25]).

4. The use of national test data[26] in monitoring performance

Examples of the use of National Test data to support government policy, in particular the success of the introduction of the National Curriculum for mathematics and later the National Numeracy Strategy, are widespread in the public domain. However these are flawed measures since teachers are well able by 'teaching to the test' to improve scores on high stakes tests with little evidence of real

[21] Melrose, J. (1982, 1983). The Mathematical Association diploma research project. Part 1,2. *Mathematics in School, 11*(5), 42-43. and *12*(1), 5-8.

[22] Harland, J. and Kinder, K. (1992). *Mathematics and Science Courses for Primary Teachers.* Slough: NFER.

[23] Askew, M., Brown, M., Rhodes, V., Wiliam, D. & Johnson D. (1997) The contribution of professional development to effectiveness in the teaching of numeracy. *Teacher Development, 1*(3), 335-355.

[24] Bottery, M. and Wright, N. (1996) Cooperating in their own deprofessionalisation? On the need to recognise the 'public' and 'ecological roles of the teaching profession. *British Journal of Education Studies, 44*(1), 82-98.

[25] Earl, L., Fullan, M., Leithwood, K. and Watson, N. (2000) *Watching and Learning: OISE/UT evaluation of implementation of the National Literacy and Numeracy Strategies*. Toronto: Ontario Institute for Studies in Education of The University of Toronto.

Earl, L., Watson, N., Levin, B., Leithwood, K., Fullan, M., and Torrance, N. (2000) *Watching and Learning 3: Final report of external evaluation of England's National Literacy and Numeracy Strategies.* Toronto: Ontario Institute for Studies in Education of The University of Toronto.

[26] Brown, M., Askew, M., Millett, A. and Rhodes, V. (in press). The key role of educational research in the development and evaluation of the National Numeracy Strategy. *British Educational Research Journal* (available from margaret.l.brown@kcl.ac.uk).

underlying improvement (e.g. Cannell[27]). A further although more minor factor is that since different tests are set each year and across different key stages, it is difficult to compare results to a high degree of accuracy, even with pre-testing.

Unfortunately, since the demise of the Assessment of Performance Unit[28] which was active in the late 1970s and 1980s, there has been no properly controlled national monitoring of performance.

There have been a few independent studies, both large and small, although these have sometimes been of specific aspects of mathematical performance. These studies tend to show that the overall changes are much smaller than the government claim, for example Brown et al. (ibid) suggest that in a third of schools the Year 4 numeracy scores on the same test have dropped since the National Numeracy Strategy was introduced, and that the average increases in performance are very small.

Very similar effects have been shown at the 6th form- university interface in mathematics, where A' level performance on mathematics has been generally steadily improving, but where diagnostic tests of students on entry to university show steadily declining performances by students with the same A' grades (e.g. Lawson[29]).

In general this work suggests that the monitoring of performance through high stakes National test or examination data is flawed: rather one seeks an independent study using a similar, carefully calibrated measure from one year to the next on a national sample (such as that of the former APU).

5. Negative attitudes to learning mathematics: anxiety and disaffection

There is a long history of research into mathematics anxiety and perceptions of utility etc of mathematics in the UK and elsewhere. However, attempts by TGAT to introduce the assessment of affect in the National Curriculum were frustrated, and again no proper nationally sampled studies have been done since the APU.

However, the relative percentage of decline in mathematicians at A' level signals a disaffection, and some studies have sought insight into this. For some recent work in the UK, see Elena Nardi and Susan

[27] Cannell, J.J. (1988) Nationally normed elementary achievement testing in America's public schools: how all fifty states are above the national average. *Educational Measurement: Issues and Practice*, *7*(2), 5-9.

[28] E.g. Foxman,D., Ruddock, G., McCallum, I and Schagen,I (1991). APU Mathematics Monitoring (Phase 2). Slough, NFER

[29] Lawson's report in 'The mathematics problem', IMA/LMS

Steward[30]. They constructed the profile that they call T.I.R.E.D.: tedium, isolation, rote learning, elitism and depersonalisation. This notion of disaffection was supported by a small study with 'A' level students[31].

6. Undergraduates' attitudes to teaching mathematics

Recent work by Rodd et al.[32] has shown that undergraduates are critical appraisers of the teaching they receive at university and recognise that good teaching is central to their learning. Furthermore, from this ongoing in-depth study of mathematics undergraduates, it appears that students have negative perceptions of teaching as a career, particularly those who had vicarious experience of teaching e.g. through family membership[33].

There is also an understandable perception, found from research with current mathematics PGCE students, (Goulding, Hatch and Rodd[34]) that mathematics learnt at university lacks relevance to teaching. School teaching requires a deep understanding of elementary mathematics and a connectedness within mathematics and between mathematics and other knowledge, yet the experience of studying mathematics at university level demands students struggle with challenging advanced mathematics, sometimes within an environment of unresponsive teaching and assessment.

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[30] Nardi, E. & Steward, S. (2002) Part I: "I could be the best mathematician in the world...if I actually enjoyed it", *Mathematics Teaching 179.* "I'm 14, and I know that! Why can't some adults work it out?" *Mathematics Teaching 180,* Part II.

Nardi, E. & Steward, S. (2003 forthcoming). "Is Mathematics T.I.R.E.D.? A profile of quiet disaffection in the secondary mathematics classroom". *British Education Research Journal, 28*(2).

[31] Burton, L. (2001). Mathematics? No Thanks - choosing and then rejecting mathematics, S. Johnston-Wilder (Ed.) *Proceedings of a national day conference, Key Stage 3 mathematics teachers: the current situation, initiatives and visions.* The Open University, Milton Keynes.

[32] Rodd, Melissa (2002) Hot and abstract: emotion and learning undergraduate mathematics *Proceedings of the second International Conference on the Teaching of Mathematics (at the undergraduate level)* John Wiley and University of Crete: Crete http://www.math.uoc.gr/~ictm2/Proceedings/pap203.pdf

Rodd, Melissa, (in press 2003), Witness as participation: the lecture theatre as a site for mathematical awe and wonder *For the Learning of Mathematics,* 23(1)

[33] Brown, M. , Macrae, S. and Venkatakrishnan, H., 'The Effects of Teacher Workloads and Other Factors on Mathematics Teacher Recruitment and Retention'. http://mcs.open.ac.uk/cme/conference01/p4.pdf

Rodd, Melissa (2003) '"Always an option": mathematics undergraduates choosing teaching as a career' *Shortage of mathematics teachers, what progress? conference, The Open University* http://mcs.open.ac.uk/cme/conference02/

[34] Goulding, M., Hatch, G. and Rodd, M.M. (in press) The undergraduate mathematics experience: its significance in secondary mathematics teacher preparation *Journal for Mathematics Teacher Education*

7. Children's images of 'mathematicians'

Research describing some results of an international comparison of the images of mathematicians held by children, reports that with small cultural differences students had very little insight into the work of mathematicians—that mathematicians are virtually invisible to them, Picker and Berry[35]. The study provides an important insight into the need to see mathematics as more than just a collection of algorithms and skills. Students showed evidence of their beliefs that the purpose of mathematics is to get the one right answer; that mathematicians are odd and work alone; that a mathematics classroom is a controlled and controlling environment ruled over by a teacher.

The authors argue that there are three purposes of mathematics education: (i) the learning of the ideas and concepts inherent in mathematics; (ii) the learning *about* mathematics, focussing on important issues such as the philosophy and methodology of mathematics, and the history of mathematics and famous mathematicians; and (iii) the learning of how to do mathematics, i.e. taking part in mathematical activities that lead to the acquisition of knowledge.

8. Learning mathematics and new technology

Developments in technology continue to raise crucial questions about curriculum design and teaching methods in mathematics. Significant British research[36] exists which illustrates how technology can change learning sequences in mathematics, and/or bring together aspects of the mathematics curriculum that are often treated separately (and/or at different times), all of which can, in appropriate circumstances, lead to improvements in pupil learning and understanding, and indeed the whole culture of mathematics (see for, example, Jones, 2000, Noss and Hoyles, 1996; Noss, 2001[37]):

This is [the computer's] ability to offer alternative means to express mathematical relationships, novel kinds of symbolism, and innovative ways to manipulate mathematical objects: in short, the emergence of

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[35] Picker, S.H. and Berry, J.S. (2000). Investigating pupils' images of mathematicians. *Educational Studies in Mathematics 43*(1): 65-94.
[36] BSRLM has a working group on geometry that has done much work on this in recent years.
[37] Jones, K. (2000), Providing a Foundation for Deductive Reasoning: Students' interpretations when using dynamic geometry software and their evolving mathematical explanations. *Educational Studies in Mathematics, 44*(1&2), 55-85.
Noss R. and Hoyles, C. (1996). *Windows on Mathematical Meanings: Learning Cultures and Computers*. Dordrecht: Kluwer.
Noss, R. (2001), For a Learnable Mathematics in the Digital Culture, *Educational Studies in Mathematics, 48*(1), 21-46.

new mathematical cultures. The computer points to new ways to say mathematical things, as well as new mathematical things to say. (Noss, 2002, p45)

This research is leading to important work on developing suitable theoretical framework(s) for designing technological tools and teaching activities for mathematics and to gains in insight into how might we encourage (more) teachers to use technological tools in mathematics teaching and about ways in which using technology changes how teachers think about the teaching and learning of mathematics. Such research is crucial if the nation is to reap the full benefit of the recent substantial investment in technological infrastructure for schools.

Conclusions

We have pointed to the danger of building a 'knowledge economy' on an out-dated, un-researched notion of education and educational practice.

We have pointed to the roles of educational research and research communities in support of and partnership with a 'learning profession' of teachers, and highlighted the academic, the R&D and the practitioner/policy informing aspects of our work.

We have illustrated the role of mathematics education research and how it might benefit policy and practice in the profession and hence indirectly the economy. Research is still very much under-funded and we have suggested how its expansion might yield major benefits for advancing practice.