Chapter 16
Policy Implications of Developing Mathematics Education Research

Celia Hoyles and Joan Ferrini-Mundy

Abstract Researchers often pursue their own interesting and specific mathematics education research questions without engaging with the practical and policy issues that may have considerable bearing on mathematics education. The final chapter of this section deals with this situation by considering three interrelated themes: developments in education policy that have implications for mathematics education research; the potential for engaging the mathematics education community in pursuing research questions that have implications for policy; and the relevance, utility, and accumulation of mathematics education research findings to support policy and practice. In particular, questions are raised about the role of standards in the specifics of mathematics teaching and learning, and the challenges of making research professionally and publicly available in ways that might be used to inform the decisions and the practices of policy makers and teachers.

Introduction

The teaching and learning of mathematics occur largely within classrooms, schools, and universities that are influenced far more strongly by educational policies—"rules and regulations promulgated in state capitals and the federal government" (Sykes, Schneider, & Ford, 2009, p. 1)—than by mathematics education research. In most countries, the importance of mathematics education is judged

The second-named author is now at the National Science Foundation. This work was based in part on work supported by the National Science Foundation.

C. Hoyles (✉)
Institute of Education, University of London, London, UK
e-mail: C.Hoyles@ioe.ac.uk

J. Ferrini-Mundy
Michigan State University, East Lansing, MI, USA

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as critical. It is presumed to be "a vehicle toward social and political progress" (Gates & Vistro-Yu, 2003, p. 62), and central to the development of a well-trained workforce that can advance the economic standing of a country. Governments face a range of distinct but related policy challenges that include providing universal mathematical literacy for all, ensuring a mathematical foundation to support the study of other subjects that are increasingly demanding higher levels of mathematics, and stimulating the most able to continue with mathematics study after it is no longer compulsory and into university.

At the same time, mathematics education research is largely conducted to take forward theory and knowledge of the domain, although impact on teaching and learning practice is a distinct purpose (e.g., Lester & Wiliam, 2002). Yet, there remains often a mismatch between questions pursued by researchers and questions facing policy makers and practitioners. It seems unlikely that most mathematics education researchers have the potential impact of their work in mind on, for example, major national economic debates or workforce capability. This has tended to mean that if mathematics education research has had rather little significant influence on practice, its influence on policy has been even less.

However, Smith and Smith (2009) have argued that policy research does influence practice but maybe not directly and obviously. As one example, Welch (1979) (cited in Smith & Smith, 2009) made a case that research on science and mathematics learning indirectly influenced the US-based K–12 curricular reforms of the 1960s and 1970s, resulting in their emphasis on hands-on instruction and inquiry-oriented approaches. A similar case can be made for comparable reforms in UK and Europe over the same period, where more investigative approaches were promoted and the need for appropriate teacher interventions recognized. Research in design experiments repeatedly reported that in such contexts, scaffolds and guidance for the teacher were needed (Noss & Hoyles, 1996). Thus, history would suggest that there is considerable untapped potential for productive interaction between the mathematics education community globally and those concerned with the development and implementation of policy that affects mathematics teaching and learning.

Education policy is defined in various ways. Wikipedia uses: "the collection of laws and rules that govern the operation of education systems" (retrieved from http://en.wikipedia.org/wiki/Education_policy). Education policies are established at the country, region, state or province, and local levels, and they are guided and communicated by documents such as national curriculum frameworks, required assessments and examinations, curriculum materials, and non-statutory guidance for use in schools. The institutions involved in setting policy "include, but are not limited to, legislatures, courts, nonprofit agencies, and national, state, and local governmental agencies" (William T. Grant Foundation, 2011). Ferrini-Mundy and Floden (2007) provide additional discussion of this area.

Policies in many countries span the range of areas of schooling (e.g., compulsory schooling policies, or assessment and examination policies that determine higher education pathways), and some are quite specific to mathematics education. In both cases—generic policies and mathematics-specific policies—there is little evidence that the mathematics education research community has engaged consistently and systematically in research that is used to formulate the policies. Nor is there a strong body of policy implementation or impact research that has examined policies that are particularly germane to issues in mathematics education. A research-like activity, policy analysis, has been undertaken in recent years by some mathematicians and mathematics educators: this might involve, for instance, assigning "grades" to standards in the USA, which often invokes comparison to standards around the world (e.g., Klein et al., 2005) and could be construed as a policy analysis activity (Clarke, 2003).

In this chapter, we explore the policy implications of developments in mathematics education research: the potential for engaging the mathematics education research community in pursuing questions that have relevance for policy, and the relevance, utility, and accumulation of mathematics education research findings to support policy and practice. The chapter will be grounded in two elaborated examples where the potential for intersection of mathematics education research and policy appears particularly fruitful, and where policy has been developed, and is developing, that is directly relevant to mathematics education. The first example is the story of the K–12 mathematics standards and related standards-based accountability in the USA. The second example traces the evolution of a national infrastructure for evidence-driven mathematics teacher professional development in England. These examples are presented as windows to illustrate how mathematics education research might relate to policy and are used to raise questions, such as: Who is involved in determining, implementing, and tracing the impact of policy? How might these stakeholders be more fully engaged with the mathematics education community? What is the role of research in these areas of policy?

With respect to these questions, we will also discuss what is available, in the research literature and elsewhere, about how policies are formed and used, focusing on the types of policies that are particularly relevant for mathematics education. In our conclusion we will discuss directions of policy, the prospects for research funding, and offer commentary on how mathematics education research agendas might embrace the possibility that mathematics education research results can inform and improve mathematics teaching, learning, and policy.

The Case of National Mathematics Standards in the USA

Efforts by the mathematics education and mathematics communities over the past two-and-a-half decades in the USA to create and implement curriculum standards as a strategy for improving K–12 mathematics education have stimulated the most vigorous policy debates and, more recently, the most widely coordinated policy incentive systems, possibly ever seen in US K–12 education within a particular discipline. The story of US mathematics standards, consistent in concept with the work of Smith and O'Day (1991) about systemic reform, illustrates a number of key policy issues that relate to research in mathematics education. In particular, these are: How does research on teaching and learning intersect with the development, implementation, and assessment of such policy levers as standards? What does research tell us about the most effective means of designing and implementing standards? What new questions become more salient when there is a lively national environment in mathematics education in the standards context? How have mathematics education researchers played key roles in this arena, and what are the prospects?

In the USA, responsibility for education is constitutionally delegated to the 50+ states and territories, which comprise about 14,000 school districts and almost 99,000 K–12 schools (see http://nces.ed.gov/pubs2011/pesagencies09/findings.asp and http://nces.ed.gov/pubs2011/pesschools09/findings.asp). Different states have different policy approaches, ranging from states with highly directive statewide curriculum standards whose adoption is expected by all districts, to states with more general standards that are then interpreted and adapted widely across school districts. Policies about such relevant matters as the required mathematical preparation of teachers, the number and nature of required mathematics courses in secondary school, and the selection of textbooks, are left to the discretion of states and vary widely.

The No Child Left Behind Federal legislation of 2001 imposed stronger Federal accountability requirements than the country had previously had, including requirements about annual assessment of students for each of Grades 3 through 8 and high school in mathematics, using instruments developed by states and aligned with state standards, and also introducing new requirements about teacher qualifications. At the same time, there have been policy influences that have emanated from the Federal level. The US Department of Education administers several billion dollars that pass directly to states, in some cases where use is highly specified. Currently the Department of Education sponsors the Mathematics and Science Partnerships program, which is heavily focussed on teacher professional development. And, the current state-led Common Core State Standards Initiative is an option that states can use in response to US Department of Education incentives to adopt standards.

A Brief History of Mathematics Education Standards in the USA

In 1989 the National Council of Teachers of Mathematics (NCTM) issued the first set of standards for curriculum guidance produced by a professional organization in the USA. The *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) not only specified the details of what should be taught in mathematics within grade bands, but also provided substantial guidance about instructional approaches, and offered examples and illustrations to guide teachers. The perspective reflected in this document was consistent with a constructivist view of knowledge, with a strong emphasis on "meaningful" engagement with mathematics, the use of "real-world" examples, and the role of technology. Although the 1989 NCTM standards document is not replete with references to research, a number of its authors were active researchers, and have commented that the development of the document was influenced by research findings at the time. A history of that development is recounted in McLeod, Stake, Schappelle, Mellissinos, and Gierl (1996).

The document was developed over several years, with an elaborate public reaction and comment process. NCTM leaders enlisted the endorsements of key professional organizations in mathematics. The standards were hailed by teachers and mathematics educators as a major step forward in guiding school mathematics instruction and placing issues of student engagement and understanding in the foreground. NCTM followed these initial curricular standards with three additional versions: the *Professional Standards for Teaching Mathematics* (1991), the *Assessment Standards for School Mathematics* (1995), and *Principles and Standards for School Mathematics* in 2000. Various ancillary materials were developed by the organization, including resources for teachers and instructional support materials. And standards development in other fields followed, including the *National Science Education Standards* developed by the US National Academy of Sciences (1996).

The US National Science Foundation, a Federal agency that funds grants in science and education through competitive processes, issued a call for proposals in 1990 to produce comprehensive instructional materials at grades K–6, 6–8, and 9–12 that would reflect national standards. Some of the programs developed under this call were commercially distributed. During this same period, states developed their state curriculum standards in mathematics. Anecdotal evidence suggests that many states attempted to align their standards with the NCTM document, and a series of policy-related tools to assess alignment of standards and curriculum were developed (Ferrini-Mundy, 2004). Notable among these were the curriculum framework analysis tools developed by Schmidt and colleagues for the Third International Mathematics and Science Study (TIMSS) for examining curriculum and standards around the world (see Schmidt, McKnight, Valverde, Houang, & Wiley, 1997). Following a careful comparative analysis, in which NCTM's (1989) *Standards* were considered, Schmidt and his colleagues dubbed the US mathematics curriculum as being "a mile wide and an inch deep" (Schmidt, McKnight, & Raizen, 1997, p. 62).

The convergence of many factors, perhaps including the visibility brought to the *Standards* by the funding of curricula to instantiate them, the international comparisons, the groundswell of activity from the NCTM teacher constituency, and the designation in 1999 of some of the NSF-funded and standards-based instructional materials as exemplary in a US Department of Education report (see http://www.k12academics.com/education-reform/us-department-education-exemplary-mathematics-programs) drew the attention of several prominent US mathematicians to the messages of the NCTM document. The concern of the mathematicians reached a high point in 1999, when an open letter to the US Secretary of Education, Richard Riley (see Klein et al., 1999), protested against the Department's designation of the materials as exemplary (http://www.mathematicallycorrect.com/riley.htm).

Thus the pathway of *Standards*, developed by the professional association for mathematics teachers, led to significant policy debates at the state and national level, engaging mathematicians, mathematics educators, local policy makers at the school district level, and state and federal leaders, in a new era of discussion about what school mathematics education should be. Despite the significance of the policy decisions—about standards, curriculum, and assessment—throughout this period, the definitive positions that were visible came largely from experts in mathematics, or in mathematics education, and represented professional judgment and opinion. Mathematics education research appears to have had little place or role in these debates and activities. In part, this was because the mathematics education research community's interests and inclinations in research—in the two decades spanning the release of the 1989 standards—were focussed in deep ways on important questions about student learning and understanding. Those concerned with policy were willing to use NCTM's (1989) *Standards* as an interesting site for understanding policy change (e.g., Fuhrmann, 2001), but were not necessarily driven by particular questions about the role of standards in the specifics of mathematics learning.

These circumstances, along with widespread US concern about international competitiveness and the science and mathematics education achievement of the nation's youth (articulated in *Rising Above the Gathering Storm*, 2007, a National Academies report) led in part to an Executive Order by the US President George Bush in 2006, establishing a National Mathematics Advisory Panel, charged to produce a report that contained

> … recommendations, based on the best available scientific evidence, on the following: (a) the critical skills and skill progressions for students to acquire competence in algebra and readiness for higher levels of mathematics; (b) the role and appropriate design of standards and assessment in promoting mathematical competence; (c) the processes by which students of various abilities and backgrounds learn mathematics; (d) instructional practices, programs, and materials that are effective for improving mathematics learning; (e) the training, selection, placement, and professional development of teachers of mathematics in order to enhance students' learning of mathematics; (f) the role and appropriate design of systems for delivering instruction in mathematics that combine the different elements of learning processes, curricula, instruction, teacher training and support, and standards, assessments, and accountability; (g) needs for research in support of mathematics education; (h) ideas for strengthening capabilities to teach children and youth basic mathematics, geometry, algebra, and calculus and other mathematical disciplines; (i) such other matters relating to mathematics education as the Panel deems appropriate; and (j) such other matters relating to mathematics education as the Secretary may require.
> (Retrieved from http://georgewbush-whitehouse.archives.gov/news/releases/2006/04/20060418-5.html)

The goal of this panel was to produce a report that could guide policy makers, and to employ a high standard of evidence for the inclusion of results from any research studies. The panel members represented a range of perspectives, and focussed on several aspects of mathematics education, including curricular content, learning processes, instructional practices, teachers and teacher education, instructional materials, and assessments. The report concluded that the research base for making policy decisions was not adequate:

> Systematic reviews of research on mathematics education by the task groups and subcommittees of the Panel yielded thousands of studies on important topics, but only a small proportion met standards for rigor for the causal questions the Panel was attempting to answer. The dearth of relevant rigorous research in the field is a concern. First, the number of experimental studies in education that can provide answers to questions of cause and effect is currently small. Although the number of such studies has grown in recent years due to changes in policies and priorities at federal agencies, these studies are only beginning to

> yield findings that can inform educational policy and practice. Second, in educational research over the past two decades, the pendulum has swung sharply away from quantitative analyses that permit inferences from samples to populations. Third, there is a need for a stronger emphasis on such aspects of scientific rigor as operational definitions of constructs, basic research to clarify phenomena and constructs, and disconfirmation of hypotheses. Therefore, debates about issues of national importance, which mainly concern cause and effect, have devolved into matters of personal opinion rather than scientific evidence. (National Mathematics Advisory Panel, 2008, p. 63)

In summary, perhaps the most important message to come from this report was that there was not enough evidence from research in mathematics education to inform or guide some of the most pressing policy areas in the USA relevant to mathematics education.

The Higher Education Opportunity Act of 2008 included consistent emphasis on scientifically-based research, scientifically-valid research, and empirically-based practice. Earlier, in 2002 the US Department of Education had launched the "What Works Clearinghouse" (http://ies.ed.gov/ncee/wwc/), which was charged with the task of identifying instructional materials for which suitably rigorous effectiveness studies had been conducted and had resulted in positive evidence. Only a small number of mathematics instructional programs, however, were judged to have met the What Works Clearinghouse standard.

So, in the space of two decades, the paths of policy, mathematics education research, and curriculum standards had crossed and become intertwined. And, in 2009, with Federal policy support for of the NCTM standards waning, with the ascendency of "evidence-based" practices and policy, and with legislation in effect requiring high-stakes frequent assessment of K–12 mathematics learners in all states, a new phase in the US standards movement was initiated—the Common Core State Standards Initiative.

Common Core State Standards: A Policy Effort Led by States for National Impact

Over the past 15 years there have been efforts in the USA for states to build coalitions for the improvement of K–12 STEM (i.e., "Science, Technology, Engineering, and Mathematics") education. In 1996 a group of governors founded Achieve, Inc., a bipartisan organization that "helps states raise academic standards and graduation requirements, improve assessments and strengthen accountability" (http://www.achieve.org/files/AboutAchieve-Feb2011.pdf). In 2006–2007, then-Arizona governor Janet Napolitano, as President of the National Governors Association, addressed the importance of STEM education as an issue for states in the document "Innovation America" (http://www.nga.org/Files/pdf/0707INNOVATIONPOSTSEC.PDF). A related report, *Building a Science, Technology, Engineering and Math Agenda* (http://www.nga.org/Files/pdf/0702INNOVATIONSTEM.PDF), though falling short of advocating national standards, set the stage for the introduction of a national curriculum with its very strong focus on the importance of standards and international benchmarking. These discussions about standards reached the highest US policy levels when President Obama, in March 2009, outlined his education plan and discussed the need for "Encouraging better standards and assessments by focussing on testing itineraries that better fit our kids and the world they live in" (see http://www.whitehouse.gov/blog/09/03/10/Taking-on-Education/). By this time, a partnership between Achieve and the National Governors Association had been established to launch the Common Core State Standards Initiative (CCSSI).

The following, which is taken from the CCSSI Web site (http://www.corestandards.org/ about-the-standards), provides a sketch of the development process used in preparing the CCSSI:

> The Common Core State Standards Initiative is a state-led effort, launched more than a year ago by state leaders, including governors and state commissioners of education from 48 states, 2 territories and the District of Columbia, through their membership in the National Governors Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO).
>
> The process used to write the standards ensured they were informed by:
>
> - The best state standards;
> - The experience of teachers, content experts, states and leading thinkers; and
> - Feedback from the general public.
>
> To write the standards, the NGA Center and CCSSO brought together content experts, teachers, researchers and others.
>
> The standards have been divided into two categories:
>
> - College and career readiness standards, which address what students are expected to learn when they have graduated from high school; and
> - K–12 standards, which address expectations for elementary through high school.
>
> The NGA Center and CCSSO received nearly 10,000 comments on the standards during two public comment periods. Comments, many of which helped shape the final version of the standards, came from teachers, parents, school administrators and other citizens concerned with education policy.
>
> - The draft college and career ready graduation standards were released for public comment in September 2009; and
> - The draft K–12 standards were released for public comment in March 2010.
> - The final standards were released in June 2010.
>
> An advisory group has provided advice and guidance to shape the initiative. Members of this group include experts from Achieve, Inc., ACT, the College Board, the National Association of State Boards of Education and the State Higher Education Executive Officers. (Retrieved from: http://www.corestandards.org/about-the-standards/process).

Using Policy to Incentivize Adoption of Common Core State Standards in Mathematics

The USA faces an interesting juncture in the standards trajectory, in that there is powerful momentum growing to support the use of the common core mathematics across states. Perhaps the first signal that the Federal government was supportive of this state-led effort appeared in the summer of 2009 when the US Department of

Education launched a competitive grants program among states called "Race to the Top," by which $4.35 billion dollars were made available to states to reform K–12 education. Although there was no specific focus on mathematics, the application for funding awarded points for states that were "developing and adopting common standards." The following information is from the application form.

Race to the Top
(**Race to the Top Application for Initial Funding**
CFDA Number: 84.395A
(http://www2.ed.gov/programs/racetothetop/application.doc)

(B) **Developing and adopting common standards** (*40 points*)
(1) The extent to which the State has demonstrated its commitment to adopting a common set of high-quality standards, evidenced by (as set forth in Appendix B):

(i). The State's participation in a consortium of States that— (*20 points*)
(a). Is working toward jointly developing and adopting a common set of K–12 standards (as defined in this notice) that are supported by evidence that they are internationally benchmarked and build toward college and career readiness by the time of high school graduation; and
(b). Includes a significant number of States; and

(ii). — (20 *points*)
(a). For Phase 1 applications, the State's high-quality plan demonstrating its commitment to and progress toward adopting a common set of K–12 standards (as defined in this notice) by August 2, 2010, or, at a minimum, by a later date in 2010 specified by the State, and to implementing the standards thereafter in a well-planned way; or
(b). For Phase 2 applications, the State's adoption of a common set of K–12 standards (as defined in this notice) by August 2, 2010, or, at a minimum, by a later date in 2010 specified by the State in a high-quality plan toward which the State has made significant progress, and its commitment to implementing the standards thereafter in a well-planned way.

Common set of K–12 standards means a set of content standards that define what students must know and be able to do and that are substantially identical across all States in a consortium. A State may supplement the common standards with additional standards, provided that the additional standards do not exceed 15% of the State's total standards for that content area.

At the time of writing this chapter, As of summer 2012, 18 States and the District of Columbia had been awarded Race to the Top grants (http://www2.ed.gov/programs/racetothetop/awards.html). The Federal Department has launched a competition for two major assessment consortia to "develop a new generation of tests." The new tests will be aligned to the higher standards that were recently developed by governors and chief state school officers (http://www.ed.gov/news/press-releases/us-secretary-education-duncan-announces-winners-competition-improve-student-asse). The standards have been adopted by 45 States and 3 territories (http://www.corestandards.org/in-the-states). It would appear that the USA is on the verge of having widely used, yet voluntary, national standards in mathematics. This is a remarkable opportunity for a wide range of policy research endeavours in which the mathematics education community could take the lead.

The Role of Research

Following on the lessons of the "math wars" and the findings from the National Mathematics Advisory Panel, it seems that the organizers of the Common Core State Standards Initiative were sensitive to the need for research and evidence to provide validation for the standards. Indeed, there was, as mentioned above, a Validation Committee whose major task was to examine the evidence used to support each set of standards. Confrey (2010) summarized the types of evidence used: "Data from ACT and SAT scores and performance in 1st-year college courses; analysis of college syllabi and surveys; surveys with business members; examination of college level math and math-client fields; whether the standards are benchmarked to international standards; and evidence from student learning studies" (p. 11). Student learning studies that may prove useful in the continuing standards implementation may include work on learning progressions, though it appears that there remain important research questions needing the attention of policy makers and mathematics education researchers.

Mathematics Education in England: Policy and Research

The example from England traces some recent efforts to transform practice by brokering partnerships among mathematics education researchers, mathematicians, policy makers and teachers. It touches on similar issues to the US case study in relation to the research and the standards agenda but also considers the role of research more broadly in promoting the teaching and learning of mathematics in the country. The theoretical basis underpinning the case study— although this was rarely made explicit—is learning design that involves valuing the need for all parties to build their solutions to problems at hand together, to reflect on them together and, crucially, to allow all the groups to feel empowered to shape any innovation to fit their own goals and purposes. Cobb and Jackson (in press) noted that the learning design perspective directs us to "analyze the soundness of the intended learning supports prior to implementation" (p. 10), and policy implementation must take account of these planned supports and how they are effectively operationalized.

Mathematics presents a challenge for policy makers. The subject is highly regarded. Tests are high stakes. In addition, mathematics is widely conceived as hard and procedural by those outside the mathematics community. Mathematics is a subject that offers diverse and unique ways by which students can express themselves in creative ways. Yet this broad agenda for teaching and learning mathematics is often invisible to those outside the community, especially, it is conjectured, policy makers, who most likely only value test results and performance measures. Yet progress in improving mathematics education can only be achieved when teachers do not narrow the mathematical diet of their students to procedures to pass tests. Rather, teachers must have the confidence to introduce a broader range of tasks and activities.

To achieve this goal in England, leaders in mathematics education have struggled over many years to set up a national infrastructure for mathematics continuing professional development (CPD) in order to confer status, priority and obligation for evidence-based professional learning that is recognized by all "layers of the system" and beyond: head teachers, mathematicians, politicians at national and regional levels, as well as teachers themselves. Thus the goal was that mathematics professional development would become an expectation and a responsibility for all those involved in teaching the subject with politicians, local leaders and head teachers in schools all supporting this agenda.

This agenda for mathematics inevitably raises the question whether mathematics has a special place in schools—because of the widespread uses of mathematical knowledge, but mainly because mathematics is a core part of the "standards agenda": an agenda that monitors student performance, schools and the system over time. Measures used for this monitoring exercise included results from national tests for all students in England at the ages of 7, 11, 14 and 16 (http://en.wikipedia.org/wiki/National_Curriculum_assessment), although the national testing at 14 years was ended in summer 2009. Performance of English students in international comparative studies, such as Trends in International Mathematics and Science Study (TIMSS) (http://nces.ed.gov/timss/index.asp), the Program for International Student Assessment (PISA) (http://nces.ed.gov/surveys/pisa/), and data about adult numeracy (see the Leitch Report, 2006, *Prosperity for All in the Global Economy—World-Class Skills*), were also to be taken into account (http://www.dius.gov.uk/publications/leitch.html). The agenda was driven by what was called National Strategies (primary and secondary), alongside a system of school inspection.

The challenge that educators in England have faced is how to support children to perform better at mathematics, that is, to achieve success in tests and examinations, without sacrificing creativity and inquiry and without exerting so much pressure on students that they are put off the subject. Too much pressure can result in teaching and learning procedural rituals for getting right answers, which bypasses the need to appreciate the structure and pattern of the subject. Teachers and researchers alike have worked hard to develop among students a mathematical way of thinking while not neglecting to support them to succeed in public examinations and high-stakes tests. This balance between learning and performance is difficult to achieve. It requires teachers who focus on teaching and learning, who know their subject and its pedagogy, and are confident enough to focus on longer-term subject appreciation alongside short-term performance outcomes. One cause of imbalance can be traced to policies that have meant that the subject agenda for teaching/learning/curriculum and the standards agenda may not have been appropriately aligned due to their different goals and management structures.

In contrast to many other countries, students in England are only allowed to drop mathematics at the age of 16 years, at the end of compulsory schooling (Hodgen, Pepper, Sturman, & Ruddock, 2010). However, it is increasingly accepted that there is a need for more engagement with mathematics, so the numbers who choose to study mathematics post-16 have been added as another government target for schools alongside the standards agenda. This has been one result of the general push to work for more success in mathematics, across the policy agenda and with a better alignment of the needs of practitioners with the realities of policy makers. We now document these policy initiatives in slightly more detail.

Some History: Giving Mathematics a Policy Voice

The Advisory Committee on Mathematics Education (ACME) was established in 2002 by the Joint Mathematical Council of the United Kingdom and the Royal Society (RS), with the explicit support of all major mathematics organizations. It comprises seven members, including teachers at different phases, and has a part-time Chair, who is a Fellow of the RS, to act as a single voice for the mathematical community. Its goal is to seek ways of improving the quality of education in schools and colleges (http://www.acme-uk.org). ACME was formed after a period of many years during which there had been no conduit through which the mathematics community could have dialogue with government, despite a standards agenda that included mathematics. Like the former Mathematical Sciences Education Board within the US National Academy of Sciences, ACME's membership includes mathematicians, teachers in different phases, mathematics advisers at local or government level, and a member of the mathematics education research community.

At the time of its formation, ACME had to acquire the commitment of government to provide appropriate contacts, as well as secure some funding for meetings to pay for the time of committee members. ACME now advises government on issues such as the curriculum, assessment, and the supply and training of mathematics teachers through face-to-face meetings and a series of highly influential reports (see http://www.acme-uk.org/the-work-of-acme/publications-and-policy-documents/policy-reports). In 2011/2012, there is to be new national curriculum for mathematics and ACME will play a leading advisory role in its development and formation, thus providing a mediating layer for mathematics education research.

Over a period of two decades, a number of significant education reports of relevance to mathematics have been commissioned by the UK government to inform and drive the policy agenda. Most were in fact about science, which of course impinged on mathematics but only in a secondary way. In fact, a major breakthrough in policy circles was the transformation of a SET agenda (science, engineering and technology) in which mathematics was largely invisible, to a STEM agenda (science, technology, engineering and mathematics) in which mathematics was acknowledged as playing an important part. Some reports specifically focussed on mathematics, with *Making Mathematics Count* (2004) and the *Review of Teaching in Early Years Settings and Primary Education* (2008) being pivotal. The latter's main recommendation called for a major policy change—that there should be a trained specialist in mathematics in every primary school, a recommendation that was accepted and led to agreement about a program of training to be delivered by consortia of universities. However, later financial constraints caused this program to be tapered, with funding being shifted away from Government to schools over a period of 3 years.

Making Mathematics Count (2004), which will be abbreviated to "MMC," was particularly significant not least because it received almost universal support from all the diverse stakeholders that comprise the mathematics community, including researchers in mathematics education and mathematicians. The government of the time accepted most of the recommendations of the report, possibly because the Secretary of State was a strong supporter of mathematics and, as a result of his university background in mathematics, appreciated that mathematics was much more than arithmetic and procedural technique. This placed the mathematics community in a strong position, at least in the short term.

The MMC report underlined the need for a strategy and strong focus for mathematics. Its recommendations included issues around stimulating the supply of specialist mathematics teachers, the designation of different mathematics pathways for the 14–19-year-old age range depending on career aspirations, and support for teaching and learning. At the time, there was also considerable concern about the numbers who were opting for specialist study in advanced mathematics (A-level), following a dramatic drop in student numbers in 2001. This decline was largely due to a new policy leading to an overarching shift in curriculum structure at A-level, which had a particularly negative effect on mathematics results. The change was bought in too quickly with students examined too soon after they had met new mathematical ideas. Many students failed the new modules leading to a general loss in confidence among students and teachers alike, and a move away from taking what was perceived as a high-risk subject. Numbers entering A-level fell from over 70,000 to just over 50,000 in a matter of years. A government target of 56,000 A-level entries in 2014 was set in 2006, a target that was judged to be quite ambitious at the time, but was in fact reached well before that date (see Figure 16.3).

One recommendation of MMC was that a post of Chief Adviser for Mathematics to the UK Government should be established to provide Ministers with direct advice on the needs and requirements of the subject. This was not a political appointment but rather involved advising the Secretary of State and relevant ministers (and their civil servants) about mathematics across all phases, performance, participation and the curriculum, drawing on all available evidence—thus providing reports verbal and written that served to mediate results and "research wisdom." The first author of this chapter was selected to take up this position in 2004 and served (part-time) until 2007 when her secondment ended. At this point, the post was discontinued, mainly as a result of a shift in policy context to STEM with a new Secretary of State in charge, combined with the fact that the overall situation in mathematics had improved quite dramatically, and that ACME had been established as a voice for policy.

Another recommendation in MMC was that there should be a better alignment of the standards agenda with the mathematics curriculum and teaching agenda. This was to be achieved by merging the existing standards team, that is the National Mathematics Strategy for the Lower Secondary School and its funding, into a new national infrastructure, the National Centre (see below), with serious consideration to be given to similarly incorporating the national numeracy strategy for primary schools, into the proposed Centre. As already mentioned, these National Strategies had substantial budgets and huge political influence within the standards agenda, and this recommendation proposed quite a radical policy shift. However, it was not accepted. The two structures, one around teaching and learning mathematics generally, and the other around mathematics as part of the standards agenda, remained distinct, and with distinct roles for the Strategies and for the Chief Adviser for Mathematics. Nevertheless, during the period 2004–2007 the two structures became better aligned due to efforts from both communities.

Another focus of the MMC was on the potential role for university mathematics departments in providing enrichment in and out of school as part of the policy drive for more mathematics. This enrichment might involve organizing national competitions, mathematics clubs, and master classes, and included the promotion of mathematics careers. In addition, at the time of the report, it was also becoming evident that Further Mathematics (an optional course of post-16 mathematics that is more advanced than A-level mathematics) was a "dying subject" as fewer and fewer schools had the capacity to offer it. There were two main reasons for this: (a) many schools did not have the specialist staff needed; and (b) schools could not afford to teach the small groups who selected it. A pilot initiative to address this challenge was supported for role-out by the Government, and this was to set up a Further Mathematics (FM) Network (http://www.fmnetwork.org.uk/), a national network of FM Centres to enable every student who would benefit from it to have the opportunity to study for Further Mathematics qualifications through distance learning and mentoring. Forty-six FM Centres came into operation across England.

Along with these larger developments, a variety of smaller initiatives were also put in place, all to promote mathematics. We only mention a couple that appeared to have widespread support in the mathematics community and relevance to the thrust of this case study: a range of extra-curricular activities for gifted and talented students which provided links to universities and to employment; a national program of one-on-one tutoring for students of all ages who were falling behind in mathematics, with a particularly well-funded program, for children under 5 years, called Every Childs Counts (see http://www.everychildachancetrust.org/counts/).

Thus, during this period, expert practitioners, mathematicians, and mathematics education researchers were able to influence policy direction together and were able to communicate across the boundary of policy/practice largely through government-sponsored boards set up to work with the Chief Adviser, specifically to take forward the recommendations of the MMC. As part of this endeavour, the importance of effective teaching of mathematics in England was not only recognized, but also what this actually meant in practice was widely agreed. In addition, the country had long suffered (and still does) from an overall shortage of mathematics teachers, limited specialist capacity among mathematics teachers at every level, constant turnover, and difficulties of retention. There was therefore a manifest and distinct need for an agenda for professional development of teachers of mathematics throughout their careers, so not only could expertise be bought into the profession through changes in entry standards, but also through promoting professional learning for those already teaching. And, because of structures that had been established to align the goals and policies of government with the knowledge and expertise of the mathematics and mathematics education communities, it was possible to move forward and agree to a new agenda of professional development to support effective teaching in the subject.

In England, professional development for teachers of mathematics had existed but had tended to be rather ad hoc and geographically patchy. It was decided at a policy level that what was needed was an infrastructure that monitored and coordinated the provision nationwide. This was a recommendation of the MMC and which led to the establishment of the National Centre for Excellence in the Teaching of Mathematics (NCETM).

The National Centre for Excellence in the Teaching of Mathematics (NCETM)

The NCETM was set up in 2006 by the UK government and continues to the time of writing (November 2011). The Centre has a clear and ambitious vision. It aims to meet the professional aspirations and needs of all teachers of mathematics so that they can realize the potential of learners. It is a constant struggle to encourage teachers to see professional learning, not as a threat or a punishment for not doing well or being in some way deficient according to a standards agenda, but as something that is geared to their needs, and inspiring.

To this end, the NCETM's objectives were formulated as follows:

- To stimulate demand for mathematics-specific continuing professional development (CPD), contributing to the strengthening of the mathematical knowledge of teachers;
- To lead and improve the coordination, accessibility and availability of mathematics-specific CPD;
- To enable all teachers of mathematics to identify and access high quality CPD that will best meet their needs and aspirations.

The NCETM set out to meet these aims through a sustainable national infrastructure for mathematics-specific CPD that starts from the needs and goals of teachers. As such, it provided a counterbalance to the top-down constraints of the much more politically powerful standards agenda, which monitored student performance in the country. It is possible that these concurrent initiatives, as they gradually became more aligned, had a surprisingly positive and synergistic impact.

The NCETM provides and supports a wide variety of mathematics education networks in the country, which include universities, subject associations and the whole range of CPD providers. At the same time, the National Centre encourages schools and colleges to learn from their own best practice through collaboration among staff and by sharing good practice locally, regionally and nationally. These collaborations take place face-to-face at national and regional events and in local

Figure 16.1. Overall structure of the framework that underpins the NCETM portal.

network meetings across England, or virtually, through interactions on the NCETM portal, http://www.ncetm.org.uk.

Figure 16.1 shows the overall structure of the professional learning framework that underpins the portal, and Figure 16.2 provides a snapshot of the portal's homepage. Any portal has to be regularly updated and improved to introduce new functionality, including Web 2.0, new design, and improved tools so as to meet the needs of teachers. The portal is concerned to help teachers meet virtually in professional communities to discuss issues facing them (e.g., how to ask open questions in mathematics, how to design good formative assessments). It also implements "behind-the-scenes" speed increases and improved search facilities. The aim has been to make the portal experience user-friendly and above all useful. The statistics for NCETM portal continue on an upward trend with over 85,000 regular users in July 2012. Another statistic of interest is that, at that time, only eight countries had not visited the NCETM portal—French Guiana, Western Sahara, Mauritania, Chad, Congo Brazzaville, Guinea, North Korea and Turkmenistan.

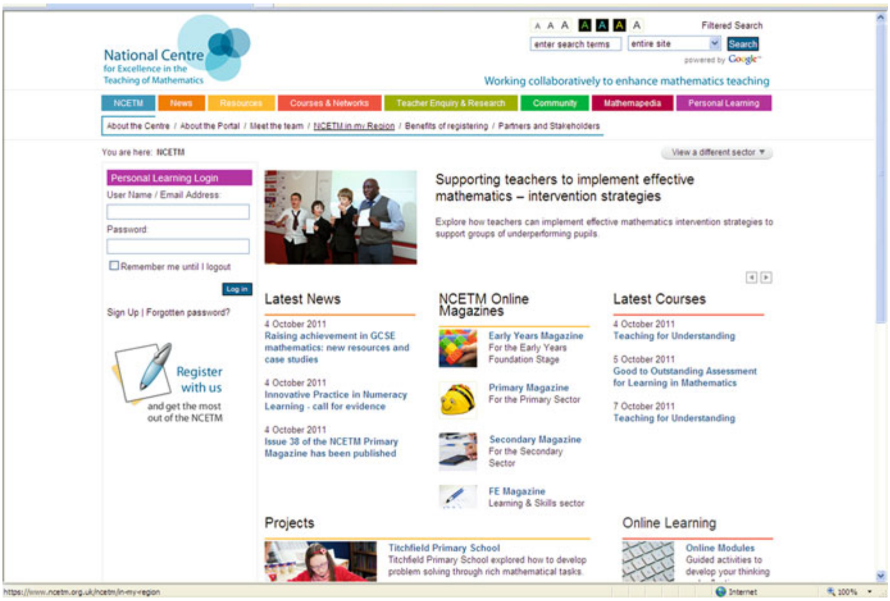

Figure 16.2. A snapshot of NCETM's portal homepage.

Framework that Underpins the Portal

The NCETM signposts high quality resources usually organized into microsites that support the professional development of teachers. Microsites include departmental workshops that help secondary school teachers examine together a range of mathematical topics that "are hard to teach," and sector-based magazines that offer monthly articles that are stimulating and timely. The site also points to useful CPD opportunities and courses offered by a range of providers in a constantly updated Professional Development Directory, which also identifies providers that hold a quality standard for CPD that is regularly monitored. There is also the NCETM *Mathemapedia,* a wiki designed by and for mathematics education. This acts as a vehicle for improving teachers' awareness of research issues in teaching mathematics, of sharing ideas, as well as providing easy access to a range of references and interesting ideas, both theoretical and practical. The range of topics—written by NCETM portal users and moderated by the NCETM—is huge. Almost 400 articles exist, accessed over 30,000 times per month.

A later innovation, the result of teachers' requests, was to find ways to support teachers in accessing research by supporting the production of Research Study Modules (https://www.ncetm.org.uk/enquiry/35990). Each study module is based on a particular, carefully chosen, and annotated research paper which was written by a collaborative group of researchers and teachers to present a structure that would support teachers more generally to think about the ideas and findings reported, reflect on their own views and practice, and consider the implications for their own practice. The starting point for the production of each module is to present questions raised by teachers when reading the papers and to support and frame their interpretations.

A complementary approach has been used by the Institute of Effective Education, which produces research articles across different areas on "what works"—in a journal named *Better: Evidence-Based Education.* These articles are concise and written for a teacher and policy audience. However, at the time of writing only one such journal has been produced for mathematics in England and that was in 2009 (Hoyles, 2009).

A Web presence for CPD is a relatively new development—at least when the NCETM began in 2006—and one that needs to be the object of research and development in its own right as new functionalities become available. The NCETM portal is not simply a provider of online learning activities, but also provides a record of a personal learning journey. Once logged in, teachers can access their own personal learning space, in which they can store a snapshot of their own CPD experiences and reflections. Research suggests that self-evaluation is a powerful and productive way to catalyze professional development. This self-evaluation can be undertaken in the privacy of home, or as part of a professional development group in a school—anywhere, in fact, where there is time to think and reflect on what a piece of mathematics might mean, how it might be represented, or how it might be taught and assessed in new ways. The NCETM has developed self-evaluation tools (SETs) in each of the following areas: Mathematics Content Knowledge, Mathematics-specific Pedagogy, and Embedding in Practice. There are many hundreds of pages of self-evaluation steps structured in age-related phases based in the English National Curriculum. If teachers record limited confidence in any area, they are sign-posted to possible activities, on and off the portal, with which they might wish to engage to help them make progress.

One policy implication is clear and is not widely recognized by policy makers, and that is that professional development is not only about courses. Teachers can and do, with appropriate tools, learn from each other and from research about effective mathematics pedagogy and practice. The policy environment for mathematics education has made it possible in England to implement such new tools and approaches. The challenge remains for mathematics education researchers to develop the research methodologies and evidence to help improve this teacher learning system and ensure its continued growth on the basis of what elements are most effective.

The NCETM has attempted to take forward into practice research that has indicated that involving teachers in collaborative reflection and enquiry pays dividends in producing real results in the classroom, and thus is an evidence-based initiative ripe for the policy arena. Four international reviews of evaluations of CPD over a 10-year period have consistently shown that the CPD that makes a difference is: collaborative and sustained, draws on evidence from research and practice, and involves participants in experimenting with new approaches and observing effects (for a review of this research see EPPI systematic reviews of evidence about CPD: http://eppi.ioe.ac.uk and Best Evidence Synthesis *BES; Teacher Professional Learning and Development; http://www.educationcounts.govt.nz/publications). Almost all of the research reported in both reviews is generic and not subject-specific, although mathematics was not excluded. Another obvious instance of this type of teacher enquiry is Japanese lesson study methodology, which has been undertaken in mathematics classrooms and shown to be effective (Krainer, 2011).

To attempt to take this teacher enquiry agenda forward, the Centre has provided a range of opportunities and frameworks through its NCETM Funded Projects Scheme. Over 300 projects have been funded and their reports can be accessed at http://www.ncetm.org.uk/enquiry/funded-projects/view-all). The Funded Projects Scheme provides resources to scaffold the research teachers may wish to carry out in collaborative groups within or across schools and colleges. Teachers bid for funds to pursue an enquiry and are provided with useful research "starting points" and references to try to promote building on previous work in the research community. The teachers have to write a report on their work and reports and findings of the projects are posted on the portal and disseminated at NCETM events. Thus, learning is shared, and the impact maximized. Teacher groups are expected to present the results of their work and are supported in doing this (if they wish). Most, if not all, find the experience of the research and the communication to others valuable. The projects usually include a member who is an "outside catalyst" or mentor—for example a researcher from a university—who supports the team of teachers, brings a broader perspective to the work, and helps the teacher group to plan the enquiry and summarize the findings in project reports. The NCETM also produces highlights from several projects describing their impact on teachers and learners for wider dissemination in annual Teacher Enquiry Bulletins, which are widely read by teachers and researchers alike. Further reading, and the full reports and bulletins, can be found on the portal under Teacher Enquiry (http://www.ncetm.org.uk/enquiry).

The 300 or so reports from the funded projects are a tribute to the diversity of the endeavour, although many topics were in fact revisited by different groups—inevitably as selections were shaped by the policy landscape. Topics have included, for example, how to support rich mathematical questions in the classroom (that is, more open-ended investigative work); using digital tools for sharing practice or to support mathematical learning; how children's play can enrich early mathematical experience; assessment for learning; and the impact on teaching and learning of collaborative planning and review.

Independent evaluation studies of the Centre contribute to the evidence base outlining the importance of developing and supporting the practice of guided teacher enquiry. One study, in particular, documented the impact of the NCETM-funded networks on teachers, on their knowledge and practice, on their schools/colleges, and on their colleagues, pupils and students (Gouseti, Noss, Potter, & Selwyn, 2011). Another study noted that the success of the Centre stemmed from its local focus, its collaborative nature and the fact that it was driven by evidence (Sheffield Hallam University, 2010).

The findings of these evaluation studies have broad significance for policy. First the authors noted the distinct "added-value" of an external independent organization supporting the activities that take place in individual schools and colleges. The modest amounts of funding provided by NCETM could have been provided using internal school funds. However, the researchers found clear benefits of having an external organization providing the funding as a lever on school and district management and to confer status on the teachers' work. Thus, funds and the recognition and validation of the process and outcomes through conferences, accreditation and award schemes together proved a powerful incentive for professional learning. The importance of the role of the "leading" and "coordinating" teachers was recognized as fundamental to the success of the networks and projects. This pointed to the need for a policy strategy to develop the organizational and inter-personal skills-sets required to guide groups of teachers successfully. Mentoring a group of teachers in research requires specialized skills over and above those needed in teaching, as does supporting teachers to report to audiences beyond immediate colleagues. There is also the constant challenge in the research community as well as in teacher research to work out how to ensure findings are, to some extent at least, cumulative. It is clear that making research reports more accessible through careful tagging and easy availability is helpful, but although this might be necessary, it is in no way sufficient.

Several other countries have either set up or are in the process of setting up similar national centres, the most recent being in the Federal Republic of Germany, where a national centre for mathematics teacher education has been established, funded by Deutsche Telekom Foundation. An important research effort for the international mathematics education community might be to assess the impact of these centres and identify factors underpinning any successes that transcend national boundaries. Each country has different goals, strategies, funding regimes and expected outcomes but if meta-analysis pulls out overarching research findings that document the successes and challenge, they would have powerful implications for policy.

The question remains: what type of evidence is needed to convince policy makers about needed resources or infrastructure in any one country, and can research form part of this evidence and, if it can, what form should it take and how can the findings be mediated so as to be meaningful for policy makers? In England, the picture of participation in mathematics shows quite dramatic improvement. Figures 16.3 and 16.4 display the number of entries in A-level and Further Mathematics A-level over a number of years. They show the significant downturn in 2000 and 2003 mentioned earlier and the continuous and significant upward trend since 2003 in the number of entries and the proportion of the cohort opting for mathematics. But which of the many initiatives were crucially important in this upturn? Or, was it a matter of a cumulative effect? Those are important questions, worthy of investigation by future research.

Policy development processes are often "top down," coming from levels of government for implementation at the school and classroom levels. Yet, the two examples provided above—the professional society and state-led standards movements in the USA, and the collaborative community-led CPD structure in England—provide

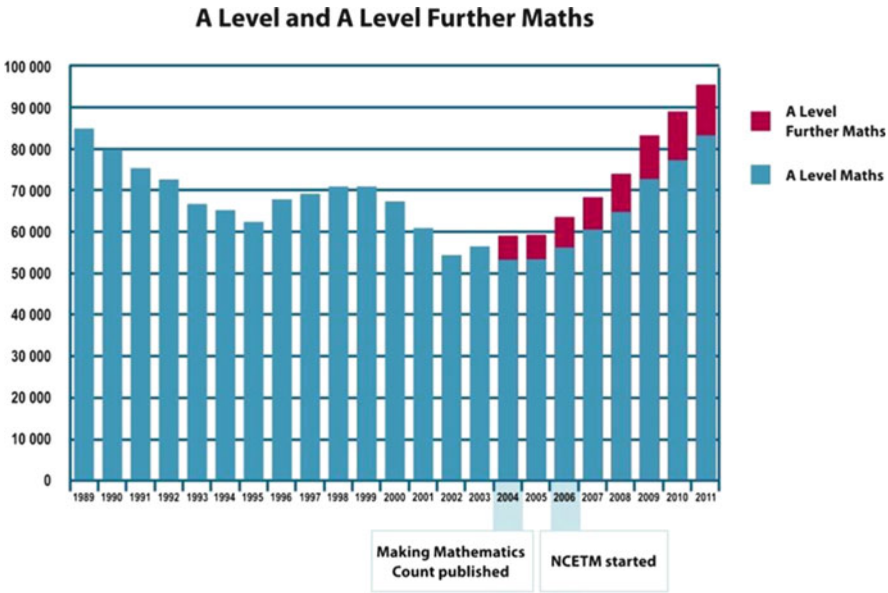

Figure 16.3. Number of entries in A-level and Further Mathematics A-level (in England).

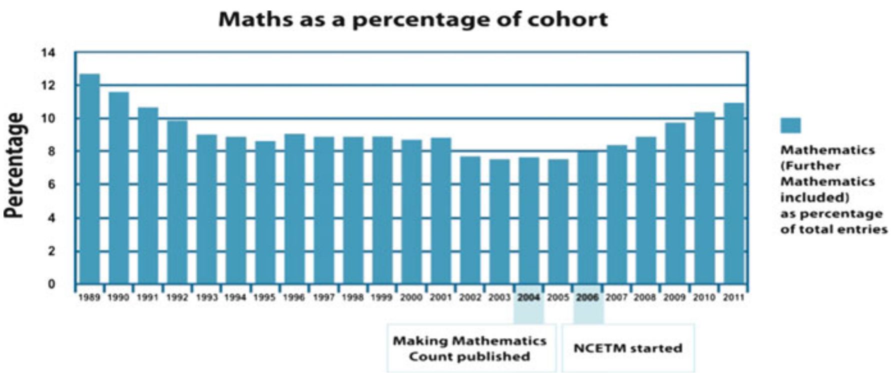

Figure 16.4. Proportion of the cohort opting for mathematics.

evidence that significant policy change can occur from a bottom-up perspective. Jacobsen (2009) discussed how the "voices of the people" are essential in development of policy. In both the US and UK examples the development of the policy has had varying levels of engagement of stakeholders and key constituencies. In contrast to these highly collaborative and inclusive processes, we offer two abbreviated examples where the approaches to policy reform have especially interesting, and different, characteristics.

Curriculum Reform in Portugal and Educational Reform in Mexico

In a fascinating account of reform in mathematics education in Portugal, Abrantes (2001) provided a description of a process of educational reform driven by a national debate about curriculum, in which schools were invited to participate. The "ultimate goal of the movement was to support the gradual creation of a new curricular organization based on a more autonomous and responsible role of the teachers and their collective structures in school" (p. 127). Given the flexibility to propose their own curricular programs, schools and teachers collaborated and formed networks over a period of years, and the activity culminated in legislation in 2001 relaxing the previously prescriptive government directions about curriculum and content, and leaving great flexibility to schools.

In contrast, the Organisation for Economic Co-operation and Development (OECD) (2011) has described an interesting partnership between the country of Mexico and OECD, an instance of an apparent trend for countries to seek collaboration from international resources to improve their educational activity. The report noted: "International organizations such as the OECD are increasingly being asked by member countries and partners to provide an analysis of state-of-the-art education policies and reform processes" (p. 30). The Mexico-OECD partnership focussed on the evaluation of schools and teachers, with efforts to draw on OECD resources, considering local issues, in developing a continual improvement strategy. The OECD team reported drawing on material in international comparative studies, on international best practices, on results of research that focussed on the specific topics of interest, and on a variety of country-based areas.

This "customized" approach to policy reform, bringing together local policy makers with teams that can bring additional research and policy evidence to the discussion, is similar to the model used in the US-based Strategic Education Research Partnership (SERP), originally grounded in work of the National Academies (2003). SERP's mission is "to conduct a program of "use-inspired" research and development, with a goal of developing, testing, and mobilizing effective programs and practices" (see http://www.serpinstitute.org/about/overview.php). The SERP partnerships involve local leaders and policy makers in school districts along with researchers concerned with the challenges faced by individual districts. Such models may offer a promising approach for more productive and influential connections between mathematics education policy needs and researchers.

Influences in the Policy Process: Considerations for Mathematics Education Researchers

How can members of the mathematics education research community internationally play a more influential role in the shaping of policy that affects mathematics education? Using the examples presented above, we will discuss some of the considerations that might be relevant as researchers become interested in undertaking studies that can intersect more directly with the world of policy formulation and implementation.

Stakeholders in the Policy Process

For mathematics education researchers contemplating how their work might be more influential in policymaking and implementation, an important context is awareness of the points of interaction by various stakeholders in the policy development and implementation process. As the previous examples illustrate, a clear understanding of the national policy context is essential in framing research agendas that will be most likely to inform future directions. Part of that context involves understanding the "intermediaries." We expand on Osborne (2011), who noted that "individuals who act as intermediaries between researchers, on the one hand, and policy makers and teachers of science on the other" (p. 27) can be important in the ways in which research might influence policy. Osborne included developers of instructional materials, local education leaders, teacher educators, and other science educators in this list. We note that in the UK, ACME serves this role. Peterson (2011) additionally suggested that advocates and lobbyists (some of whom come from professional societies) are also key intermediaries. In addition, in many countries the most important influences on policy are central ministries and departments of education.

Other entities outside of university academe have key roles—"think tank" organizations such as the RAND Corporation, the International Association for the Evaluation of Educational Achievement (IEA), and OECD provide substantial research and analysis for policy makers, and are especially skilled at the formats of policy briefs that can appeal to policy makers who are attempting to become informed quickly about a range of issues. Fowler (2004, cited in DeBoer, 2011, pp. 3–4) highlighted the importance of "issue definition," something often accomplished by intermediary groups.

In ongoing work funded by the William T. Grant Foundation, Tseng (2010) pointed out that Daly and Finnigan are studying the role of intermediary organizations in bringing research directly to policymakers. Interestingly the authors have found that grantees report that relationships have been more influential than written materials for making policymakers and practitioners aware of the results and implications of research. It seems that many policymakers and practitioners prefer to seek out information from trusted but knowledgeable personnel who are aware of comparable situations.

Prestigious national academies and high-level government panels provide authoritative reports aimed at policy makers, and international groups that engage in assessments and international comparative studies figure prominently in the directions of policy in many countries (DeBoer, 2011). Advocacy groups, professional organizations, and other interest groups also strive to be influential with policy makers.

In the USA, professional societies help to provide this function; Mexico is working with an international intermediary, OECD. And, as we have seen in the UK examples, and in Portugal, citizens and teachers can greatly influence policy makers by assembling evidence and examining key questions emerging from policies. Relationships and personal contact with those who have access to policymakers are important; indeed, in the research of Finnigan, Daly, and Che (2012) and Palinkas et al. (2011), the ways in which such relationships work in shaping policy, using social networking and other approaches, has been a subject of study. Thus, for research to inform policy, it is important that the research be useful to these "intermediaries." Using the two cases presented earlier, we explore how this happened, or could have happened in the two examples.

In the case of the US standards movement, the policy makers who in the end will either ensure successful implementation or not of the Common Core State Standards Initiative will be state leaders—governors, state boards of education, and legislative bodies—as well as local district officials, including superintendents, principals, and curriculum coordinators. Indeed, the development team was something of a microcosm of the appropriate intermediary groups. The team was headed by a mathematician with a history of working collaboratively with mathematicians and mathematics educators at both K–12 and with the undergraduate curriculum at the national level. Throughout the process there was substantial engagement of mathematicians, along with teachers and mathematics educators. This process is relatively well aligned with development processes used in the NCTM *Standards* activities, so it remains to be seen whether or not these efforts will have a role in translating to effective implementation at the state and local level—this would be an important subject of research that would require collaboration between policy makers and mathematics education experts.

In the UK, for the CPD infrastructure to be sustained, the Government and Ministers will need to be convinced of its utility, not only in terms of building a professional teacher community but also ultimately in relation to its impact on pupil learning, and the standards agenda. In this case, the "indirect" approach of engaging teachers in undertaking action research to examine the questions of interest to them in their classrooms, or even questions shaped by the policy context, is ambitious. It aims to build a network of evidence that is drawn from use-inspired research. But will the data prove convincing in the face of new political priorities? Its potential for informing future policy is as yet untested. A new contract was awarded by the Government for the NCETM to continue until 2015.

Meeting Policy Makers' Needs

There is considerable literature available indicating that if researchers better understood both the needs of policy makers and the characteristics of research and evidence that render it useful to policy makers, then their research efforts might have more impact. What mathematics education researchers might count as research and evidence are indeed only components of the various types of evidence that policy makers will use. According to Honig and Coburn (2008), school district staff were prepared to take into account evidence from social science research, from student achievement data, from practitioners, and from expert testimony, including parent and community input. In related work, Nelson, Leffler, and Hansen (2009) found that policymakers tended not to use research evidence as a primary source of guidance. They reported:

> The study revealed a surprising absence of interest by policymakers and practitioners in using research evidence. In fact, focus group members and interviewees exhibited a high degree of skepticism about the value of research. And, they did not draw a distinction between evidence based on empirical findings and "research findings" derived from the media, popular professional journals, the experiences of others, gut instinct, and their personal experience. In looking at both the research literature and the study findings, we found five common types of evidence used to inform educational policy and practice: research evidence, local data, public opinion, practice wisdom, and political perspectives. (pp. 50–51)

There are a number of factors under the control of researchers that might help ensure more visibility and usability of their work. Several authors call for framing the issue in a broader policy context (Smith & Smith, 2009; Gates & Vistro-Yu, 2003). For the UK situation, this might mean reconsidering both theoretically and practically the relationship of work in CPD to the broader standards requirements. Others call for attempting to describe causal links (Smith & Smith, 2009); in the US standards efforts, this would mean finding ways to relate student achievement to implementation of standards. Still others call for including stories to ground the claims (Smith & Smith, 2009). The evidence from this chapter suggests that both systematic evidence along with rich and interpretative narrative are needed. McDonnell (2009), suggested that researchers develop more sophisticated survey research techniques in order to address the needs of policy makers. That approach might be especially useful in mathematics, where there is a need to develop a stronger grasp of public attitudes to the importance of mathematics, including its influence on employment opportunities.

Policymakers are often forced into the situation of creating policy despite the fact that the evidence, one way or another, is inconclusive. They need tools to justify their proposed policies to other decision makers (legislators, or school board members, for example) who may not have deep familiarity with the issues. Within the educational research literature there is guidance about the needs of policymakers. For instance, Beaton and Robitaille (1999, p. 30, cited in Clarke, 2003), observed: "Educational policymakers around the world recognize the need for more and better information about the effectiveness of schools." Clarke (2003) speculated that this was a reason for the great interest of school policymakers internationally in international comparative studies such as TIMSS and PISA. In the USA, legislators have sometimes conveyed interest in identifying factors which positively influence practice. In a recent example, the US Congress requested that the National Science Foundation commission a study that would examine the characteristics of US K–12 schools that are especially effective in the areas of science, technology, engineering, and mathematics (STEM). The resulting report, *Successful STEM education: Identifying effective approaches in science, technology, engineering, and mathematics*

(National Research Council, 2011), was aimed at policy makers at the local level, and represented a synthesis of available research about effective practices (see http://www.stemreports.com/wp-content/uploads/2011/06/NRC_STEM_2.pdf). This is a current example of an intermediary entity responding to a direct request from a government policymaking body.

Tseng et al. (2008), in writing about the various ways in which policymakers use research, drew attention to the following five categories (p. 13):

1. *Instrumental* use occurs when research evidence is directly applied to decision-making.
2. *Conceptual* use refers to situations in which research evidence influences or enlightens how policymakers and practitioners think about issues, problems, or potential solutions.
3. *Tactical* use, also called political and symbolic use, occurs when research evidence is used to justify particular positions such as supporting a piece of legislation or challenging a reform effort.
4. *Imposed* use refers to situations in which there are mandates to use research evidence, as when government funding requires that practitioners adopt programs backed by research evidence.
5. *Process* use differs from the preceding terms; it does not refer to how research evidence is used but rather to what practitioners learn when they participate in conducting research.

In the case of the development of the US Common Core Curriculum Initiative, it seems that there is evidence of both conceptual use (e.g., the development of the standards using knowledge gained from research investments in learning progressions) and tactical use (e.g., the components of the validation activity calling on experts to validate whether the research cited for inclusion of particular standards was adequate). In the UK example, concerning the policy initiatives generally, and the CPD and NCETM examples, in particular, it seems that instrumental, conceptual, and process uses are all in play.

Concluding Discussion

In order for mathematics education research to be more likely to influence policy, scholars may need to consider several notions. First, deriving research questions from larger contextual circumstances that transcend mathematics education could be more important than presenting results that are directly attractive to teachers and to the mathematics education research community. As Smith and Smith (2009) noted:

> Studies designed to provide information about how to teach a specific, important concept in elementary mathematics will not be useful to policy makers in federal and state governments or even in most district offices, though they may be useful to teachers, principals, and publishers. (p. 376).

Second, the methodological preferences that are often used in mathematics education in order to address the questions of interest to researchers are dominated by descriptive work, design studies, teaching experiments, and implementation studies, which do not provide direct evidence about the potential effectiveness of innovations at scale. That limits the potential for the studies to influence policy, unless they are interpreted and seen to be valid by powerful intermediaries.

US government agencies, through policies about K–12 educational change as well as research funding policies, have placed greater emphasis on assembling research results of large-scale interventions than of small-scale studies as a source of policy guidance. Both the What Works Clearinghouse and US National Math Advisory Panel examples provide indications about what might be needed: is the methodological bar the "right one," and then what are the directions for mathematics education research that will meet the evidence standards that are put in place for influencing policy makers?

Third, it must be recognized that the particular educational challenges that a particular country is facing are essential context for framing the more specific mathematics education research questions for which an accumulation of research might well guide policy. For instance, Gates and Vistro-Yu (2003) observed that in developing countries, transforming the mathematics education system from one that was modeled originally on a system to "serve the European elite" to a system that offers universal access to mathematics education, is a key challenge faced by policy makers. Addressing both ambitious mathematics and equity is a crucial challenge in the USA. It relates closely to the global mathematics education policy challenge of how to formulate mathematics education to meet the needs of all subcultures in a society and to build on the mathematical assets inherent in those subcultures.

Finally, most Governments acknowledge the need to prepare the next generation for a world that is very different from ours. That world will innovate in mathematics teaching and learning specifically around the use of digital technology. Education in general and mathematics education in particular has been slow to grasp and exploit the findings of technology-related research into teaching and learning. This area is ripe for innovation and research with promising avenues to pursue emerging in the international scene (see, e.g., Hoyles & Lagrange, 2009).

In a world facing global challenges of unprecedented seriousness, the importance of scientific and mathematical literacy and expertise has never been more central. Around the world, nations have recognized that the mathematical education of their young people is critical to personal, societal, and economic well-being. The policies that govern education, and mathematics education in particular, have enormous relevance and implications for the effectiveness of the mathematical education of our students. Research in mathematics education stands to contribute to the shaping, implementation, analysis, and revision of these policies, and is doing so in many cases. Through strong collaborations among researchers, practitioners, and policy makers, it is possible to achieve convergence and synergy so that policies, research, and practice can address similar problems in mutually synergistic ways. The international mathematics education community has collective experience and is beginning to accumulate policy-relevant research, and the opportunities to do so more systematically and to achieve more impact in the future should be a focus in the years to come.

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