increasing capacity in STEM education research

a study exploring the potential for a fellowship programme

Karen Halsey
Jennie Harland
Iain Springate

Contents

Executive summary

1 Introduction

The National Foundation for Educational Research (NFER) was commissioned by the Royal Society to complete a study exploring the potential of a Fellowship programme for early- to mid-career education researchers in STEM (Science, Technology, Engineering and Mathematics). The study was set within the broader context of increasing capacity in STEM education research and was intended to assist the Royal Society in its aim to ensure that the next generation of leading STEM education researchers are recruited and sustained in their careers. Hence the study scopes perceptions around relevant issues in this arena, including:

- career routes into STEM education research
- the drivers of STEM education research
- the distribution of expertise within STEM education research
- the interactions between STEM education research, and policy and practice
- aspects of international collaboration and competitiveness
- the enabling factors and barriers to building and sustaining expertise in STEM education research.

The study was organised into four phases of data collection, beginning with a rapid response search of literature. This was followed by collecting the views of 16 policy and practice representatives via telephone interviews/proforma. The third strand of data collection involved interviews with 30 STEM education researchers across the UK (25 from England and the remainder from Scotland, Northern Ireland and Wales). Towards the end of the project a focus group was held to discuss emerging findings and consider in more depth the possible contribution of a fellowship programme.

2 Factors that affect the commissioning of research

The type of STEM education research undertaken was primarily said to be driven by policy concerns, the availability of funding and the motivation to advance knowledge and understanding. It was also noted that sometimes STEM education research was undertaken because of practice concerns, and may depend upon the availability of quality researchers capable of carrying out a study.

These commissioning factors may well have some implications for the capacity building in STEM education research. For example, policy concerns were identified as the main driving factor of research yet policy related

research can be subject to certain constraints (e.g. RAE lack of recognition of policy focused research, the lack of attractiveness of some policy research, and the lack of impact of STEM education research on policy, see Chapters 3 and 7). This apparent incongruence between STEM education research commissioners and researchers may highlight a bias in the interview sample (for instance, a lack of input from research funders less concerned with policy, such as the research councils). However, more worryingly, the data presented here may allude to a mismatch between funders needs and what researchers offer.

Secondly, the availability of suitable researchers was mentioned as a factor that sometimes influences the commissioning of research. Commissioners may require researchers in particular specialist areas, in particular regions and to undertake research in a particular timescale. A fellowship programme could potentially replenish the capacity of researchers in each of these ways. For instance, a fellowship scheme could release people from teaching responsibilities to focus on research.

3 Competitiveness

Some interviewees experienced the competitiveness in UK STEM education research as high and healthy, a number of others felt competition was low and varied. Very often though, competitiveness was seen to be conditional depending on a number of factors: attractiveness and status of the research, the availability of funding, the reputation of the institution and researcher, the specific expertise required and the commissioning process.

The finding that competitiveness is variable perhaps raises some implications for building the capacity of the community. Given the current picture of UK STEM education research as a market monopolised by a ‘small pool’ of centres of excellence, should investment focus on building the capacity of the current centres of excellence or develop new and additional centres of excellence across the UK? Meanwhile, as STEM education research is a more competitive market place for early and mid career researchers should greater emphasis be placed on supporting researchers to acquire the ‘survival skills’ of successful bid writing? The availability of funding for STEM education research was reported as an issue by respondents, in particular that ‘piecemeal’ funding appears to be relatively unattractive to researchers. Thus, the capacity for research may be strengthened by a more collaborative and consistent approach to funding. Finally, it was observed that quality researchers may be constrained by their dual roles as researchers and educators, limiting the number of research projects they can compete for. A fellowship programme could potentially release researchers for periods from their teaching roles to enable them to participate more in the STEM education research market place.

4 Career pathways into STEM education research

The most common route into STEM education research was to undertake a STEM subject degree (and possibly higher degree), followed by teacher training and teaching experience, and then the transition into teacher education and education research at a higher education institution. The transition from school teaching to academia was often achieved by completing a higher degree or becoming involved in research or with a university while teaching. Interviewees in this study had often received funding support to undertake further study and taken time out from employment. Maximising the availability of funding support for higher degree study would appear to be a crucial feature of building the capacity of the STEM education research community.

Less frequently, interviewees described entry via social science and STEM subject specialist routes. Many respondents reported a lack of career structure and clear career routes into the profession. If there are viable alternative routes into the profession, perhaps these could be made clearer and potential career progression routes could be more clearly associated with fellowship study. In addition, the fellowship programme could also consider facilitating the careers of those who do not wish do pursue a route which leads to a lectureship.

The most important factor influencing participants' career route into STEM education research was their own interests and motivations to improve teaching and learning. Capacity building exercises may thus need to focus on supporting people to make the entry to the profession but also to retain them. Other facilitating career factors included: getting a permanent position in a university and whether or not researchers could win funding for projects (which was felt to depend on the status of the institution). For more recent entrants to the profession, being part of a strong research culture was seen as very beneficial. Institutions seeking new researchers, as well as the design of a fellowship programme, may need to consider how they will provide a solid structure of support, particularly from senior colleagues.

5 Availability of expertise

This chapter describes STEM education researchers own views about the distribution of expertise within the field. Pedagogic and subject knowledge were reported to be strong areas of expertise. Interviewees suggested a lack of expertise in terms of terms of methodology, perspectives and theory, interdisciplinary work and specific subject areas. Respondents' views about the areas of insufficient expertise provide implications for the focus of capacity building exercises.

In order to address the lack of methodological and theory/perspectives expertise in the STEM education research community a fellowship scheme could focus on both increasing the routes into the field (e.g. from social

sciences backgrounds) and equip researchers with the necessary methodological skills. The fellowship scheme could offer certain quality standards of training to ensure equity of support available to students in a similar way to the ESRC funded studentships.

A lack of interdisciplinary working could also be addressed at least partially by a fellowship scheme. The scheme could encourage collegiate working between those on the scheme by offering programmes of support that brought cohorts of researchers together. This structured system of support would ensure greater consistency rather than simply relying on senior colleagues to provide support.

Providing opportunities to engage with practitioners would also seem to be a feature of maintaining and building expertise in the STEM education research community. Contact with practitioners would allow educationalists to stay informed about current practices and help those entering from primarily social science backgrounds to develop their educational knowledge.

6 International collaboration

Although some researchers felt that international collaborations were not relevant to their research, others clearly wanted to be involved in such research. Early career researchers tended to be interested in such work, but were the least likely to have been involved in internationally collaborative research. There were several aspects that could be included in a fellowship programme to encourage international collaboration. Firstly, ensuring that researchers are involved in international networks in their field, and are given opportunities to go to conferences and meet other researchers. Secondly, providing funding to support researchers to develop collaborative bids with colleagues abroad, as this can be an expensive process. Lastly, a fellowship could give support to help researchers, especially early career researchers, bid for and administer funding.

7 Innovation in STEM education research

Overall, interviewees in this study did not feel STEM education research is particularly innovative. Interviewees called for more innovation in terms of methodology and approaches that would ultimately improve the relevance and usefulness of STEM education research.

Some STEM education researchers in this study believed that greater innovation could be achieved with more large scale, quantitative, representative and internationally comparative research. Some STEM education researchers called for greater emphasis on research and development and engaging with practitioners. Funders would seem to have a key role to play in facilitating innovation in terms of the type of research they commission

and the extent to which the requirement for innovation is specified and prioritised.

Some interviewees contended that innovation in STEM education research was constrained by a dominant natural science research ideology. Policy makers and funders were reported by participants to often require research that measures educational approaches in a scientific way, which does not always suit the social phenomenon of education. The introduction of new approaches and ideas may therefore help the education community (including researchers, practitioners and policy makers) to move beyond the constraints of a dominant natural science research model. Specific attention should perhaps be paid to how this could be achieved in the designing of a future fellowship programme. Research fellows would be well placed as new entrants to the community to bring new and innovative ideas and approaches.

For many respondents innovation was about working with practitioners to move educational practices forward. In order for this to happen the interplay between researchers and practitioners needs to be strengthened and greater emphasis on translating research findings into practical applications (Ratcliffe et al., 2004). Indeed in a working paper undertaken for NERF (National Educational Research Forum) the authors Dyson and Desforges (2002) recommend research capacity is considered as a system, embracing both research-producers and research-users and that capacity building exercises should aim to strengthen the system of research holistically. A potential fellowship programme may consider how students will learn innovative ways to engage practitioners in research and place emphasis on presenting and conveying research findings to practitioners in an accessible and useful way.

8 Quality of STEM education research

The quality of STEM education research was reported as variable across the field, and interviewees suggested that high quality work tends to be concentrated in a small number of institutions and individuals. One of the issues around less high quality research was a lack of methodological rigour. Therefore, a key issue for a fellowship programme is to develop methodological expertise in the STEM education research community, and to ensure that all have access to high quality training, especially those from a teaching background.

Interviewees felt that the methodological rigour and relevance were the most important criteria for assessing the quality of STEM education research. Researchers also stressed the importance of theory use, suggesting that all research should be well underpinned by theory and should contribute to advancing theory. Those earlier in their careers were more likely to say that having impact is a mark of quality research than those further on in their

careers, suggesting that it is important for the former to know that their work is making a difference.

9 Impact of STEM education research

The impact of STEM education research is an important issue for researchers, as the aim of their work is to eventually impact on teaching through policy or practice. Interviewees suggested that the most common impacts of research were that it affirmed existing ideas and contributed to the body of knowledge. Other more direct impacts on policy or practice were less common, and researchers were keen to see their work have more impact. They suggested that research does not have impact due to ineffective communication of findings, and the fact that much research is small scale and not part of a coherent set of findings. The characteristics of successful research suggest that to have impact, researchers need to take account of the needs of policymakers and practitioners, involve them in the whole research process, and ensure that findings are effectively and appropriately disseminated.

There are several implications here for a fellowship programme. Firstly, more impact could be achieved if practitioners are involved in the research that is carried out. A way to achieve this could be to target teachers who are interested in doing research for the fellowship. Secondly, if the fellowships had a research theme, all the individual pieces of work carried out could fit together and complement each other, leading to a more coherent set of messages than a body of more disparate work. Lastly, research carried out as part of the fellowship programme needs to take note of the characteristics of research that has impact and apply them appropriately to the work. Part of the support given to researchers could be to help them ensure that their research incorporates these characteristics as far as possible.

10 Increasing capacity

This chapter collated interviewees' views on the factors that could potentially increase capacity for STEM education research, as well as the specific contribution of a fellowship programme.

Access to training, support and better career prospects were highlighted as the main factors that could help build and sustain expertise in STEM education research. The different backgrounds of entrants was felt to affect the kinds of training they would be needed. It was suggested that those entrants coming from a classroom environment may well benefit from training which focuses on developing their research skills. For those entrants with a social science background it was recommended that they receive training on the education system and pedagogic issues. In terms of longevity as a STEM education researcher, it was deemed essential that all new entrants to the profession quickly acquired the practical business skills associated with research (e.g. writing bid, managing projects).

According to interviewees, the life of a STEM education researcher can be insecure (due to temporary contracts) and relatively stagnant (with few opportunities to move forward). In terms of capacity building therefore, any strategy (a fellowship or other) would need to address the longer term issue of career progression and to consider how an individual's prospects could be improved and the progression of their career facilitated. The disparity between researcher and teacher salaries was cited as a factor that deterred prospective researchers from leaving the classroom.

Interviewees were unanimously positive about the suggestion of fellowship programme. In terms of its style and composition they suggested that it could:

- Be offered within a structure of support, training, mentoring
- Develop the practical skills associated with research (writing bids, managing projects)
- Give recipients freedom to pursue their own research interests
- Provide opportunities for collaboration between disciplines, institutions
- Release staff from some/all of their teaching commitments in order to dedicate time to research.

11 Summary and concluding comments

This final chapter seeks to illuminate the main messages from the research and pinpoint the important decisions which need to be made, should the Royal Society wish to proceed with a fellowship programme. In reading this synopsis it is important to recognise that the study was conceived as a scoping exercise – it was intended to be selective and illustrative rather than fully comprehensive. On the basis of this, it would be unwise to present definitive recommendations. Instead, we pose a range of questions, alongside various options for a fellowship and signal those which were most strongly supported by interviewees.

1 Introduction

The National Foundation for Educational Research (NFER) was commissioned by the Royal Society to complete a study exploring the potential of a Fellowship programme for early- to mid-career education researchers in STEM (Science, Technology, Engineering and Mathematics). The study was set within the broader context of increasing capacity in STEM education research and was intended to assist the Royal Society in its aim to ensure that the next generation of leading STEM education researchers are recruited and sustained in their careers.

1.1 Background to the study

The health of Science, Technology, Engineering and Mathematics (STEM) education research in this country faces two inextricably linked challenges:

- the demand for STEM education research, which is potentially increasing
- the supply and retention of suitably qualified STEM education researchers.

1.1.1 Demand for STEM education research

On the demand side, the increasingly rapidly changing face of STEM skills, employment and industry requires that education keeps up with such changes. This involves consideration of developments around the STEM curriculum and pedagogy, young people's attitudes towards and participation in STEM, and the interaction between STEM education research and STEM education policy and practice more broadly.

According to the STEM Programme Report commissioned by the Department for Education and Skills (DfES) and the Department for Trade and Industry (DTI), there are currently 470 initiatives supporting STEM education (DfES/DTI, 2006). This in itself is an indication of the urgency with which the STEM community and education policy makers are addressing the issues involved. Curriculum innovations include, for example, developments around the 21st Century Science courses (http://www.21stcenturyscience.org/), and the development of bridging units between primary and secondary school science (e.g. Braund and Driver, 2005). Research needs to explore these changing contents in the STEM curriculum and the pedagogical and organisational challenges of delivering a relevant STEM education. There are also wider considerations for further developments around the training of new and existing teachers to better deliver that curriculum (e.g. Gilbert, 2006).

Research needs not only to ensure that the STEM curriculum is updated and relevant, but also to ensure that more young people opt to study within this

arena. There is mounting anxiety about the decline in pupils opting for STEM subjects at A-level and degree-level (e.g. Roberts, 2002; Stagg *et al*., 2003; Jagger, 2004). Various reasons are emerging for this, including a perception that the subjects are too difficult, that they lead to limited career options and that the subjects are boring compared to other curriculum areas (e.g. Murray and Reiss, 2005; Munro and Elsom, 2000; Cleaves, 2005; Lord and Jones, 2006; Lord *et al*., 2006). Again, initiatives to support young people include those around AimHigher and the Government's Science and Innovation Investment Framework 2004-2014.

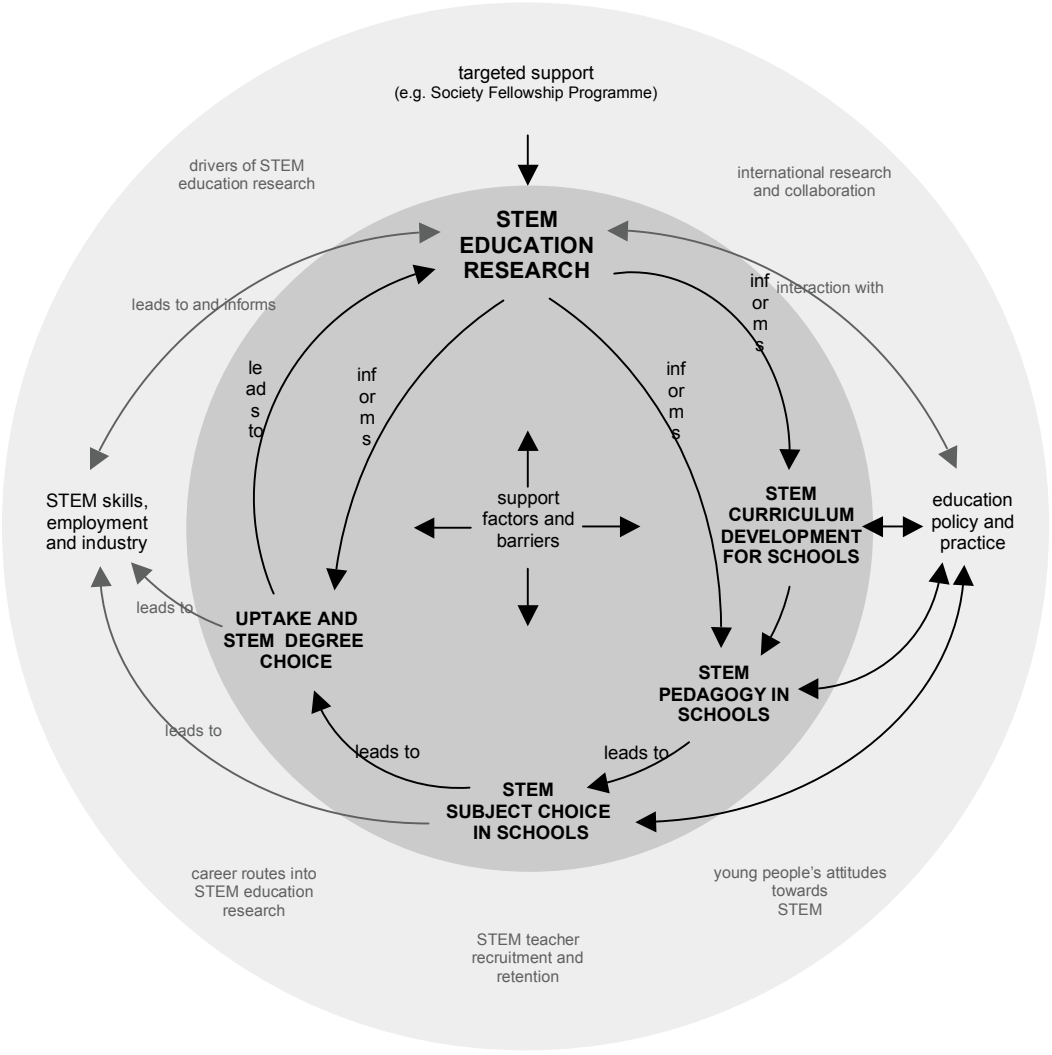
1.1.2 The supply of STEM education research

On the supply and retention side, there is an inevitable knock-on effect from declining student uptake of STEM for both teacher recruitment and retention (e.g. DfES/NFER, 2006) and for the STEM education research community (e.g. Roberts, 2002; Adrian Smith, 2004). There are fewer candidates available to go on to become the next generation of specialist researchers or teachers. Those students that do opt for STEM subjects then become the object of much greater recruitment competition, not only from schools, but from the specialist-starved industrial sector. The STEM education research sector then finds itself part of this highly competitive market situation.

The situation is such that it may be necessary to take new measures to ensure that there is a suitably qualified and resourced body of STEM education researchers. Considerations around supply and retention include the competitiveness of salaries, career progression routes, the environment in which STEM education develops, and the drivers of STEM education research. It is necessary to ensure that STEM education research is an attractive career option in which leaders can emerge, diversity of thought can flourish and rigorous peer debate can flourish.

1.1.3 Increasing capacity for STEM education research

The challenge may now be to ensure that it is possible to meet STEM education research needs in the future. STEM education researchers are part of an essential cycle of development (see illustration overleaf). As the illustration suggests, increasing capacity within STEM education research might have knock-on effects within the STEM education 'cycle' and, potentially, across other spheres of influence.



1.2 Aims and objectives

The main aim of the research was to inform the Royal Society about the support needs of the STEM education research community, and in particular for a Fellowship programme for early- to mid- career education researchers in STEM education.

The study therefore set out to determine the current climate of STEM education research by examining issues such as availability of expertise, the impact of research and the extent of international collaboration. From this information, the study endeavored to highlight the kinds of support that those working in the field of STEM education research might benefit from.

Key questions for the study included:

1 Where are today's leaders of STEM education research in the UK, and how did they get there? (i.e. career routes into STEM education research)

2 What drives the type of STEM education research undertaken (funding, existing centres of excellent, availability of researchers, etc.) and how is innovation promoted and/or constrained under the current system? (i.e. the drivers of STEM education research)

3 How is 'excellence' in STEM education research measured and what are the distributions of, and tensions between, methodological, pedagogical and subject knowledge expertise? (i.e. the distribution of expertise within STEM education research)

4 How well is STEM education research informed and used by policymakers and practitioners? (i.e. the interactions between STEM education research and policy and practice)

5 How internationally collaborative and competitive is UK STEM education research? (i.e. international collaboration)

6 Under what conditions (e.g. well-defined career routes, competitive salaries, adequate funding and an academic environment encouraging communication, peer review and peer/mentor support) do excellent individuals in STEM education research thrive and how could these conditions be optimised? (i.e. the enabling factors and barriers to building and sustaining expertise in STEM education research)

1.3 Methodology

The study was organised into four phases of data collection:

- a literature rapid response search
- telephone interviews with policy and practice representatives
- telephone interviews with STEM education researchers
- focus group discussion

1.3.1 A document/literature rapid response search

The purpose of the rapid response search was to scan summaries of the research literature to extract information pertinent to the objectives of this study. In particular, the literature summaries were reviewed in order to:

- identify the key leaders of STEM education research
- look for examples of international collaboration
- identify the key drivers of STEM education research
- look for interactions between STEM education research and policy and practice

The British Education Index was searched and for the year 2006 produced 430 possible hits/items. Outputs from the index were examined and 95 items were identified as relevant to the study. Information on the areas listed above was then extracted and findings from the rapid response search are included in the relevant chapters.

1.3.2 Proforma/telephone interviews with policy and practice representatives

Representatives and stakeholders from key policy and practice arenas were invited to contribute to study. The original research proposal suggested that data be collected via a proforma to 16 relevant organisations. However, there was some concern about whether this would generate a sufficient response rate. After discussion with the sponsor it was decided that a better strategy would be to collect data via a combination of individual interviews as well as proformas.

In total, 8 interviews were completed with:

- Office of Science and Innovation, Department of Trade and Industry
- Association for Science Education (ASE)
- Gatsby Technical Education Projects (proforma also completed)
- Qualifications and Curriculum Authority (QCA)
- Department of Education and Skills (DfES)
- Institute of Education, University of London/Teaching and Learning Resource Programme
- Higher Education Academy

A further 5 proformas were returned from:

- Wellcome Trust
- Royal Academy of Engineering
- Royal Society of Chemistry
- Institute of Physics
- Gatsby Technical Education Projects

The proforma and interview included questions on the:

- factors affecting the commissioning of STEM education research (e.g. competitiveness, distributing of expertise and capacity for international collaboration)
- quality of STEM education research
- impact of research on policy and practice
- factors associated with increasing capacity for STEM education research

1.3.3 Telephone interviews with STEM education researchers

The third strand of the research involved telephone interviews with 25 STEM education researchers in England, including nine key leaders, eight early

career researchers and eight who were regarded as mid career. The interview covered the same areas as listed above, with additional questions on the STEM researchers' career path.

In addition, towards the end of the study, five researchers from Scotland, Wales and Northern Ireland were invited to comment on whether the findings from the study reflected their own views and circumstances. They were also given an opportunity to add anything which was different or unique about the context of STEM education research in Scotland, Northern Ireland and Wales.

1.3.4 Focus group

Towards the end of the research a focus group discussion was held bringing together a range of organisations to discuss the findings and their implications for a fellowship programme. The group included representatives from:

- Nuffield Foundation
- DfES
- University of Bristol
- Wellcome Trust
- Economic and Social Research Council (ESRC)
- Gatsby Technical Education Projects
- The Royal Society
- King's College London (post-doctorate research fellow and an overseas PhD student)

2 The factors that affect the commissioning of STEM education research

2.1 Introduction

This section discusses the commissioning stage of STEM education research. Respondents were asked to comment on the extent to which the following were factors motivating them to commission research: availability of suitable researchers; funding; policy concerns and advancing knowledge. In addition, participants were asked to identify any other factors and further comments.

The three major drivers of STEM education research (in order of importance) were highlighted as:

- policy concerns
- funding
- advancing knowledge.

Other factors that were considered to sometimes influence the STEM education research that is undertaken include: concerns of practitioners and the development of practical implications and availability of suitable and qualified researchers.

2.2 Policy concerns

It was reported by interviewees that policy concerns were the main factor in driving the type of STEM education research undertaken. The term 'policy concern' is used in its widest sense and includes the commissioning of research on specific questions, problems and targets that perhaps sit within a broader policy issue. Examples of research that have been undertaken because of policy concerns include: the retention and recruitment of girls in physical science study; curriculum reviews and development and teachers' continuing professional development in science.

2.3 Funding

Respondents intimated that funding was a key driver of STEM education research. The type of STEM education research undertaken is thus influenced by the availability of funding and the priorities associated with funding different types of research within the organisation. For instance, some organisations have funding available predominantly for policy or theory-relevant research, others have funding available for more developmental and

action orientated research, while other organisations may have funding available for both.

2.4 Advancing knowledge

The motivation to advance knowledge emerged as a key factor affecting the type of STEM education research that is undertaken. Some respondents were involved in commissioning 'blue skies' research to explore uncharted areas of STEM education. Research was also commissioned on a smaller scale for the purposes of advancing knowledge, such as in the funding and evaluation of innovative projects trialling new and different approaches to teaching and learning. The advancement of knowledge however, was in some instances felt to be a bi-product of research driven primarily by policy concerns and funding.

2.5 Concerns of practitioners and the development of practical implications

A number of respondents with a policy or practice perspective felt they funded research that aimed to develop practical applications for the classroom and science learning. Such research is often small scale and localised, involving action based and evaluative research with practitioners. One respondent also commented that through working closely with practitioners the organisation may be motivated to commission research that directly addresses such concerns and therefore has practical implications.

2.6 Availability of suitable researchers

The availability of suitable and qualified researchers was occasionally reported as a factor determining the STEM education research undertaken. A couple of interviewees felt that the availability of researchers was sometimes a factor in driving research when the nature of the project required researchers from a particular specialism, region or proximity. Indeed an issue was raised regarding the availability of university staff, given that they have lecturing as well as research responsibilities. Respondents commented that the quality of proposals and track record of the research team are factors that might determine the awarding of a research contract. However, overall, policy representatives felt there was not currently a shortage of researchers. This may be a future factor though given that many other respondents commented on STEM education research as an 'aging' profession and lacking in 'young blood' and expertise entering the profession. Indeed, according to a researcher based in Wales, there were now fewer full time university science educators in the country than ever before. Recent years has witnessed a reduction in research activity, with departments closing and others re-focussing on teaching:

When you are talking about STEM education research in Wales, most institution don't have any, most are teaching only. So the difficulty for STEM research in Wales is maintaining the research that used to exist in a period where there is effectively only one research institution
(Senior Lecturer)

2.7 Summary

The type of STEM education research undertaken was primarily said to be driven by policy concerns, the availability of funding and the motivation to advance knowledge and understanding. It was also noted that sometimes STEM education research was undertaken because of practice concerns, and may depend upon the availability of quality researchers capable of carrying out a study.

These commissioning factors may well have some implications for capacity building in STEM education research. For example, policy concerns were identified as the main driving factor of research yet we shall see in later chapters that policy related research can be subject to certain constraints (e.g. RAE lack of recognition of policy focused research, the lack of attractiveness of some policy research, and the lack of impact of STEM education research on policy, see Chapters 3 and 9). This apparent incongruence between STEM education research commissioners and researchers may highlight a bias in the interview sample (for instance, a lack of input from research funders less concerned with policy, such as the research councils). However, more worryingly, the data presented here may allude to a mismatch between funders needs and what researchers offer.

Secondly, the availability of suitable researchers was mentioned as a factor that sometimes influences the commissioning of research. Commissioners may require researchers in particular specialist areas, in particular regions and to undertake research in a particular timescale. A fellowship programme could potentially replenish the capacity of researchers in each of these ways. For instance, a fellowship scheme could release people from teaching responsibilities to focus on research.

3 Competitiveness

3.1 Introduction

This chapter describes the findings to the question '*In terms of choice and availability, how competitive is UK STEM education research?*' Respondents' views were found to vary, from those who felt competition was high, to a smaller number who suggested competition was low. The majority of responses however, advocated that competitiveness was conditional and was both high and low depending on a number of key factors.

3.2 Factors affecting competitiveness

The factors that determine whether competition in STEM education research is high or low are outlined below in the order of the frequency they were raised.

- the attractiveness of the research
- the availability of funding
- the reputation and capacity of institution and researcher
- the specific expertise required
- the commissioning process

3.2.1 Competition depends on the attractiveness of the research

Many respondents felt that competitiveness in STEM education research depended on the status, profile and attractiveness of the research. The attractiveness of the research is very often determined by the funder and the type of work they require. The ESRC typically offer larger sums of money and longer timeframes for research to be undertaken enabling longitudinal, larger scale and more representative research. The ESRC also tend to be associated with academic, pure research with a focus on theory development. The ESRC has a rigorous peer review commissioning process, maintaining high levels of competition. These factors make the ESRC an attractive funder for STEM education research and hence competition for achieving ESRC funding in the STEM education research community is very high.

> *If you want to do research, rather than curriculum related work, there is pretty much only ESRC who fund that, it's quite difficult to get research out of the other players* [charitable organisations]. *In general they are not that keen on pure research, they're looking for curriculum or some useable outcome for education, for teachers. So the kind of stuff we've been doing the last three years, the ESRC is pretty much the only organisation funding it and it is very competitive.*
>
> Mid-career researcher.

Competitiveness is also likely to fluctuate according to the extent to which research is topical, with issues of current and public concern attracting more bidders. For instance, the current call from the ESRC for initiatives to raise participation in the physical sciences was reported by all interviewees to be attracting a very competitive response.

Interviewees commented that other key funders of STEM education research, such as government and charitable organisations, tend to fund practical and often small scale localised research into curriculum and practice or perhaps specific policy concerns. Depending on the nature and attractiveness of the content of the research, this type of research often receives lower levels of competition. The amount of money available and scale of the project may lack in appeal to STEM education researchers if they are not able to draw implications from the study. Funding from such organisations may also lack attractiveness due to the time scales involved, perhaps offering short term projects and tight deadlines.

Other factors such as the timing of the research may also influence the amount of researchers that are attracted to the work. One policy and practice representative from a charitable funding organisation said it can be a challenge to get universities to do a piece of research at a particular time because the academic staff usually only have limited time available for research given their teaching commitments. The numbers bidding for projects also depends on the position of the researchers. Contract researchers need to bid for research funding regularly to ensure their salary, so may experience a more competitive climate. Whereas, for lecturers and university academics salaries are supplemented by lecturing responsibilities and the lesser imperative to win externally funded work perhaps leads to the perception of a less competitive field.

3.2.2 Competition depends on the availability of funding

Funding for STEM education research was felt by interviewees to be scarce and hence, competition for the funds available was often high. In particular, the lack of significant and ongoing funding was identified. Consequently, on occasions when larger sums of funding are made available for large scale, longitudinal and significant research studies, competition is particularly high.

The smaller sums of funding attract less competition because there is less capacity to develop the research into an influential piece of work.

Interviewees also identified that there is only limited funding specifically for STEM education research. Such funding tends to come from charitable organisations. Competition for research council funding is again fiercer given education researchers must compete with other disciplines for funding.

> *In maths education one of the issues in the UK has been a lack of funding and a lack of ongoing funding for research.*
>
> Key leader

> *I'm not sure that there has been an agency in this country that have been commissioning STEM education research in anything other than a highly piecemeal way.*
>
> Key leader

Several interviewees identified that UK STEM education research is a leading competitor in the international field. However, others suggested UK STEM education research struggles to compete with the America field due to a comparatively inconsistent and inadequate funding stream.

3.2.3 Competition depends on the reputation of researcher and institution

A number of interviewees suggested that STEM education research was particularly competitive because the market place tended to be monopolised by a few leading institutions:

> *There is a very small number of departments who are doing high quality research and a large number, say 100 university departments, who are doing very little or none at all.*
>
> Mid-career researcher.

Winning work in this market place appeared to rely heavily on the reputation and renown of the institution and research team. Researchers at non-leading institutions may well perceive STEM education research to be more highly competitive than do those representatives from the leading centres of excellence. The majority of researchers spoken to as part of this research came from leading institutions in the field of educational research (i.e. RAE rating 4/5) and hence it is difficult to explore the relationship between perceptions of competition and being in a centre of excellence.

Early and mid- career researchers identified that the STEM education research field can be particularly competitive in the early years of entering the profession. Newer researchers thus rely heavily on the renown of their senior

colleagues to win work for the research team. Mid- and early-career interviewees in particular, noted that they had received little support in learning to survive in this competitive market, with little training on how to write bids and secure external funding. Given this competitive climate and emphasis on reputation, new researchers reported finding this community particularly hard to break into.

> *I think it's partly a problem with the way in which the ESRC commission research in that you have a much better chance of getting it if you're established and they're cutting out the routes into it dramatically. It relies on being in big institutions.*
>
> Mid-career researcher

> *It's very hard to get into without strong mentoring and being part of a prestigious institution.*
>
> Early-career researcher

Although interviewees with a policy and practice perspective reported good levels of competition amongst a few centres of excellence, their responses also hinted that competition was perhaps lacking from a wider spectrum of institutions. Indeed, several policy and practice interviewees noted that there are only a handful of leading universities to choose from when awarding work.

3.2.4 Competition depends on the specific expertise required

The levels of competition for research were reported to vary according to the types of methodology and approaches required by the funder. Only a small number of organisations were felt to have the capacity and expertise to bid for mixed method, large scale survey and qualitative research or research that required diversity of expertise or interdisciplinary approaches (e.g. more likely to be found in larger research departments). Hence, demand for certain specialisms, expertise and multi-disciplinary approaches tend to generate only low levels of competition.

> *People who've got capacity to do assessment instruments for example, very few of those around. The quantitative and psychometric skills are sadly lacking.*
>
> Key leader

3.2.5 Competition depends on the commissioning process

The organisations funding research often have different commissioning procedures; some require a formal, scrutinised bidding process and others may approach researchers directly. Two interviewees commented that it was hard to get funding for research to look at the detail of classroom practice without having worked with, or being known to, the commissioners previously. One

interviewee alluded to a lack of clarity about the rules of competing for research council funding, where it was claimed that writing a thorough and knowledgeable proposal did not necessarily correlate with winning research funding.

3.3 Summary

Some interviewees experienced the competitiveness in UK STEM education research as high and healthy, a number of others felt competition was low and varied. Very often though, competitiveness was seen to be conditional depending on a number of factors: attractiveness and status of the research, the availability of funding, the reputation of the institution and researcher, the specific expertise required and the commissioning process.

The finding that competitiveness is variable perhaps raises some implications for building the capacity of the community. Given the current picture of STEM education research as a market monopolised by a 'small pool' of centres of excellence, should investment focus on building the capacity of the current centres of excellence or develop new and additional centres of excellence across the UK? Meanwhile, as STEM education research is a more competitive market place for early and mid career researchers, should greater emphasis be placed on supporting researchers to acquire the 'survival skills' of successful bid writing? The availability of funding for STEM education research was reported as an issue by respondents, in particular that 'piecemeal' funding appears to be relatively unattractive to researchers. Thus, the capacity for research may be strengthened by a more collaborative and consistent approach to funding. Finally, it was observed that quality researchers may be constrained by their dual roles as researchers and educators, limiting the number of research projects they can compete for. A fellowship programme could potentially release researchers for periods from their teaching roles to enable them to participate more in the STEM education research market place.

4 Career pathways into STEM education research

4.1 Introduction

This chapter describes the routes into STEM education research careers taken by the sample of 25 key leaders, mid and early-career researchers interviewed for this study. Exploring the backgrounds of current STEM education researchers helps build a picture of the composition of expertise within the community. Interviewees were also asked about the main factors that influenced their career development. Their responses reveal the conditions that are necessary for individuals in STEM education research to thrive.

4.2 Routes into STEM education research

By far the most common route into STEM education research within the sample was to undertake a STEM subject degree (and possibly higher degree), followed by teacher training and teaching experience, and then the transition into teacher education and education research at a higher education institution. Respondents often made the transition from school teaching to academia by undertaking a higher degree or becoming involved in research or with a university while teaching. Less likely was entry via social science and STEM subject specialist routes, with only a handful of such examples.

However, when comparing across the entry routes of key leaders, mid-career and early-career researchers, an interesting pattern emerges, suggesting the routes into STEM education research are becoming slightly more diverse. Key leaders in the field nearly all report entering education research from a teaching background. Small numbers of mid-career and early-career researchers however, report entering the profession from social science and subject specialist only backgrounds. Entrants from social sciences and subject specialisms are likely to undertake higher degrees in education to support their move into STEM education research careers. However, transition from STEM subject research to pedagogic research was felt by interviewees to be uncommon given the lack of comparative incentives, renumeration and status associated with pedagogic research (see Chapter 10, section 10.3).

Furthermore, a minority of recent entrants to STEM education research are carving careers solely as researchers, where traditionally undertaking research may rely on holding a lectureship position. From all routes into STEM education research (teaching, subject specialists and social sciences) higher degrees appeared to form a critical vehicle enabling people to make the respective transitions into educational research. This finding would support the introduction of a fellowship scheme that increased the opportunities for people from these three careers to make the transition into STEM education research.

4.3 The factors influencing career routes

The most important factor influencing participants' career route into STEM education research was their own interests and motivations to improve teaching and learning. Pursuit of a research career thus depended on the research opportunities that became available to an individual. Other researchers identified getting a permanent position in a university as a factor that had influenced their career decisions. Whether or not researchers could win funding for projects was also an issue determining respondents' career routes. This issue was linked to the status of the institution, in that institutions with a strong research programme were more likely to receive funding for projects and hence could continue to offer work to researchers.

For more recent entrants to the profession, being part of a strong research culture was an important factor supporting entry into STEM education research. Support and training from senior colleagues, role models and other PhD students were valued as helping researchers access and remain in the research community, helping them to develop their interests and skills.

4.4 Summary

This section aimed to describe how today's researchers got where they are and the conditions that helped them to thrive. The most common route into STEM education research was to undertake a STEM subject degree (and possibly higher degree), followed by teacher training and teaching experience, and then the transition into teacher education and education research at a higher education institution. The transition from school teaching to academia was often achieved by completing a higher degree or becoming involved in research or with a university while teaching. Interviewees in this study had often received funding support to undertake further study and taken time out from employment. Maximising the availability of funding support for higher degree study would appear to be a crucial feature of building the capacity of the STEM education research community.

Less frequently, interviewees described entry via social science and STEM subject specialist routes. Many respondents reported a lack of career structure and clear career routes into the profession. If there are viable alternative routes into the profession, perhaps these could be made clearer and potential career progression routes could be more clearly associated with fellowship study. In addition, the fellowship programme could also consider facilitating the careers of those who do not wish do pursue a route which is tied to a lectureship.

The most important factor influencing participants' career route into STEM education research was their own interests and motivations to improve teaching and learning. Capacity building exercises may thus need to focus on supporting people to make the entry to the profession but also to retain them. Other facilitating career factors included: getting a permanent position in a

university and whether or not researchers could win funding for projects (which was felt to depend on the status of the institution). For more recent entrants to the profession, being part of a strong research culture was seen as very beneficial. Institutions seeking new researchers, as well as the design of a fellowship programme, may need to consider how they will provide a solid structure of support, particularly from senior colleagues.

5 The availability and distribution of expertise

5.1 Introduction

This chapter aims to describe the current picture of the distribution of expertise within the STEM education research community. Interviewees were asked to consider whether they felt there was a sufficient mix of expertise within the STEM education community and also whether they felt there were any areas lacking in expertise.

Some respondents reported that the mix of expertise within the STEM education research community was good. In particular, interviewees felt that pedagogical and subject knowledge were strong areas of expertise. However, respondents predominantly reported that the mix of expertise was insufficient. The chapter will now highlight those areas that were felt to be lacking.

5.2 Areas lacking in expertise

Interviewees and proforma respondents identified the following gaps in expertise:

- insufficient methodological expertise
- insufficient diversity of perspectives/theory
- insufficient interdisciplinary work
- insufficient expertise in specific and subject areas

5.2.1 Insufficient methodological expertise

A large proportion of comments related to the lack of expertise in quantitative methodology (though one comment was to the contrary), including experimental approaches, psychometric assessments and statistical analysis. Interviewees related this lack of quantitative expertise in some instances to a limitation in the capacity and resources available in the organisation or institution. Interviewees felt that the majority of STEM educational research employed qualitative methodology.

> *I think where it is probably a bit short is in the quantitative area. I think there are probably more people who are qualitative researchers in mathematics education and rather few who have, not only the expertise, but also the kind of resources in their own institution to be able to do the quantitative work.*
>
> Key leader

The lack of methodological expertise in STEM education research was in a number of instances related by interviewees to the limited routes into the profession. As entrants to STEM education research typically come from a teaching background they may lack research experience and methodological knowledge.

5.2.2 Insufficient diversity of perspectives/theory

Interviewees in the three categories recognised a lack of expertise in the perspectives and theories drawn upon to inform education. Specifically, respondents noted a lack of expertise in terms of sociological, psychological, philosophical, economical, historical and political perspectives and theories of education.

> *I would like my researchers to be better informed in mainstream psychology, sociology, history of education, political economy and policy making.*
>
> Policy and practice representative

> *We're jack of all trades and masters of none, we lack people with any kind of extensive knowledge of philosophy or psychology.*
>
> Key leader

The historically typical routes into the STEM education research community were felt, by some individuals, to be responsible for this lack of expertise. Most entrants to the STEM education research community come from a teaching background or a STEM subject expertise area (and often both); it is less common for people to enter the profession via a social sciences background.

5.2.3 Insufficient interdisciplinary work

Both key leaders and early and mid career researchers acknowledged a lack of sharing of expertise across disciplines and working in multi-disciplinary teams. There appeared to be little opportunity for such interdisciplinary working currently and respondents went so far as to suggest there were barriers to this in the form of reluctance within the community to work across disciplines. One interviewee reported a current environment of ‘ghettos’ of expertise. Another two interviewees blamed the competitive climate in the education research community. Suggesting competition between institutions and RAE demands (Research Assessment Exercise) discouraged collegiate working and cross fertilisation of expertise and knowledge beyond individual departments and institutions.

Respondents felt that greater interdisciplinary working between pedagogical experts, subject experts and social scientists would enhance the joint expertise

brought to a research enquiry. Policy and practice participants suggested they would like multiple perspectives to be drawn upon in interpreting research findings, as outlined in the previous section above. The lack of interdisciplinary working in STEM education research appears to constitute something of a missed opportunity, given that both policy makers and researchers identify the potential value in such practices.

5.2.4 Insufficient expertise in specific and subject areas

A small number of interviewees identified insufficient expertise in specific subject areas and aspects of education. Policy and practice respondents reported a lack of expertise in the area of engineering educational research. Two researchers identified a lack of expertise and research in biological education. This is perhaps an unexpected finding given that Monk (2006) in a survey of science teacher educator research outputs finds that there are slightly more science education tutors with a biological background. Other aspects of STEM education research were felt to lack expertise, including urban science education and STEM subject teaching and learning in primary, higher and adult education.

> *Engineering is a bit of a new kid on the block. So generally there isn't the same kind of level of research knowledge or people who can do research in that area.*
>
> Policy and practice representative

Despite reports from interviewees that pedagogical knowledge was a strong area of expertise in the STEM education research community, the concern was also raised that this knowledge could become out of date after leaving teaching. In this regard the value in researchers maintaining contact with practitioners to inform quality research was advocated. A lack of pedagogic knowledge was also an issue for entrants from social science backgrounds.

Lastly, respondents in Northern Ireland suggested that STEM education research in further and high education contexts was currently under-researched.

5.3 Summary

This section described STEM education researchers own views about the distribution of expertise within the field. Pedagogic and subject knowledge were reported to be strong areas of expertise. Interviewees suggested a lack of expertise in terms of terms of methodology, perspectives and theory, interdisciplinary work and specific subject areas. Respondents' views about the areas of insufficient expertise provide implications for the focus of capacity building exercises.

In order to address the lack of methodological and theory/perspectives expertise in the STEM education research community a fellowship scheme could focus on both increasing the routes into the field (e.g. from social sciences backgrounds) and equip researchers with the necessary methodological skills. The fellowship scheme could offer certain quality standards of training to ensure equity of support available to students in a similar way to the ESRC funded studentships.

A lack of interdisciplinary working could also be addressed at least partially by a fellowship scheme. The scheme could encourage collegiate working between those on the scheme by offering programmes of support that brought cohorts of researchers together. This structured system of support would ensure greater consistency rather than simply relying on senior colleagues to provide support.

Providing forums to engage with practitioners would also seem to be a feature of maintaining and building expertise in the STEM education research community. Contact with practitioners would allow educationalists to stay informed about current practices and help those entering from primarily social science backgrounds to develop their educational knowledge.

6 International collaboration

6.1 Introduction

Carrying out STEM education research that involves an element of international collaboration has the potential to be beneficial both in terms of the research produced, as well as the skills and experience of the researcher. Such collaboration provides opportunities to compare a UK experience with that of another country, and to learn lessons that could have impact in the classroom. Along with this, the researcher gains from collaborating with researchers in another country, and potentially being introduced to new ideas and ways of doing research.

This study explored the extent of international collaboration amongst STEM education research, as well as exploring the perceived barriers and enablers to working with researchers in other countries.

6.2 Extent of involvement in international collaboration

The rapid response search found that there was a significant proportion of internationally collaborative STEM education research in the UK, with 12 out of 95 articles having an element of international collaboration. The type of research being undertaken varied, but seven out of the twelve were comparing teaching approaches, styles and systems between the UK and other countries. This implies that comparative research makes up a significant proportion of internationally collaborative STEM research.

Interviewee comments suggested that there was a bias towards more experienced STEM education researchers participating in internationally collaborative projects. Nearly all those classed as 'key leaders' had taken part in some internationally collaborative research (seven out of nine interviewees), as had most of those classed as mid-career researchers (seven out of eight). However, only two out of eight early career researchers had participated in such research. This may be because the longer an individual stays in the field, the more opportunities they have to get involved in such work. However, some of the early career interviewees mentioned the complexity of European funding and the fact that UK researchers were often expected to take a leading role in managing the project, implying that they were not ready or able to do this at the current stage of their career. Commenting on the Scottish and Welsh situation, interviewees felt that the relatively small size of these two regions meant that they had to look outwards and make connections with external researchers.

6.3 Barriers to internationally collaborative STEM education research

The research explored whether there were any barriers to involvement in internationally collaborative STEM education research. Three main barriers were evident:

- the differences between educational systems and practices
- funding
- communication with researchers abroad

6.3.1 Differences between educational systems and practices

Firstly, different countries have different education systems and educational practices. This means that schools operate differently, teachers teach in different ways, and there are not the same problems being faced. Some researchers felt that there was little common ground between the different systems, and questioned the relevance of international collaboration to their work. As many issues to be investigated were specific to the UK system and context, they felt there was no value in adding an international dimension. Related to this is the fact that countries can have different research traditions, potentially making it difficult to decide on appropriate methodologies. For example, one researcher suggested that countries other than the UK tend to want a greater focus on quantitative research than researchers commonly use here.

In Northern Ireland, however, STEM education researchers were said to readily establish links with colleagues in the Republic of Ireland, facilitated by cross-border funding. Strong links were reported between institutions and the differences in educational systems was said to serve as a source of research interest, rather than a barrier to cooperation. Thus, different systems do not necessary preclude collaboration, although the geographical proximity of these two regions perhaps makes researcher interaction a more workable venture.

6.3.2 Funding

Funding for research was cited as another barrier. Interviewees commented that it was difficult to get funding for internationally collaborative work, and several suggested that European research funding was very complex to apply for and then administer. This was accentuated by the fact that research with an international element tends to be more expensive because of the travel and communication involved. A barrier to engaging with European research funding is that it only pays for 20 percent of the overheads on a project, whereas UK Research Councils typically pay 80 percent of the costs of overheads. In general, then, a lack of appropriate funding was seen as a barrier to international collaboration:

Generally your head of department would not be so happy if you are doing an international collaboration unless it was hugely well funded or highly prestigious.

Senior lecturer

6.3.3 Communication

Finding out about potential partners abroad, and then communicating with them, was also seen as potentially problematic. Some interviewees said that it was difficult to find the time to go to international conferences and network with potential partners. Yet taking the time to do this was critical to finding the right people to work with. Once contacts had been established, and projects were set up, it was still difficult to communicate due to the extra costs involved with meeting or talking over the phone with colleagues abroad. Some interviewees also said that language could be a barrier, and that different cultures and educational systems often meant that it was more difficult to communicate effectively.

6.4 Enabling internationally collaborative STEM education research

There were two main factors that interviewees raised which had the potential to enable internationally collaborative STEM education research - networks and funding.

6.4.3 Networks

Interviewees emphasised the need to get involved in international networks of researchers doing similar work, and ideally to have opportunities to meet up and develop relationships. They suggested electronic networks (e.g. email lists), conferences and journals as important ways to do this. One interviewee noted that it helped when working with colleagues in your institution who were already involved in such networks, and who could facilitate introductions to relevant people.

You have to have some reason, there needs to be some initiative, some activity that builds relationships and visits and discussions and challenges. So it might be based around a journal, or it might be a regular conference that happens, or people might get together to do a handbook, reviewing a field or a project.

Policy and practice representative

The first thing to facilitate is people meeting other researchers…if you don't meet them you're not going to collaborate with them.

Early-career researcher

A researcher in Northern Ireland observed that currently there was a relatively small UK presence at international conferences and felt that more could be done to encourage attendance. Perhaps a fellowship programme could include opportunities to participate in international events?

6.4.4 Funding

The second issue that could enable internationally collaborative research was changes to funding. Interviewees suggested that there should be less bureaucracy associated with getting funding, and one early career researcher suggested that they would be more likely to bid for such funding if there was support available to manage and administer the funding. The issue of joint funding was also raised, as often the same bid goes to research councils in more than one country. This raises the chance of the project failing, as all the bids have to succeed to enable the research to happen. If the research councils worked together and had just one team assessing all the different parts of the project together, it would be more workable for applicants. It was also suggested that funding was made available to develop research bids with international partners. The development costs associated with putting together such a proposal can be very high, and so funding would enable more researchers to develop international projects.

6.5 Summary

Although some researchers felt that international collaborations were not relevant to their research, others clearly wanted to be involved in such research. Early career researchers tended to be interested in such work, but were the least likely to have been involved in internationally collaborative research. There were several aspects that could be included in a fellowship programme to encourage international collaboration. Firstly, ensuring that researchers are involved in international networks in their field, and are given opportunities to go to conferences and meet other researchers. Secondly, providing funding to support researchers to develop collaborative bids with colleagues abroad, as this can be an expensive process. Lastly, a fellowship could give support to help researchers, especially early career researchers, bid for and administer funding.

7 Innovation in STEM education research

7.1 Introduction

This chapter will present respondents views about the extent to which STEM education is innovative and the factors both that limit and promote innovation.

7.2 Views on the extent of innovation

Overall, across all groups of participant innovation in STEM education research was not reported to be high. Most respondents commented that they conceived of innovation in terms of methodological innovation or the focus and content of the research in terms of educational and curriculum innovation.

Where STEM education research is most likely to be innovative, according to respondents' views, is in terms of the focus and content of research. STEM research was felt to explore and promote innovative programmes and approaches to teaching and learning.

> *What we've been good about on the whole is taking research ideas and turning them into materials, curriculum materials or strategies and practice.*
>
> Key leader

However, a smaller number of respondents felt innovation was lacking in this sense, for instance they suggested aspects of education were revisited and that there was not sufficient innovation in applying research findings to practice.

Interviewees suggested that where STEM education research is most lacking in innovation is in terms of the methodological approaches undertaken. Research was felt to lack innovation in terms of interdisciplinary methodology, advanced quantitative methodology, longitudinal research, international comparisons and engaging practitioners and other stakeholders in research. STEM education research is deemed by some in the community to be quite conservative and traditional, rather than necessarily innovative.

It should be noted that some participants did not feel innovation was a priority in terms of capacity building, nor necessarily a marker of good quality research. These respondents advocated that STEM education research was not particularly innovative because well established tried and tested methodologies were employed and that these worked and met demands.

7.3 Factors limiting innovation

Interviewees reported that there are a number of barriers that limit the capacity for innovation. These are, in order of the frequency they were raised:

- culture of academia
- dominant research model in the UK
- education system
- lack of new entrants
- dual remit of researchers
- funding pressures

7.3.1 Culture of academia

The culture of academia is such that emphasis is placed on specialisation and competition, limiting the capacity for innovative interdisciplinary approaches. Successful careers in academia rely on becoming the leading knowledge in a particular area. Academics may be reluctant to work on studies that detract from their specialism. The language and discourse used within highly specialist areas may limit the capacity for interdisciplinary work. According to a researcher in Northern Ireland, this compartmentalisation was said to hamper the movement of ideas from one subject to another. The climate is also competitive, with institutions competing for scarce resources and being reluctant to work with and strengthen the work of others.

> *We tend to think of ourselves in little compartments and we focus on that compartment to the detriment of all others. We're often not prepared to break down the barriers because we then perceive that that means that our own subject area is somehow lessened.*
>
> Policy and practice representative

Research Assessment Exercise (RAE) was also felt to constrain STEM education researchers' capacity to innovate, placing demands on researchers' time, constraining the type of research undertaken and presenting a challenge to collegiate working between institutions.

7.3.2 Dominant research model in the UK

Some interviewees believed that innovation in STEM education research was constrained by a dominant natural science research ideology. Some interviewees felt constrained by a lack of methodological capacity suited to this rhetoric. Other interviewees rejected a natural science ideology, believing it to be poorly suited to the social phenomenon of education. Nevertheless, these interviewees also felt constrained by the dominant research model in the UK, struggling to meet policy makers demands for this 'gold' standard in research. Policy makers and funders were reported by participants to often

require research that measures educational approaches in a scientific way and offer representative findings and messages. Ratcliffe et al.'s (2004) study into science education practitioners' views of research reveals that practitioners tend to use a natural science model of research when assessing quality and relevance. The expectation of the natural science model (amongst both research users and some research producers) may either need to be met by increased research capacity (funding, capacity and methodologies) congruent with this rhetoric or a model more suited to the researched phenomenon may need to be prioritised. Condliffe Lagemann (2000) suggests that education research is an essentially applied field that has traditionally struggled with its identity and sought to achieve greater status in academia by adopting a scientific model.

7.3.3 Education system

Interviewees suggested that the lack of innovation in the current education system limited their capacity to explore innovative approaches to teaching and learning. Researchers believed that those responsible for designing the curriculum, assessment and education initiatives seldom required or expressed interest in research that explored innovative approaches to education. Rather, the researchers felt policy makers required research evidence that confirmed current educational practices. Accordingly, there is little point in researchers themselves being innovative in the practices and approaches they explore if this does not inform changes in practices. Researchers are also constrained by the education system with regard to the availability of funding, as this will be determined in part by the governments priorities for education. The education system was also felt to limit practitioners capacity to work with researchers on innovative projects, placing high demands on their time with little scope to trial new approaches.

> *It's completely prescriptive, so there is no point doing research outside the box because you have to have implications for practice if it's going to have any impact. So there are external constraints that are not really the fault of the researchers. There are exceptions, but they tend to be small scale projects where people try out something innovative, and that's great. But to do that on a large scale, how would you get funding for that because the government don't want to necessarily fund anything wacky or anything that challenges the current status quo*
>
> Mid-career researcher

7.3.4 Lack of new entrants

Interviewees reported a lack of new entrants to the STEM education research community and hence a lack of introduction of new and innovative approaches and ideas. The STEM education research community was felt to currently employ only a limited repertoire of techniques. The lack of innovation in

STEM education research was also attributed to the paucity of routes into the profession. STEM education researchers predominantly enter the community from teaching backgrounds, and receive methodological training as part of the development of a subsequent career in research. Entrance to STEM education research from a social sciences background, where methodological expertise may be more developed, was deemed by respondents to be a less common and recognised route.

7.3.5 Dual remit of researchers

Much STEM education research is carried out by teacher educators who have teaching commitments as well as research interests. Therefore, a key factor constraining innovation for many interviewees was the lack of time and resource to innovate and explore new approaches. However, this dual remit was also considered to provide the teacher-researcher contact that is valued as a critical element of education research.

7.3.6 Funding pressures

Researchers are usually involved in having to acquire external funding for research projects. Accordingly, the pressures upon them to achieve funding and cover salaries restrict their capacity to explore innovative approaches in between projects. However, when working on funded research projects the extent to which researchers can innovate will also be limited by the requirements of the study. For example, it was noted that funding is often short term which does not permit innovative longitudinal studies capable of measuring the true impact of particular approaches or initiatives.

7.4 Factoring promoting innovation

Interviewees were asked to comment on the ways they felt innovation was currently promoted or could be promoted. They offered the following list of factors as facilitating innovation (in order of frequency):

- interdisciplinary approaches
- funders requirements
- exploration of new methodologies and approaches
- emphasis on research and development

7.4.1 Interdisciplinary approaches

Interviewees suggested interdisciplinary working was an effective way to facilitate innovation by sharing insights, expertise and methods. Interdisciplinary innovation was felt to be promoted by removing the current barriers established by the culture of academia, creating more common

dialogues between disciplines and by commissioners calling for multidisciplinary approaches to research projects.

7.4.2 Funders requirements

Interviewees believed that the funders of research have a key role to play in promoting innovation, both in terms of the projects that they fund and the extent to which they call for researchers to innovate. One example was provided of an organisation that commissioned small scale interdisciplinary projects in order to help researchers to build links across specialisms. Interviewees expressed the need for greater specification and exemplification of what was considered to be innovative research.

7.4.3 Exploration of new methodologies and approaches

Respondents suggested that time and resource would help to facilitate greater innovation in STEM education research. Innovative new ideas were developed by contact with other researchers, attending conferences, reading and trialling different methodologies. One interviewee suggested a fellowship scheme could emphasise innovation, allowing candidates to explore pioneering research and feed this back to colleagues.

7.4.4 Emphasis on research and development

Interviewees felt that innovation could be facilitated by a greater emphasis on research and development. There was a perception amongst interviewees of a current imbalance between the status of what might be considered pure and applied research. In order to promote greater innovation this status imbalance needs to be redressed, primarily by funding support for the developmental aspect of research. This innovation also relies on strengthening the interplay between the research community and practitioners in terms of their involvement with and perceptions about the usefulness of research. Innovation in education could also be achieved by a greater emphasis on research that clarifies what works and what is good practice. Here lessons may be learned from other capacity building initiatives, such as the Teaching and Learning Research Programme (TLRP) funded by the ESRC which aims to maximise the impact of educational research on policy and practice. The initiative funds projects that synergise research findings and engage with and ensure research findings are applicable to key stakeholders.

7.5 Summary

Overall, interviewees in this study did not feel STEM education research is particularly innovative. Interviewees called for more innovation in terms of methodology and approaches that would ultimately improve the relevance and usefulness of STEM education research.

Some STEM education researchers in this study believed that greater innovation could be achieved with more large scale, quantitative, representative and internationally comparative research. Some STEM education researchers called for greater emphasis on research and development and engaging with practitioners. Funders would seem to have a key role to play in facilitating innovation in terms of the type of research they commission and the extent to which the requirement for innovation is specified and prioritised.

Some interviewees contended that innovation in STEM education research was constrained by a dominant natural science research ideology. Policy makers and funders were reported by participants to often require research that measures educational approaches in a scientific way, which does not always suit the social phenomenon of education. The introduction of new approaches and ideas may therefore help the education community (including researchers, practitioners and policy makers) to move beyond the constraints of a dominant natural science research model. Specific attention should perhaps be paid to how this could be achieved in the designing of a future fellowship programme. Research fellows would be well placed as new entrants to the community to bring new and innovative ideas and approaches.

For many respondents innovation was about working with practitioners to move educational practices forward. In order for this to happen the interplay between researchers and practitioners needs to be strengthened and greater emphasis on translating research findings into practical applications (Ratcliffe et al., 2004). Indeed in a working paper undertaken for NERF (National Educational Research Forum) the authors Dyson and Desforges (2002) recommend research capacity is considered as a system, embracing both research-producers and research-users and that capacity building exercises should aim to strengthen the system of research holistically. A potential fellowship programme may consider how students will learn innovative ways to engage practitioners in research and place emphasis on presenting and conveying research findings to practitioners in an accessible and useful way.

8 Quality of STEM education research

8.1 Introduction

Feeling part of a research community that produces good quality work can be an important factor affecting the retention of individuals in the field. Indeed, one early career researcher commented that:

> *If I thought quality was particularly low, I don't think it would be a career I'd choose to be in really.*
>
> Lecturer/PhD Student

Interviewees were asked about the quality of STEM education research in the UK, and about the importance of different criteria when assessing the quality of the research.

8.2 Views on the quality of research

Interviewees were asked to rate the quality of STEM education research on a scale of one to five, where one was low quality and five was high quality. Overall, interviewees felt that research tended to be move towards the high quality end of the scale than the low quality end, with an average rating of just over three and a half. However, it was clear from their comments that there was a wide variation in quality within the field.

Interviewees suggested that whilst there was some high quality STEM education research, there was much that was poor quality. Some also suggested that the majority of the high quality work came from a small number of institutions and individuals, and that if they stopped producing work, the quality of the research taken as a whole would drop significantly. Related to this was the fact that most of these individuals are senior academics and therefore close to retirement. Interviewees said that there are no young researchers producing the same quality of research in the field.

> *Some departments I'd give a five, some I'd give one. I'm not sure there is a normal distribution…If two or three people stopped doing research, the overall quality would be a two.*
>
> Senior lecturer

The imminent retirement of many of those producing high quality STEM education research highlights the urgent need to increase capacity in the field.

As well as this, there was a variation in quality between different subjects. Science, technology, engineering and mathematics are all fields in themselves, and some interviewees said that quality was variable between the different

fields. For example some said that science and mathematics education research were comparatively strong, and one commented that technology education research was not of such high quality as it currently lacked a strong theoretical base.

8.3 Factors affecting the quality of research

There were two main issues that were felt to have a negative impact on the quality of STEM education research. The first was that the research was not always methodologically sound, and the second related to research funding.

8.3.1 Methodological rigour

Whilst some research made good use of methodologies, other pieces of research were thought to be methodologically flawed. One respondent suggested that this was due to the fact that a high proportion of the researchers were drawn from teaching mid career, and there was no clear point in their career transition where they were taught about research methods. Another suggested that it was down to poor quality research methods teaching, which was an issue across the social sciences more generally.

> *As a general thing that's hit the social sciences in the UK, and education in particular is that the quality of the methodology training has been poor for at least a couple of decades…Often people are not very good at understanding a variety of methodologies and how they can be helpful.*
>
> Key leader

A key need, then, is to develop methodological expertise in the STEM education research community.

8.3.2 Funding issues

Interviewees also suggested that a lack of funding for STEM education research had a detrimental effect on the quality work overall. In areas where research is better funded, such as the US, research was able to be more substantial, leading to a better quality of work than the often small-scale work funded in the UK. One interviewee also commented that in order to attract scarce funding it was necessary to publish work, and the pressure to publish sometimes led to work being published before it was really ready.

8.4 Criteria used in assessing the quality of research

Interviewees tended to be in agreement when asked about the relative importance of different criteria in assessing the quality of STEM education research. The criteria they were asked to rate were:

- the impact of research
- methodological rigour
- relevance
- the extent to which the research meets its aims
- innovation

All the criteria were seen as important to some degree but methodological rigour and relevance were seen as the most important. Relevance was seen as important as research should relate to current policy or practice concerns, so that it is potentially able to have an impact. Methodological rigour was seen as even more important, as interviewees felt that a fundamental aspect of quality research was a methodology that was rigorous and well executed.

> *If it's not good research in methodological terms, there's not much point in doing it…*
>
> Policy and practice representative

Innovation was seen as the least important criteria in assessing research quality. This was because interviewees felt that high quality research did not necessarily have to be innovative. Some interviewees felt that innovation could actually be a mark of low quality research, as innovative work in their opinion tended to be less well theoretically grounded.

In general all groups of interviewees had similar opinions. The only differences were with early and mid career researchers, who had slightly different opinions to the rest of the sample. They rated the impact of research relatively higher as a criteria for assessing the quality of research, and the extent to which research meets its aims relatively lower. The fact that the early and mid career researchers rated the importance of impact higher suggests that it is important for them to know that their work is making a difference.

Interviewees suggested other criteria for assessing the quality of research, and two main issues emerged. Those interviewees who were researchers stressed theory use, suggesting that research should be well underpinned by theory and also be able to contribute to advancing theory. Interviewees from a policy or practice background suggested that the track record and relevant experience of the individuals doing the research, as well as the status of the institution they were part of, were both criteria they used to assess the quality of research. Essentially, they were judging the people involved and not the product, assuming a direct correlation between the two.

8.5 Summary

The quality of STEM education research was reported as variable across the field, and interviewees suggested that high quality work tends to be concentrated in a small number of institutions and individuals. One of the issues around less high quality research was a lack of methodological rigour. Therefore, a key issue for a fellowship programme is to develop methodological expertise in the STEM education research community, and to ensure that all have access to high quality training, especially those from a teaching background.

Interviewees felt that the methodological rigour and relevance were the most important criteria for assessing the quality of STEM education research. Researchers also stressed the importance of theory use, suggesting that all research should be well underpinned by theory and should contribute to advancing theory. Those earlier in their careers were more likely to say that having impact is a mark of quality research than those further on in their careers, suggesting that it is important for the former to know that their work is making a difference.

9 Impact

9.1 Introduction

The purpose of STEM education research is to impact on the way subjects are taught, whether that be through policy-makers or practitioners. Arguably, if research has no impact there is little point in carrying out the work, and therefore this issue is an important one for the STEM education research community.

Interviewees were encouraged to talk about the typical impacts of research and to identify the factors that influence impact, either positively or negatively.

9.2 Typical impacts of research

Interviewees were asked how often STEM education research impacted in the following ways:

- affirms existing ideas
- informs by contributing to the body of knowledge
- changes understanding
- changes views
- affects policy decisions
- changes practice
- improves educational outcomes

Their answers suggested that the most common impacts were that research affirms existing ideas or informs by contributing to the body of knowledge. These impacts were seen to be quite likely compared to the others. Interviewees felt that research could sometimes change understanding, but that it was not very likely to change views or practice, affect policy decisions, or improve educational outcomes. However, these less common impacts are arguably those that are most important.

In general, when asked about the extent of impact interviewees felt that STEM education research should make a much stronger impression, stressing that the whole point of doing the research was to make a difference:

> *Largely I think much of our research doesn't impact very much on schools and education, and we've got to do something about that.*
>
> Lecturer

9.3 Factors affecting the impact of research

This next section identifies the factors that were considered by interviewees to influence the impact of STEM education research.

9.3.1 Limiting factors

Firstly, interviewees suggested that researchers were too far removed from policymakers and practitioners. The language of much research makes it hard to understand and apply, and often it is not translated into a format that enables practitioners and policymakers to make immediate use of it. It was said that practitioners and policymakers often have no involvement in research, and the end product is less applicable to them than it might have been. Researchers in Northern Ireland highlighted the potential negative effect of the Research Assessment Exercise. It was said that the RAE appeared to favour publication in academic journals read by a few over publication in professional journals read by many, thus reducing the potential impact of research.

> *There is still a big job to do in terms of making the outcomes of STEM education research more usable, more user-friendly, communicable.*
>
> Early-career researcher

Interviewees also commented that much of the research was small-scale, and not part of a wider programme of work, meaning that there were lots of individual pieces of research, each with their own messages. These do not tend to be drawn together into an overview of definitive findings relevant to an issue. For the policymaker or practitioner it can be difficult and time-consuming to decipher a picture from so many individual pieces of information.

> *The fact that…research is piecemeal from very small research to quite large research, but subject related, means that there's so many voices shouting then the impact is massively reduced because people say 'well which one am I supposed to use?*
>
> Policy and practice representative

There are two implications here for a fellowship programme. Firstly, more impact could be achieved if practitioners and policy makers were involved in the research that is carried out. A way to achieve this could be to target teachers who are interested in doing research for the fellowship or to support applications for a fellowship that entail an element of practitioner and/or policy collaboration. Secondly, if the fellowships had a research theme, all the individual pieces of work carried out could fit together and complement each other, leading to a more coherent set of messages than a body of more disparate work.

9.3.2 Facilitating factors

Interviewees also commented that some research had more impact than others, and that there was a small number of institutions and researchers whose work consistently had impact. To explore this issue further, interviewees were asked to identify a piece of STEM education research that had successfully impacted on policy and/or practice, and talk about the reasons why this had happened. From these comments, several characteristics of successful research emerged. Some research showed more than one of these characteristics, but not all characteristics were necessary for research to have had an impact.

The characteristics of high impact research appeared to be:

- **practical application-** Research that is grounded in the needs and concerns of practitioners in the classroom and that has a direct practical application in the classroom.
- **involvement of policymakers or practitioners-** Research where policymakers and/or practitioners are involved in the process of devising, carrying out and analysing the findings.
- **relevance-** Research that is applicable to the current concerns of policymakers and/or practitioners.
- **effective dissemination-** Research that is disseminated in a way that makes it easy for policymakers or practitioners to understand the findings and apply them to their situations. This takes time and needs to go beyond traditional academic methods of dissemination.
- **long term-** Research that has been carried out over a long period, with different phases building into a coherent body of information.
- **large scale-** Research that is large scale tends to be seen as more rigorous and substantial.
- **clear messages-** Research that has one or more clear messages that can then be taken forward by policymakers or practitioners.
- **collation of findings-** Research that involves drawing together and synthesising findings in an area, producing a summary of messages from research in that area.

These factors have been identified by other studies examining the impact of research. For example, Percy-Smith *et al*., 2002 discovered that research was most likely to impact in the context of local government if it was 'clearly relevant to the locality', 'available at the right time' and also 'produced by a trusted and authoritative source'. Meanwhile, in a cross sector literature review focusing on models for increasing impact, it was concluded that research should be 'translated' with findings tailored to the particular research audience (Nutley, 2003).

Research carried out as part of the fellowship programme therefore needs to take note of the characteristics highlighted above and apply them appropriately

to the work in order to maximise impact. By raising researchers' awareness and monitoring the application of these features throughout a fellowship study, it is more likely that the research will register a much stronger impact in the longer term.

9.4 Summary

The impact of STEM education research is an important issue for researchers, as the aim of their work is to eventually impact on teaching through policy or practice. Interviewees suggested that the most common impacts of research were that it affirmed existing ideas and contributed to the body of knowledge. Other more direct impacts on policy or practice were less common, and researchers were keen to see their work have more impact. They suggested that research does not have impact due to ineffective communication of findings, and the fact that much research is small scale and not part of a coherent set of findings. The characteristics of successful research suggest that to have impact, researchers need to take account of the needs of policymakers and practitioners, involve them in the whole research process, and ensure that findings are effectively and appropriately disseminated.

There are several implications here for a fellowship programme. Firstly, more impact could be achieved if practitioners are involved in the research that is carried out. A way to achieve this could be to target teachers who are interested in doing research for the fellowship. Secondly, if the fellowships had a research theme, all the individual pieces of work carried out could fit together and complement each other, leading to a more coherent set of messages than a body of more disparate work. Lastly, research carried out as part of the fellowship programme needs to take note of the characteristics of research that has impact and apply them appropriately to the work. Part of the support given to researchers could be to help them ensure that their research incorporates these characteristics as far as possible.

10 Strategies for increasing capacity in STEM education research

10.1 Introduction

Having examined the current climate of STEM education research, this section of the report moves on to consider the possible contribution of a fellowship programme towards increasing capacity for STEM education research. During the course of interviews, respondents offered other suggestions which could potentially provide a boost to the profession more generally, helping to ensure that sufficient numbers are recruited and retained to STEM education research.

The chapter begins first by discussing those issues which may inform or influence the nature of a fellowship programme. This is followed by a consideration of broader issues associated with increasing the capacity for STEM education research.

10.2 Issues for a fellowship programme

Interviewees' comments relating to a possible fellowship programme were compiled from across a number of questions (e.g. factors that could sustain and build expertise, views on a fellowship programme, factors that influenced careers). These comments will now be presented under the following headings:

- support
- training
- autonomy
- collaboration
- target group
- timing

10.2.1 Support

Amongst interviewees there was strong sense that a fellowship programme should be set within a supportive framework. Interviewees advised against fellowship students working on research projects in isolation, suggesting the need for a greater structure of support, training, and apprenticeship, ideally within a network or team of other fellows and senior colleagues. For instance, it was proposed that the fellowship scheme could involve joint training (e.g. in research methods) with a cohort of PhD students.

One early career researcher felt that mentoring could indeed be an important component of any fellowship programme, as it would ensure that researchers received sufficient guidance and feedback on their work. In their experience, the quality of support available to researchers was often inconsistent:

> *At the moment it's just too adhoc and bitty, it really depends on who your supervisor is, the research group that you work in, the university that you're in and whether people have got time and that's just disorganised and not very good.*
>
> Early career researcher

The value of peer support was also recognised by a key leader who, reflecting on his own career, remarked that it was very valuable to 'work with established researchers and learn from them'. He also believed that having colleagues to 'bounce ideas off' had been a great assistance. Expressing similar sentiments, a mid-career research remarked that 'it's been quite important for me to be part of a large group and to be part of a group that's quite research active and is very focused on research'.

Whilst many interviewees appeared to advocate an apprenticeship model, there was one early career researcher who expressed a contrasting viewpoint. They were very much in favour of scheme which afforded the researcher complete independence to pursue their own interests. The only requirements, in their opinion, would be a salary, expenses and office – the research should be entirely self-motivated and self-directed. This theme of independence and autonomy is covered again in section 10.2.3.

10.2.2 Training

STEM education researchers tend to be drawn from three different professional avenues: they may be teachers, subject specialists or have a background in social science research. Consequently, interviewees felt that each group possessed a different set of training requirements and these identified areas for development may inform the possible content of a fellowship programme

It was suggested that those entrants coming from a classroom environment may well benefit from training which focuses on developing their research skills. For example, a senior research associate noted that if teachers joined HE departments without PhDs then they may not have received any specific methodological training. In the case of this particular individual, half his colleagues were in such as position and had therefore missed out on training in research skills. Furthermore, teacher trainers may decide to embark upon a PhD to acquire research experience, but often find this difficult to complete on top of their tutoring responsibilities. It was also intimated that STEM

teachers, who are used to looking for the 'right' answer, may need some help in adjusting to a world of social science where there is likely to be much greater ambiguity and uncertainty.

> *There is something that is very deep, in terms of where you are coming from and how you view … and how you think social problems can be addressed and changed.*
>
> Policy and practice representative

This cultural adjustment could be enabled through social studies courses which expose teacher researchers to an alternative way of conceptualising educational problems/questions.

Meanwhile, those with subject expertise e.g. physicists, chemists and mathematicians, etc were said to face a different problem. A policy representative believed that there was now greater recognition for educational research in universities and that it was increasingly being undertaken by subject departments. This development was thought to have been encouraged by the RAE which now counts educational research as part of some subject research (e.g. pedagogic research in physics now falls within the descriptors of the physics assessment panel). With more subject experts involved in research on teaching and learning, it was suggested that they could benefit from training around the theories of education and the social science/methodology approaches to educational research. Giving these individuals a better understanding of the conceptual frameworks surrounding education research was said to help integrate their research into the larger body of educational research, by ensuring it was grounded in relevant theory.

For those entrants with a social science background it was recommended that they could also receive training on the education system and pedagogic issues. In addition, for this particular cohort of researchers, training which enhanced subject knowledge was regarded as necessary:

> *One of thing the things that plagues the science education system is the number of people who feed into that process whose own knowledge of the underlying science is shakey.*
>
> Key leader

In terms of longevity as a STEM education researcher, it was deemed essential that all new entrants to the profession quickly acquired the practical business skills associated with research. Only by writing successful bids and effectively managing projects would a researcher be able to sustain themselves in a career long term. A senior researcher contended that these skills and knowledge were best learnt through an apprenticeship model, as had happened in his case. However, the same individual observed that the investment of time for senior colleagues to develop the careers of less experienced colleagues

meant that this did not always happen. Therefore, in addition to allowing fellowship students to pursue their research interests, a scheme may also wish to consider offering support and advice about the research management process itself. This would help equip beneficiaries with the necessary skills to take their careers forwards, once the fellowship had ended.

10.2.3 Autonomy

One possible advantage of a fellowship programme would be the opportunity to pursue research on a theme of your own choosing. Interviews highlighted the frequent problem of post-doctorates leaving academia because they were unable to find a post that permitted them to continue their research interests. A loss of control and ownership of research was said to leave some researchers feeling disillusioned and as a result, looking for employment elsewhere (e.g. moving into industry). Thus, the prospect of autonomy and the freedom to select a topic for research may prove enticing for researchers at a critical juncture in their careers.

> *It's a case of again, having some kind of ownership over the work you're doing and being able to develop a line of research, that's how careers develop and work. Not by being somebody else's dogs body, which is not actually a gross exaggeration.*
>
> Senior research associate

> *It's frustrating and disappointing when you've done your PhD for three to four years and you're looking to try something else and it frustrates you that it's not the kind of world that you imagined. So everybody's going to the industry after*
>
> Early-career researcher

10.2.3 Collaboration

The size of education departments was highlighted as a constraint to capacity building. This was seen as a problem both in terms of opportunities to climb the career ladder and to exchange ideas/knowledge/expertise (which in turn could adversely affect the career development of researchers). Hence, there were calls for greater collaboration between institutions, whereby researchers with shared interests could be brought together. In a similar vein, interviewees felt there was more room for interdisciplinary work, so that education research would be strengthened by the input of different specialists and their methodological approaches.

> *Doing good research in this field is an interdisciplinary endeavour, both in terms of the fact that you might bring psychological and sociological methods to bear on a problem, indeed anthropological ones. But also you've got to enable a dialogue between those who know*

about the subject and those who know about this kind of pedagogical research. There is an important interdisciplinary challenge.

Key leader

A fellowship programme therefore may wish to consider whether it is possible to foster greater interaction between specialisms – bringing together expertise in the areas of pedagogy, subject knowledge, psychology of learning, etc. This may also include more liaison between researchers and practitioners. Drawing on an expanded reservoir of expertise is likely to enhance the quality of STEM education research, which in turn may contribute to its later impact on policy and practice.

10.2.4 Target group

One consideration for the fellowship scheme will be to decide on the extent of its coverage – for example, should particular institutions be targeted and who should be eligible?

Although not specifically asked, interviewees did at times refer to this issue. It was proposed by some that a fellowship programme could be used to broaden the development of expertise at a greater range of institutions, rather than encourage a situation where a select few institutions monopolise the market for STEM education research. Similarly, interviewees intimated that schemes could be made available to researchers at different stages of their careers to promote early career progression, career development and ultimately establish independent reputations.

You basically create opportunities at every stage, which I think is so important, there's no one stage that's more important than any other stage.

Mid-career researcher

One strategy for attracting teachers to educational research may be by encouraging them to take Masters degrees. However, there was a key leader who felt that this was difficult for newly qualified teachers to do whilst settling into a new profession and recommended instead that teachers further on in their careers be targeted, after they had acquired some relevant experience. For another key leader, the main challenge was how to identify those teachers who had the potential to become excellent researchers. They appreciated that it could be difficult for teachers to 'break into the university system', where there is an increasing emphasis on producing high quality research. To bridge the gap between school and university employment, the key leader described a new course which linked the National Science Learning Centre with a Department of education studies. The course would enable teachers to receive accreditation towards a part time MA. Through this opportunity, it was hoped that teachers with research potential would emerge

and received a qualification that would make them eligible for university level posts.

10.2.5 Timing

Aside from the need to offer a fellowship programme over a reasonable length of time (e.g. 2-3 years), a sentiment frequently expressed was that if staff were going to dedicate time to research, they would have to be relieved from their teaching responsibilities. In Northern Ireland for example, it was noted that many staff were required to fulfil a very heavy programme of school-based visits as part of their initial teacher training supervisory duties. On the one hand, this was said to keep researchers close to the realities of the classroom but on the other, time for research suffered.

> *You've got expertise locked up in the people who deliver PGCE in science but its difficult for them to be released from that PGCE work to do meaningful research and yet they have a wealth of understanding and expertise of what's really going on in schools. So fellowships that release them for between one and three years to carry out a research project could be really useful.*
>
> Key leader

One mid-career researcher though pointed out that this may not be viewed positively by the institution who would then have to look at arranging teaching cover. A more attractive scenario may be to opt for a split contract – a proportion of time allocated to research with the opportunity to continue teaching. Such an arrangement would have suited this particular individual who enjoyed the teaching aspect of their work. At the same time, by maintaining a commitment to teaching, it was felt their employer would be more accepting of this career development, enabling the individual to remain within the institution.

Furthermore, in terms of long-term employability it may be desirable to protect teaching opportunities, because:

> *If they don't have that opportunity they can never develop the expertise to go for a full secure lectureship. I don't think you are necessarily helping somebody in their early career by giving them another three years without any HE teaching experience.*
>
> Key leader

10.3 General issues for increasing capacity in STEM education research

Data collection also revealed other issues which could be regarded as detrimental to the health of STEM education research. These problems cannot

necessarily be tackled solely by the introduction of a fellowship programme and are therefore discussed separately. The challenges highlighted by interviewees related to:

- Status of research
- Salaries
- Career progression
- Funding streams

10.3.1 The status of research

A number of interviewees drew attention to the fact that research often has to compete with demands for teaching, and can therefore loose out in terms of staff capacity, commitment and opportunities.

For example, a scenario was cited whereby those in more senior positions would off load teaching commitments to other staff (due to a desire to focus on research). The consequence for those staff was that their time was taken up with teaching, leaving little space to follow their own research interests. Another early career researcher noted it could be difficult for staff to manage the balance between teaching and research. Indeed, the requirement to teach may actually exclude some valuable entrants from the educational research community – a mid career researcher referred to a colleague who had struggled to find a post because they were not able to teach on PGCE courses. However, it was suggested that with investment and opportunities this individual (with their considerable research experience) could become "one of international stars in 10 years time". Under the current conditions where teaching was prioritised, they were finding it difficult to progress their career in educational research. Perhaps it is individuals such as this, with a strong interest and track record in educational research that could flourish under a fellowship programme?

Inequalities were also highlighted between how subject research and educational research were regarded generally. A researcher in an engineering department implied that there was little interest in educational research because it did not to lead to recognition and promotion. According to a key leader in the field of science research, the RAE does not support researchers who wish to embark on educational research (instead favouring activities which are subject focussed). This bias may explain why educational research is not so highly regarded or supported within certain institutions. A researcher based in Wales felt that STEM education research generally needed to be valued more highly by schools, the funding council (HEFCW) and the Welsh Assembly Government [1]A fellowship programme may therefore be one way of

[1] In Wales, there is currently a proposal for the development of an Institute of STEM education research, which would include a fellowship programme

ensuring that STEM educational research is not overlooked, creating an outlet for people to pursue research that would generally not be regarded as a priority.

10.3.2 Salaries

A significant barrier to recruiting teachers was the gap between what they could earn in the classroom and the renumeration they would receive as a researcher. Several interviewees felt that on a very practical level, there was simply no financial incentive to make such a career change, especially with commitments to a family and a mortgage.

> *People out there are interested in the job but they're rational people and they're saying well can I afford it.*
>
> Key leader

> *New people coming in from schools have to take quite a massive pay cut. I think that's a big issue because you think well why would you do that. It's partly to do with schools pay has gone up quite a bit and academic pay hasn't really kept pace. I think initial starting salaries might have to start matching what it means to be a head of department in a secondary school.*
>
> Mid-career researcher

Commenting on the Scottish situation, one interviewee suggested there may be much untapped research potential amongst the teaching population due to a number of recent initiatives/developments. Specifically mentioned was a major science educational initiative that encouraged teachers to buy into professional development that involved a case study research approach. More recently, the Assessment for Learning project also involved case study work and if a teacher wishes to earn 'chartered status' (and remain in the classroom rather than pursue a management post) they must research and evaluate their own classroom practice. However, whilst there was evident enthusiasm for research amongst teachers in Scotland, the difference in salaries meant it was not generally regarded as realistic career move. A Northern Ireland commentator noted that many teachers were involved in Masters programmes with a research element and some in Doctoral programmes. They felt that more could be done to tap into the resource this represents.

Even if teachers decide to take the leap and enter STEM education research, career progression can prove difficult. To achieve promotion they need to do a PhD which can take several years at which point 'they might get promoted to senior lecturer'. Had they remained in teaching they could have reached the position of deputy head with a much higher salary. This lack of comparability between the two professions meant that in the eyes of one key leader 'it's a disaster area'. Indeed one researcher, an ex-teacher, admitted that he was only

able to pursue a career in education research because of an inheritance he received and that for others 'it is a very painful career transition'

Apart from offering a greater financial inducement, strategies are perhaps needed for raising awareness amongst teachers of a potential career in STEM education research. Interviewees spoke of secondments and sabbaticals from teaching; a range of supported and part-time MAs and greater involved of practitioners in the research process. Indeed exposure to the research community appeared to be an influential factor in the career pathways of key leaders.

> *What helped me was doing a masters because I could see that I liked doing research and I liked academia ..... If you haven't been there, tried it out and done it, you are unlikely to go and do it. So give people more experience of doing, by doing MAs or further study.*
>
> Mid-career researcher

In order to encourage and support teachers into higher education, funding was regarded as vital. A key leader noted that *'there are very few English people doing fulltime PhDs in maths and science education',* instead places were taken by overseas students.

10.3.3 Career pathways into STEM and career progression

Staff are more likely to be retained in professions where there is the prospect of career advancement. According to interviewees however, the life of a STEM education researcher can be insecure (due to temporary contracts) and relatively stagnant (with few opportunities to move forward). The predicaments of both an early and mid career researcher illustrate the difficulties faced. The early researcher explained that it can be difficult to get research posts, as it took a long time to build up a reputation and '*You are seen as a junior researcher, and your skills end experience that feed into that are not taken account of. This is a bit insulting when you're experienced in your field*. Meanwhile, a mid-career researcher was applying for a lectureship, despite having carved out a successful career as a contract researcher. They felt that this position offered better security without the hassle of having to find their own salary every two to three years. In terms of capacity building therefore, any strategy (a fellowship or other) would need to address the longer term issue of career progression and to consider how an individuals prospects could be improved and the progression of their career facilitated. Indeed, when interviewees were asked to rate the importance of different factors for building and sustaining capacity in STEM education research, career progression received the highest ratings, closely followed by training opportunities.

10.3.4 Ongoing funding programme for STEM research

An interesting point was made on funding streams for research by one key leader. They were of the opinion that if STEM education was to flourish then it required an ongoing, dedicated source of funding. Currently, STEM education research was said to fall between the ESRC, Engineering and Physical Sciences Research Council and the Biotechnology and Biological Research Council. A clear source of funding would signal commitment to STEM education research and ensure it was adequately supported.

10.4 Summary

This chapter has collated interviewees' views on the factors that could potentially increase capacity for STEM education research, as well as the specific contribution of a fellowship programme.

Access to training, support and better career prospects were highlighted as the main factors that could help build and sustain expertise in STEM education research. The different backgrounds of entrants (teachers, subject specialists, social scientists) was felt to affect the kinds of training they would need. For example, it was suggested that those entrants coming from a classroom environment may well benefit from training which focuses on developing their research skills. In terms of longevity as a STEM education researcher, it was deemed essential that all new entrants to the profession quickly acquired the practical business skills associated with research (e.g. writing bid, managing projects).

A lack of security and limited opportunities to advance one's career were cited as significant disincentives to those considering a future as an educational research. The disparity between researcher and teacher salaries was also believed to deter prospective researchers from leaving the classroom. In terms of capacity building therefore, any strategy (a fellowship or other) would need to address the longer term issue of career progression and to consider how an individual's prospects could be improved and the progression of their career facilitated.

Interviewees were unanimously positive about the prospect of fellowship programme. In terms of its style and composition they suggested that it could:

- Be offered within a structure of support, training, mentoring
- Develop the practical skills associated with research (writing bids, managing projects)
- Give recipients freedom to pursue their own research interests
- Provide opportunities for collaboration between disciplines, institutions
- Release staff from some/all of their teaching commitments in order to dedicate time to research.

The final chapter of the report will now draw together findings from this and previous chapters in order to summarise the key messages and offer some recommendations for the development of a fellowship programme.

11 Summary and concluding comments

This study, although small-scale, has been extensive in its exploration of the issues relating to the current health of STEM education research. It has touched on innovation, collaboration, quality, impact, competitiveness, commissioning, career pathways and the distribution of expertise. In a climate where the numbers of researchers are dwindling, one key question remains:

> **What can be done to boost the overall capacity for STEM educational research?**

This final chapter will seek to illuminate the main messages from the research and pinpoint the important decisions which need to be made, should the Royal Society wish to proceed with a fellowship programme. In reading this synopsis it is important to recognise that the study was conceived as a scoping exercise – it was intended to be selective and illustrative rather than fully comprehensive. On the basis of this, it would be unwise to present definitive recommendations. Instead, we pose a range of questions, alongside various options for a fellowship and signal those which were most strongly supported by interviewees.

11.1 Is a fellowship programme wanted?

It should first be registered that there was unanimous support for a fellowship programme across those who contributed to this study. It was regarded as a legitimate strategy for attracting individuals to the profession and for nurturing the next generation of education researchers.

11.2 How flexible should it be?

Given different backgrounds and circumstances it would be necessary to allow some degree of flexibility and personalisation of the fellowships. If fellowships were very prescriptive in their requirements, for example a required two years full time study, this may exclude applicants with other commitments (e.g. to teaching or family). A magnet for potential applicants may be the ability to customise the fellowship to their own interests, as well as tailoring any associated training. Many post-doctoral researchers were said to leave higher education because of the sparse opportunities to pursue their preferred areas of research. Thus, the prospect of being able to freely select a topic for research may prove enticing for researchers at a critical point in their careers.

Alternatively, the fellowship programme may wish to identify certain themes for research. Such an approach could encourage interaction between researchers, resulting in a more cohesive body of work, which may in turn lead

to a much greater impact. The production of high impact research would then certainly help propel new researchers onto the next step of the career ladder.

- Should any particular research areas be prioritised for a fellowship programme or should it be entirely free choice?

11.3 Broadening the expertise or targeting centres of excellence?

It was noted that the highest quality work tends to be concentrated in a small number of institutions that could be regarded as centres of excellence. A fellowship programme may therefore prefer to target such environments where success in STEM education research has been proven. In doing so, the fellows would be positioned at the heart of a established research culture, capitalising on the skills and knowledge available in the institution. It could be argued though that to build overall capacity for STEM education research, it is necessary to broaden the base of expertise across the country, thus widening the pool of good quality researchers.

- Does the fellowship scheme wish to encourage a spread of expertise or focus on established centres of excellence?

11.4 Single or co-fellowships?

A fellowship could be offered to individual researchers and/or it could decide to target clusters of researchers with different but complimentary backgrounds. Those with backgrounds in teaching, social science or subject experts could be brought together which ultimately may lead to more innovative and in depth work. Additionally, a group of fellows would benefit from the mutual support they are able to offer each other.

- Should the fellowship programme encourage applications from groups of researchers, working together in a cluster model approach or single researchers?

11.5 Support arrangements?

There was a clear consensus amongst interviewees that support should be firmly embedded within any fellowship programme. It was deemed imperative that the research fellows have access to some kind of mentor who could offer advice and guidance. Through this 'apprenticeship' model the fellow would have access to the skills and knowledge of a more experienced researcher. With support being viewed as such a vital element of any scheme, the question will be how to secure and guarantee the best quality support. The host institution would perhaps need to sign a contract agreeing the type and level of support that can be offered to research fellows. Then, in order to ensure that

this contract is being honoured some sort of monitoring should be in place as part of the schemes administration.

A second form of support could be provided by other fellows themselves – especially if a cluster model were adopted or if fellows across institutions were networked, they could draw on their support of their counterparts when necessary.

- Who should identify the mentor? What role should the research fellow play in this process?
- Would it be desirable or feasible to have two mentors – reflecting the multidisciplinary nature of educational research?
- For a mid-career researcher, would a mentor be necessary?
- To ensure the quality and consistency of support, should some kind of training/information programme be established for mentors? (e.g. outlining the nature of support expected)
- What kind of contract is needed between the host institution and the funder?
- How could the obligations of the host institution be monitored to ensure that the fellow is being appropriately supported?
- What sort of networks could be established to ensure that fellows were able to provide peer support?

11.6 The role of collaboration?

With international research being largely the domain of key leaders and the natural limitations of small education departments, opportunities for collaboration could become a worthy feature of the fellowship programme. Bringing together researchers with different knowledge and backgrounds could facilitate an exchange of ideas, creating a breeding ground for innovative work, as well as provide another layer of support for those involved in the fellowship. Furthermore, interactions between researchers and practitioners was identified as a feature of high impact research so this could be a productive avenue for a fellowship programme. Overall, through greater collaboration it may be that a much stronger research community emerges, which is likely to impact positively on the careers of those involved.

- What types and scale of collaboration does the fellowship wish to prioritise? Within the institutions (across different departments), between institutions or even on an international scale?
- How could opportunities for collaboration by created? e.g. attendance at conferences (BERA)
- Should some form of collaboration be written in as a requirement of a fellowship?

11.7 Planning for career progression?

Whilst a fellowship may succeed in attracting and recruiting individuals to STEM educational research, it is equally important to consider the next stage of their career development. In order to retain researchers long term some thought needs to be given to how they can move on to become firmly rooted in the STEM community. To an extent this may be outside the control of a fellowship but a comprehensive programme of skill development would ensure that fellowship researchers are given 'added value' placing them in a competitive position, when applying for other posts.

- How can long term career progression be built into the fellowship?
- Could the host institution be required to offer employment on completion of a fellowship?

11.8 How to meet different training needs?

The different routes taken by those entering STEM education research (i.e. teaching, social science, subject specialists) means that their training requirements are likely to vary. All entrants though would benefit from acquiring the generic skills of research (proposal writing, presentation skills, project management). When interviewees judged the quality of research, methodological rigour and knowledge of educational theory appeared to rank highly. Hence to facilitate STEM educational research, which is of the highest standard, a fellowship would need to consider the provision of training in these essential elements (if required by the recipient).

Having stated the value of professional development for future career progression the dilemma for a fellowship programme would be how best to ensure that fellows can access training opportunities. There may be a case for a centrally administered programme whereby fellows from different institutions are brought together, thereby ensuring a standardised quality of provision as well as opportunities for support and networking. However, if the funders of a fellowship were to take responsibility for arranging training for researchers, would this have implications for ownership of the fellowship by the host institution? In the long term, would it be better to encourage the development of a training programme to increase capacity for STEM education research within the university? Indeed, the host institution itself may already run appropriate courses and so long as fellows are eligible for participation, this may be another source of training.

- To ensure that fellowship researchers receive relevant training, should some kind of skills analysis be undertaken on entry to the programme, identifying their strengths and weaknesses?
- In setting up a fellowship programme, should organisers first ascertain the availability and accessibility of provision already offered within HE?

- Having undertaken an audit of existing provision, would a centrally administered programme be a worthwhile strategy to pursue?

11.9 Teaching within the fellowship?

University staff often have to juggle their time between teaching and research, with a balance which is not always favourable to the latter. Entry to a fellowship programme could provide those who are interested in the opportunity to concentrate solely on research. At the same time, in order to maximise future employability in the HE sector, it may be wise to allow for a proportion of teaching as this is likely to be a requirement of most education posts.

- Should a fellowship programme specify the number of teaching hours, in order to protect research activities?
- Should a fellowship programme encourage researchers to retain teaching responsibilities?

11.10 Learning from other schemes?

Several other fellowship schemes are currently available for those working in other fields, administered through organisations such as the Nuffield Foundation, ESRC and the TDA. In the US the National Science Foundation has a specific programme aimed at renewing the workforce in STEM and STEM education research. It may therefore be beneficial to liaise with these organisations and link in with existing schemes. In doing so, it would be possible to profit from the knowledge and experience of those already offering fellowships.

- How could the Royal Society learn from existing fellowship schemes and would it be worthwhile creating links with a STEM education research fellowship?

11.11 A fellowship for whom?

The final issue for consideration is who a fellowship programme should invest in. As educational research tends to attract entrants from different professional backgrounds, one possible strategy would be to cater for all types of researcher – teachers, social scientists and subject specialists. After all, each cohort would legitimately have something to bring to a profession that is currently struggling to operate at full capacity. An open approach to fellowship eligibility could potentially drive up the numbers choosing STEM education research as a career. What of quality though? Would it be more preferable to focus on those who show real potential, the future high fliers, the top calibre researchers? In this case, it is likely they will already be in academia and have demonstrated their research capabilities, through PhD studies. The decision of who to target has economic implications also – it would cost considerably more to entice a teacher away from the classroom

than to offer a post-doctorate their next research opportunity. If resources are limited, it may be wiser to invest in those individuals who already have some research experience and who have indicated talent and potential. Education departments are likely to be aware of these individuals and could refer them to a fellowship as a means of advancing their careers in STEM education research. This kind of investment would offer the least risk, but may constrain the types of researcher who are able to benefit from the scheme.

There is also the issue of early versus mid career researchers. One interviewee from Scotland implied that the middle tier of researchers was currently overlooked in terms of funding opportunities. They felt that early career researchers were already supported by existing grants, whilst the key leaders in the field had no problems securing larger pots of funding. It was those who had perhaps entered the profession 5-10 years ago who needed a boost, in the form of opportunities for interdisciplinary and international work, which could potentially expand their horizons and challenge existing theories and ideas.

- With limited resources, should a fellowship programme target those who have proven their research skills?
- Where resources are more plentiful would it be possible to widen the parameters of eligibility, creating a suite of fellowships for different types of researcher?

To conclude, this project has accumulated evidence which supports the proposition of a fellowship programme. By reflecting on the questions highlighted above, it is hoped that the Royal Society can work towards formulating a scheme that yields maximum benefit from the resources that are available.

References

Braund, M. and Driver, M. (2005). 'Pupils perceptions of practical science in primary and secondary school: implications for improving progression and continuity of learning', *Educational Research*, **47**, 1, 77–91.

Cleaves, A. (2005). 'The formation of science choices in secondary school', *International Journal of Science Education*, **27**, 4, 471–486.

Condliffe Lagemann, E. (2000). *An Elusive Science: the Troubling History of Educational Research*. Chicago: University of Chicago Press.

Department for Education and Skills (2006). *The Science, Technology, Engineering and Mathematics (STEM) Programme Report* [online]. Available: http://www.dfes.gov.uk/hegateway/uploads/STEM%20Programme%20Report.pdf [23 March, 2007].

Dyson, A. and Desforges, C. (2002) *Building Research Capacity: Some Possible Lines of Action* (National Education Research Forum Working Paper Number 1.1) [online]. Available: http://www.nerf-uk.org/word/WP1.1BuildingResearchCap.doc?version=1 [23 March, 2007].

Gilbert, J. (Ed) (2006). *Science Education in Schools: Issues, Evidence and Proposals. A Commentary by the Teaching and Learning Research Programme* [online]. Available: http://www.tlrp.org/pub/documents/TLRP_Science_Commentary_FINAL.pdf [23 March, 2007].

Jagger, N. (2004). *The Right Chemistry: the Choice of Chemistry Courses and Careers. A Report for the Royal Society of Chemistry* [online]. Available: www.rsc.org/education/policy/rightchemistry2004.asp [3rd November, 2006].

Lord, P., Harland, J. L. and Gulliver, C. (2006). *An Evaluation of the Royal Society of Chemistry Careers Materials* [online]. Available: http://www.rsc.org/Education/Policy/CareersEval.asp [23 March, 2007].

Lord, P. and Jones, M. (2006). *Pupils' Experiences and Perspectives of the National Curriculum and Assessment: Final Report for the Research Review* [online]. Available: http://www.nfer.ac.uk/publications/pdfs/downloadable/NCAe-report.pdf [23 March, 2007].

Monk, M. (2006). *A Survey of the Nature and Distribution of Science Education Research Amongst Science Education Tutors in the UK at Spring 2006*. Report for the Science Education Research Committee (unpublished)

Moor, H., Jones, M., Johnson, F., Martin, K., Cowell, E. and Bojke, C. (2006a). *Mathematics and Science in Secondary Schools: the Deployment of Teachers and Support Staff to Deliver the Curriculum* [online]. Available: http://www.dfes.gov.uk/research/data/uploadfiles/RR708.pdf [3rd November, 2006].

Munro, M. and Elsom, D (2000). *Choosing Science at 16: the Influences of Science Teachers and Careers Advisers on Students' Decisions About Science Subjects and Science and Technology Careers* [online]. Available: http://www.crac.org.uk/nicec/publications/pdfs/new_briefings/choosing_science.pdf.[23 March, 2007].

Murray, I. and Reiss, M. (2005). 'The student review of the science curriculum', *School Science Review*, **87**, 318, 83–92.

Nutley, S. (2003). *Increasing Research Impact: Early Reflections from the ESRC Evidence Network* (ESRC UK Centre for Evidence Based Policy and Practice: Working paper 16) [online]. Available: www.evidencenetwork.org/documents/wp16.pdf [23 March, 2007].

Percy-Smith, J., Burden, T., Darlow, A., Dawson, L., Hawtin, M. and Ladi, S. (2002). *Promoting Change through Research: the Impact of Research in Local Government.* York: Joseph Rowntree Foundation

Ratcliffe, M., Bartholomew, H., Hames, V., Hind, A., Leach, J., Millar, R. and Osbourne, J. (2004). *Science Education Practitioners' Views of Research and its Influence on their Practice* (Evidence-based Practice in Science Education Research Report). York: University of York.

Roberts, G. (2002). *SET for Success: the Supply of People with Science, Technology, Engineering and Mathematics Skills* [online]. Available: http://www.hm-treasury.gov.uk/documents/enterprise_and_productivity/research_and_enterprise/ent_res_roberts.cfm [23 March, 2007].

Smith, A. (2004). *Making Mathematics Count: the Report of Professor Adrian Smith's Inquiry into Post-14 Mathematics Education*. London: The Stationery Office.

Stagg, P., Laird, R. and Taylor, P. (2003). Widening Participation in the Physical Sciences. An Investigation into Factors Influencing the Uptake of Physics and Chemistry. Final Report [online]. Available: http://ntserver002.liv.ac.uk/ltsnpsc/devprojs/reports/pdfs/WidenPartChem.pdf [23 March, 2007].

For more information about this report contact our enquiries line on 01753 637289 or enquiries@nfer.ac.uk. For more information about NFER reports contact our Publications Unit on 01753 637002 or book.sales@nfer.ac.uk.

NFER ref: STU

National Foundation for Educational Research
The Mere, Upton Park, Slough
Berkshire SL1 2DQ
www.nfer.ac.uk