

Understanding the European policy landscape and its impact on change in mathematics and science pedagogies

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Abstract Effecting an increase in the use of inquiry-based learning pedagogies in mathematics and science at a large scale across Europe has been promoted within the European education policy space. The primary goal is greater numbers of young people having more positive dispositions towards future careers in science, engineering and technology (Rocard in EUR22845—science education now: a renewed pedagogy for the future of Europe, <http://www.eesc.europa.eu/resources/docs/rapportrocardfinal.pdf>, 2007). We report on policy research as part of a European funded project that aims to support professional development that might bring about such changes. Our analysis points to policy activity that, to a greater or lesser degree, appears to be ineffective in meeting the desired outcomes in respect of teacher change. We identify why, although there is much policy activity, initiatives struggle to make an impact on teaching practices and learners' experiences. Overall we point to misalignment in what policy defines in terms of input to learning, what is measured and valued in terms of outcomes, and what is desired in the teaching process. We also point to how policy fails to support development of the individual teacher and the teaching profession as a whole in ways that might effect the desired change.

Keywords Policy · Inquiry · Pedagogy · Professional development · Assessment

1 Introduction: European policy imperatives

Mathematics education is increasingly at the centre of political debate, not only in education but also in pursuit of future economic activity across other sectors relating to employment, business and the economy. This paper seeks to draw on policy research within the EU funded project Promoting Inquiry in Mathematics and Science Education Across Europe (PRIMAS)¹ to develop understanding of the European policy landscape in relation to education and the impact this has on mathematics and science pedagogies. Analysis leads to recommendations to policy makers about how they might better direct energies in this complex field.

The project PRIMAS seeks to promote pedagogies that support inquiry-based learning (IBL) in mathematics and science throughout compulsory schooling. This in itself is evidence of the European Union's attempts to influence the globalisation of education policy (European Union 2006). From a sociological perspective, education has a particularly important role to play as nations respond to emergent trends across the world in economic, political, cultural and social aspects of life (Ball 2008). In recent years, even prior to economic crisis, increasingly global market-orientated thinking focused on the idea of the 'knowledge economy' (European Union 2000). This has provided leverage in developing policies that seek to position the old industrial nations advantageously as sources of know-how, expertise and creativity. Meanwhile, emerging nations find themselves conveniently positioned to provide cheaper labour to fuel manufacturing requirements globally. Consequently in

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¹ PRIMAS is an international project in which 14 universities from 12 different countries participate. The project has received funding from the European Union Seventh Framework Programme (FP7/2007–2013) under Grant Agreement No. 244380.

the European Union much policy activity has been predicated on the assumption that constituent nations need to be at the forefront of innovation in science, technology, engineering and mathematics (STEM) (European Commission 2004). Such intentions are driven by analysis of current and predicted future global economic forces. They signal our politicians' intentions towards sustaining and developing European economies through the activities of its workforce. This leads to calls for our citizens and workers to be better educated than currently in STEM subjects. European education policy is further informed by evidence that young people, in general, are not favourably disposed to study mathematics and science (Rocard 2007). In light of this, the argument is further developed suggesting that our schools need to provide IBL as this will provide greater motivation for young people to engage in productive study of, and future work in, STEM (ibid. 2007). In this regard IBL is seen as placing student thinking and learning more centrally within socially connected classrooms, and thus appealing more widely to young people than the more transmissive teaching practices that currently dominate. Through funding of a range of initiatives at all levels of education, therefore, the European Union has provided the catalyst for a globalising movement that intends to stimulate substantive change in pedagogic practices in its pursuit of a pan-European STEM-based knowledge economy.

Important in setting this policy agenda at a European level, with its focus on teaching and learning in schools, have been the Maastricht Treaty of 1992 and the Lisbon Agenda of 2000. These have ensured that education has a central role in informing European policy direction more widely. In pursuit of this the Lisbon Treaty sought to highlight the 'knowledge triangle'—research, education and innovation—as a core factor in European efforts to meet the ambitious Lisbon goals.

[the] Community shall contribute to the development of quality education by encouraging co-operation between Member States and, if necessary, by supporting and supplementing their action, while fully respecting the responsibility of the Member States for the content of teaching and the organisation of education systems and their cultural and linguistic diversity. (Maastricht Treaty 1992, p. 28)

In a first phase of its planned work in the policy arena PRIMAS, led by the lead author of this article, has considered how systems, structures and, most importantly, people (teachers, educators, policy makers) react differently to 'global' policy imperatives because of 'local' contexts resulting in what Robertson (1995) has termed 'glocalisation'. In this phase of work PRIMAS asked how emergent globalising intentions interact with national

contexts to result in localised outcomes. It is our intention here to give some insight into our findings and to discuss their implications in terms of how policy at a European level might better achieve its aims in respect of developing new classroom practices.

2 Underpinning theoretical constructs

In discussion of policy in a European context Dale (2009) draws our attention to two important terms: *European Education Space* and *European Education Policy* and is careful to explain the differences between them. Our work, as reported here, is intimately bound within the European Education Space, but it may be helpful in informing future iterations of European Education Policy. Fundamental to drawing this distinction is an understanding of the limitations to how European collaboration and policy direction might impact upon national educational systems, and the constraints under which it works. As Dale points out, European Education Policy must be conceptualised as very different to the education policy frames with which we are more familiar in our own national² contexts. European policy in education does not operate in parallel to national policy but in a very different and European context: there is no parallel to national ministries with their range of services and offices of bureaucratic and professional support. Rather more broadly it aims at:

1. developing the European dimension in education;
2. encouraging the mobility of students and teachers;
3. promoting co-operation between educational establishments;
4. supporting exchange of information and experiences;
5. encouraging the development of distance education.

(European Union 2004, Article 149.2 quoted in Dale 2009)

The work of projects such as PRIMAS clearly contribute to such aims through the networks of educators that they build and through the collaboration they foster across national boundaries. The totality of all the different initiatives that the European Union stimulates and financially supports provides a *policy space*. This in turn results, implicitly if not always explicitly, in exploration of how the objectives set out within the Rocard Report (2007) are being met, and helps mould future iterations of European Education Policy. In this way the work of projects such as

² Throughout the paper 'national' is used, although it should be recognised that in the case of federal states (such as Germany, Spain, Switzerland) the evidence which is drawn upon here pertains to only one discrete region (Baden-Wuerttemberg, Andalusia, Geneva) and may only be indicative of the nation as a whole. 'National' therefore might be read as national or regional throughout.

PRIMAS can be conceptualised as informing future policy direction. The role of such projects in this space is to provide important grounded data that can ensure that alternative perspectives are provided, complementing other influential stimuli such as the PISA comparative studies and reports such as that of Rocard (2007). It is the European Policy Space that provides the essential feedback loop, informing subsequent iterations of European policy on realities of the education systems of member states.

Underpinning our survey of policy intentions is a socio-cultural historical perspective of the development of education, in particular at the grain size of the school and classroom, with students, teachers, curriculum managers and others as key actors and stakeholders within activity systems. As Elmore (2011) points out, it is in this ‘zone of instruction’ that any planned change stands or falls. Without making a complete cultural-historical activity theoretic (CHAT) analysis (see, for example, Engestrom 2001), we think it important to gain and articulate an understanding of how policy is mediated by rules, implicit and explicit. These rules encapsulate the intentions and values of the society in which the policy is situated and enacted, which are particularly important for future policy development and implementation. From this perspective it is the cultural and historical setting and expectations of the community in which it is intended that the new directions of policy operate. As our analysis confirmed, it is often the well- and long-established expectations of the community that provide obstacles to policy intentions being realised. The classroom implementation of any initiative is strongly embedded in the ‘contrat didactique’ (Brousseau 1997), the unwritten set of mutual expectations between teacher and students (and parents) regarding the learning of, say, mathematics in the classroom. Schoenfeld (2010) describes how teachers’ decision-making in the classroom is based on their *knowledge, goals and beliefs*; all these are involved, all are difficult to change. Consequently, many teachers find it difficult to innovate in changing their pedagogy even if they are intellectually disposed to do so. A change in formal rules, such as a new curriculum specification or new aspects of pedagogy encouraged in initial teacher education (ITE) courses, may not result in fast-paced change on the ground. ‘Old’ practices, well-embedded in daily routines and practices and the beliefs behind them, provide stability and are naturally resistant to change. Our analysis of context (Dorier 2010) points to a natural ‘conservatism’ in education with practices being strongly routinised on a day-to-day basis, particularly in the classroom and in the actions of teachers and their students. This is vividly illustrated in an analysis (Burkhardt 2013) of national reports on the implementation of long-accepted learning goals related to IBL (problem solving, modelling and the use of technology in mathematics), which shows

the gulf between national policy intentions and classroom practice; the analysis of reasons and possible ways to achieve greater convergence between intentions and outcomes complements that given here.

Further to this, our analysis of policy implementation in the consortium nations was built on the theoretical approach taken in the project’s initial analysis of national context (Dorier and Garcia 2013). This used the work of Chevallard who developed the construct of *Didactic Transposition* (Chevallard 1985, 1992). From a sociological perspective this situates and considers the didactical system as part of society at large, interacting with and in various spheres. Of particular importance in this theory is the academic sphere of the discipline that produces and controls the scholarly knowledge and its transposition into taught knowledge. Chevallard developed this work further to model the educational system as a complex hierarchical structure of different institutions. In much the same way, CHAT might consider these as activity systems which bring together key actors and stakeholders. This *institutional approach* considers a hierarchy of *didactical organisations* that are co-determined through their mutual interaction. It is important to note that the framework used in the national policy analysis on which this paper is based has, without making this explicit, been informed by this approach. The analytical framework used integrates school structures at a national/regional level, curriculum organisation, assessment/qualification structures, and teaching, together with ITE and teacher professional development at both national/regional and school levels.

3 Methodology

3.1 Analytical framework

There is already much published contextual and background information in relation to mathematics and science education across Europe. Particularly important in this regard are the Eurydice reports on mathematics (EACEA/Eurydice 2011a) and science (EACEA/Eurydice 2011b), and the Eurypedia website. These give an overview of how mathematics and science education is implemented across Europe. The policy work we report here adds to these by seeking to understand the *policy* context at a national or regional level. Our specific intention is to understand how the European policy space is responding to the overall European policy objective of increasing positive dispositions towards the learning of mathematics and science through the widespread implementation of inquiry-based pedagogies in schools. Our focus, therefore, is on the wide range of policies that interact with each other and impact upon what is happening in schools and classrooms, as

teachers, school leaders and others respond to the intended and unintended consequences of policy. In pursuit of this aim we provide evidence-informed analysis at a national level, and in summary across the partnership, of:

- (a) the **priorities** that policies give to mathematics and science education and the professional development and the **values** that underpin these priorities;
- (b) how systems and structures **mediate/manage** the implementation of policies;
- (c) the processes of providing **data and evidence** that informs policy decisions.

The first two of these categories arise from the CHAT approach that views policy resulting in both explicit and emergent implicit rules that mediate the activity of systems as the collective actions of individuals. The final category attempts to provide insight into policy development by understanding policy as constantly evolving by drawing on data and evidence as feedback often provided by, and resulting from, policy enactment or from commissioned research or evaluation.

To inform this analysis a data collection framework was developed in an iterative cycle of improvement. Each partner in the PRIMAS consortium contributed data with respect to their own nation/region. This required (1) responses to a series of questions related to the key issues for each of the themes, (2) references to the policy evidence base, and (3) identification of affordances and constraints in relation to the aims of PRIMAS.

Here we give further details of the underpinning rationale and in tabular form (Tables 1, 2, 3) the questions that were asked for each theme.

3.1.1 Theme 1: The priorities promoted by policy

Across European industrialised nations in recent years there has been policy rhetoric that there is a need to ensure better education of young people in STEM in pursuit of a well-prepared technology-focused workforce. These priorities, at a strategic European level, are expected to work through to national level to inform detailed policy in relation to many aspects of education. In light of the European strategic aim of developing more active and engaging learning in mathematics and science it was our intention to identify how national policy priorities, and the values they reveal, may afford or constrain these intentions.

3.1.2 Theme 2: How systems and structures mediate/ manage the implementation of policies

There are many different approaches towards achieving the same ends for any given policy or strategic direction. Although governments can attempt to make structural and

Table 1 Framework questions and exemplification under Theme 1: The priorities promoted by policy

Question	Exemplification
In what ways are mathematics and science education prioritised (or not) by policy? In relation to	
(1) The structures of the school system	(For example, particular schools may specialise in technology, funding may be increased for students following particular courses,...)
(2) Curriculum organisation at a system level	(For example, more time may have to be allocated to mathematics than other subjects, nationally curriculum support materials may be provided that promote science, certain topics in mathematics/science may be prioritised above others,...)
(3) Assessment/ qualifications	(For example, it may be that students are required to have passes in mathematics examinations before being allowed to progress to the next phase of education, more value towards university admittance may be provided by qualifications in science than in other subjects,...)
(4) Teaching	(For example, active or passive teaching methods may be supported by inspection systems,...)
(5) Initial teacher education	(For example, those training to teach mathematics and the physical sciences may receive more funding, teacher training institutions may be given increased recruitment targets in mathematics,...)
(6) Teacher professional development	(For example, more funding may be made available for mathematics and science training,...)

systemic changes, there are often deep-rooted ways of working, culturally and historically evolved, that become part of how 'things are'. As we have noted, these are often resistant to change. In this theme we sought to understand, at a national level, how systems and structures mediate the implementation of policies in relation to the priorities in key areas of education.

3.1.3 Theme 3: Data and evidence that informs policy decisions

Policy makers use a wide range of data, as well as drawing on personal and collective philosophies and ideologies, to inform their policy actions. In this theme we sought to understand across the partnership how key aspects and outcomes of national education systems are measured and consequently what data and evidence is available to inform

Table 2 Framework questions and exemplification under Theme 2: How systems and structures mediate/manage the implementation of policies

Question	Exemplification
(1) How is the curriculum specified and how independent can schools be in implementation of this, in general, and in relation to mathematics and science in particular?	(Overall, how is curriculum specification controlled by policy—in general and in relation to mathematics and science in particular? Are there regulations about what schools must teach?)
(2) How similar and how different is curriculum implementation and teaching of mathematics and science allowed to be between school-types (for example, primary or secondary, vocational or academic, public or private) and between schools of the same type?	(Overall, how centrally controlled is the classroom practice of teachers? For example, do they have free choice in their selection of resources or is there a state-controlled text book?)
(3) How is the assessment of mathematics and science managed at a national level? What impact does assessment have on teaching and learning of mathematics and science?	(How centrally controlled is assessment/qualifications? Do teachers contribute to assessment of pupils that leads to nationally recognised qualifications? What is the potential in the form and management of assessment for IBL?)
(4) How is initial teacher education managed/controlled in general and in relation to mathematics and science teaching in particular?	(What are the policies, if any, in relation to initial teacher preparation in pedagogy/didactics? Is this at the discretion of the initial teacher education provider or in some way controlled centrally?)
(5) How is teacher professional development managed/controlled in general and in relation to mathematics and science teaching in particular?	

Table 3 Framework questions and exemplification under Theme 3: Data and evidence that informs policy decisions

Question
(1) What data is collected about educational outcomes at a system level to inform policy in relation to mathematics and science education (e.g. participation, attainment in assessment)?
(2) How are outcomes of schools measured? How are these measures used? What particular role, if any, does mathematics and science education play in relation to these measures?
(3) How are the outcomes of teaching and learning measured? How are these measures used? In relation to this are there any particular issues in mathematics and science education?
(4) To what purposes are measures of pupil performance in assessment used at individual, school and systemic levels? In relation to this are there any particular issues in mathematics and science education?
(5) How are the outcomes of initial teacher education measured? How are these measures used? In relation to this are there any particular issues in mathematics and science education?
(6) How are the outcomes of professional development measured? How are these measures used? In relation to this are there any particular issues in mathematics and science education?
(7) What has been the impact of international studies such as PISA and TIMSS on educational policy in general and in relation to mathematics and science in particular?

policy development. In pursuit of understanding of the evidence base the framework asked the key questions in Table 3.

3.2 Analysis

The questions across all three themes were answered by the partners as mathematics and science education experts for each consortium nation. To ensure validity, only responses

that were provided with full references (often web-linked) to national documents were admitted as data/evidence. Additionally, potential affordances and constraints for the work of PRIMAS arising from these aspects of policy implementation were identified and explained in some detail. In completing this section partners referred to their analysis of national context within this project. Ultimately the completed framework allowed insight into key policy intentions and outcomes in what might be considered two different directions:

1. vertically, providing understanding of how different policies interact and result in a particular nation's unique historically evolved educational setting (examples include teacher supply and training, curriculum specification, and assessment);
2. horizontally across nations, providing insight into how global intentions for a specific issue are enacted locally, often in very different ways, in pursuit of the same intended outcomes.

Like the project's earlier analysis of national contexts (Dorier and Garcia 2013), the reports from individual nations of the consortium reflected considerable diversity in the cultural and historical settings in which education is developing, and in which the work of PRIMAS and similar projects struggle to gain a foothold. The localisation of the policy intentions that are emerging as a result of European Education Policy exemplifies well how globally emerging trends are adapted to meet the specific situations and changing political intentions in different nations.

Here we report an overview of issues arising from the synthesis of our *horizontal* analysis across national contexts. Our intention is to identify key issues that emerge

across nations whilst acknowledging that much detail and subtle nuances within any one nation might only be fully understood by those immersed in its cultural and historical roots. The details are often difficult for an outsider to understand because of the complex way in which policies interact. The analysis that is reported here is a synthesis of more detailed work, a deliverable outcome of the project (Wake 2011a), in which the answers to each of the questions in Tables 1, 2 and 3 were extracted from national responses and scrutinised across nations to arrive at a summary overview.

4 Results

4.1 Curriculum

Like Grek (2009), most partners identify the OECD's international comparative studies (PISA) as a major influence on school curricula in recent years. These studies, together with those in Trends in International Mathematics and Science Studies (TIMSS), measure outcomes that are easily quantifiable, leading to key headline figures and league tables of performance, which are especially influential in initiating policy development in relation to curriculum at a national level. Reflecting the focus of PISA assessment on the application of knowledge in solving problems from meaningful situations, most countries have shown curriculum redesign that promotes problem solving that might be expected to support IBL pedagogies in various ways. For example, in Germany the major debate stimulated by results of national performance on PISA tests (Neumann et al. 2010) has made considerable impact. Curriculum specification now defines expected output in terms of competencies to be acquired rather than merely content to be taught. It also reorganises science as inter-rather than mono-disciplinary.

In some cases detailed findings of the PISA studies have been influential in informing curriculum change in relation to specific sub-populations. For example, in the Netherlands it was found that too few students were in the cohort of high performers; policy initiatives there have, therefore, focused on improving outcomes for this sub-population for mathematics and language. The role of science has been diminished as a consequence.

In relation to how curriculum policy affects mathematics and science as disciplines, two major issues appear to emerge: the importance of science within the curriculum, and interdisciplinarity (both within the sciences and more widely). All countries report that policy in relation to curriculum prioritises mathematics and language above science. This is more prevalent in primary school years, with less time and curriculum space being available for

science in this phase. Also, in most nations of the consortium 'science' is really a catch-all term for individual sciences. This isolation of separate disciplines provides structures that inhibit IBL that is focused on 'real world' scientific issues that require interdisciplinary thinking rather than application of rules and procedures and recall of knowledge. In Malta, for example, a new National Curriculum Framework has moved to a more cross-curriculum, thematic and interdisciplinary approach, where boundaries between subjects can become blurred, providing greater potential for IBL approaches.

4.2 Assessment

Almost without exception across the consortium, partners report that national assessment is not designed in ways that support IBL practices in classrooms. In most cases the emphasis in mathematics and science is on timed written assessment that is narrowly conceived. This leads to 'teaching to the test' that focuses on application of knowledge relying on rules and procedures. This is particularly problematic because of the high value placed on assessment of mathematics and science (for example, in the PISA studies), particularly for mathematics. We find that assessment outcomes have important implications both for individual students and their potential progression, and for schools because individual students' results are often aggregated to provide data used to measure school effectiveness. In most nations knowledge of measurement outcomes is formally restricted to those charged with effective running of schools. However, in some cases results are made available more widely to the public, for example in the UK. The pressure on teachers to ensure that their students perform well in assessments is therefore particularly intense and tends to sustain pedagogies that are well-established, non-risk taking and therefore provide further obstacles to change.

The format of assessment leading to qualification is an important factor influencing curriculum implementation and policy impacts upon this. We found that, although there is diversity in the extent to which control of assessment is centralised, patterns of assessment seem to be dominated by timed written papers prioritising technical fluency and knowledge recall over other skills such as problem solving and modelling. Less restrictive modes of assessment that are supportive of student inquiry are fairly rare, even where teachers have autonomy and responsibility for the development of the assessment. We did find exceptions in some cases. For example, in Denmark more innovative forms of summative assessment leading to certification, such as teacher-controlled oral assessment, provide potential support for IBL methodologies.

4.3 Lessons and pedagogy

Our survey of policy finds relatively little in the way of policy intentions that are directly focused on defining how teachers should teach, but there appear to be many policies that have indirect but influential impact. Where teachers appear to have considerable autonomy in how they develop their classroom practice, they are in fact under considerable pressure to comply with what is the accepted or newly emerging norm.

This is eloquently illustrated in England, where there is no explicit policy defining how teachers should teach, but a number of other policies support and reinforce convergence on a cultural script (Wierzbicka 1999) in teaching mathematics and science that is at best neutral and, at its worst, is negative towards IBL. Of particular importance are two policies that purport to measure the outcomes of schooling:

1. the high profile and widely distributed publication of pupil performance data, aggregated at whole school level, and
2. the inspection of schools by the government regulator Office for Standards in Education (Ofsted) and the publication of these reports that include reference to the standards of observed lessons.

Neither of these two policies explicitly states expectations in relation to teaching, although it might be expected that the latter would be most influential in influencing aspects of teaching at a classroom level. However, it is the publication of each school's headline figure of student performance in public examinations at age 16 that proves dominant, consequently confirming the important role of the form of national tests as a focus for teaching. In England this assessment is narrowly conceived in terms of focusing on procedural competence and technical fluency rather than problem solving (Noyes et al. 2010). This ensures that teachers are reluctant to implement IBL practices even when they may be supported by Ofsted inspectors who recognise the need for students' broader competence, interest and enjoyment of STEM subjects to be fostered and supported.

4.4 Teacher preparation and professional development

The initial education and professional development of teachers at all stages of their career is central to the work of PRIMAS in promoting change in teaching practices. However, we found that, in different ways across the partnership, aspects of policy that are supportive of IBL teaching methodologies are often dissipated because of structural and systemic aspects of teacher education.

Perhaps most worrying of all to a project such as PRIMAS is the lack of coherence in terms of the lifelong

learning and professional development of the teaching workforce. Across the consortium it seems that teachers are expected to learn and develop on the job with little in the way of planned professional development, although there is some expectation of participation in some of the eastern European nations. There is increasing devolution of control (and often funding) for teacher professional development to individual schools (for example Romania, England, Norway, Netherlands) leading to few opportunities for strategic capacity-building in IBL teaching practices. This means that it often proves difficult for many teachers to access the type of professional support they desire or require. Although ITE is mainly situated in, or at least directed by, research-informed university departments, this is often not the case for in-service professional development.

In ITE there is invariably a lack of specification of a curriculum for courses, which are mainly designed, implemented and assessed by higher education institutions. This provides both opportunities and challenges for projects such as PRIMAS that aim to bring about change in teaching practices. It may be possible to ensure that some such courses incorporate the approaches to teaching being advocated but it also means that dissemination to those in charge of such courses can be a time-consuming venture.

Overall, across partnership countries, we note a lack of strategic policy towards planning and coordination in professional development with little, or at best poorly coordinated, lifelong learning for teachers in a professional sense. This is not always the case; for example, in Spain there has been recent prioritising of professional development in the use of technology and the development of students' competencies. This has in general been a problematic area for the work of PRIMAS with partners having to be flexible in their approach to implement models of professional development with common features. Systems and structures that support professional development vary widely. In Romania, teachers are required to gather a number of professional development credits over a given period (although there is no strategic direction to the accumulation of credits). In Cyprus, professional development is reported to be mainly informal, individual and voluntary. The progress of the project in England provides a stark example of how unforeseen policy change due to a change of national government can prove difficult although the policy at issue is not specifically focused on professional learning. Rather, the policy that has had impact has been the removal of a layer of local education governance with the delegation of budgets directly to schools. This has led to a time of uncertainty in the provision of professional development and training as schools readjust to their new responsibilities at a time when an important layer of support and provision has been removed.

4.5 Teacher performance

In general, we found not much evidence of policy that is specifically directed towards what teachers actually do in their classrooms. In countries where inspection of teaching in classrooms takes place, there is usually some support for active teaching that supports IBL (for example, in Malta and England). However, we find that this is the exception rather than the rule. There is also evidence in some instances of quality assurance and inspection being more focused on management rather than quality in teaching and learning issues (for example, in Spain and also in Germany). We also found that the preparation of new teachers, as reported by a number of countries, is characterised by a lack of emphasis on teaching quality at the expense of a focus on theoretical underpinning related to pedagogy and didactics. Only in few instances is there a focus on classroom practice in the assessment of new entrants to the profession, although this may be the focus at the end of the induction phase. A commonly reported issue is the low subject knowledge-base of generalist teachers in primary schools. This is particularly problematic for developing IBL practices in primary schools, since teachers who are not secure in their own knowledge of mathematics and science are unlikely to be able to support students whilst working with inquiry methods.

5 Discussion

Our analysis of how policy priorities, their management and mediation are informed by the monitoring of data highlights the variation and complexity of policy initiatives across all aspects of education within the nations of the project partnership. They illustrate the usefulness of the construct of European Education Space (Dale 2009) in drawing our attention to the difficulty of envisioning a European Education Policy. Although there is some discernible alignment of overall policy intentions in partnership nations, there are very different approaches to how these might be achieved. The different approaches reflect the historically developed systems and policies of individual nations as well as reflecting culturally developed expectations and ways of working as well as the prevailing ideologies of current politicians with responsibilities for education.

In attempting to compare and contrast policies across the nations of the consortium within the different themes of our analytical framework, time and again we noted similarities, differences and interestingly contradictory priorities and values. For example, as some countries develop curricula that bring the separate sciences together (such as Malta), others appear to be moving in the opposite direction and dismantling their current interdisciplinary approaches (such

as England). Some nations have centrally controlled and administered assessment, whilst others devolve responsibility to classroom teachers. This provides evidence that although there may be agreement about the preferred outcomes of teaching and learning of mathematics and science there is no one route or set of policies that will ensure this across European nations. Perhaps the complexity of the situation, both within and across nations, cannot be captured on the page here, particularly as it is difficult to capture and describe the temporal aspects of policy development. In addition to the policy propositions, enactments and intended outcomes, the context at the point of their introduction and throughout the time taken for them to become embedded in the system are important in coming to understand policy as it is now. Crucial also are the important actors who because of their personal qualities may have more or less influence and impact than warranted by their role as policy makers in the policy domain. Four overarching issues appear to emerge. We raise and discuss these here and suggest that they need to be considered in relation to the future direction of European education policy in relation to effecting change in teachers' pedagogies and learners' experiences in mathematics and science education.

5.1 The influence of PISA as an outcome measure

The OECD, however unintentionally, through its longitudinal series of international comparative studies finds itself with powerful influence in the European education policy space (and more widely). The OECD and its PISA studies has high value as a brand in providing data that compares and contrasts our national systems. Although official reports are couched carefully and warn readers of limitations when making comparisons, they provide some of the best data available (alongside the TIMSS series of studies). Policy makers use these to inform, or often confirm by selective selection of outcome data and its interpretation, policy initiatives. Priorities are determined, and systems and structures redesigned, in pursuit of improvement internally over time and competitively with other countries in pursuit of improved performance in the outcomes that the studies measure. All nations in our project report the importance paid to the outcomes of PISA but it is indicative of the varying political ideologies across Europe that different and, on occasions, polar-opposite approaches are being pursued. Because of the complexity of interlocking issues and the cultural situativity in which they apply, it is unlikely that any policy move can be identified as providing a universal answer to provide improved performance. But it is important to recognise the restricted vision in terms of outcomes of schooling that inevitably results from such testing.

At a national level, policy makers respond to their country's performance by enacting reform which, inevitably, takes considerable time to design and implement. So much so that the next round of data is harvested, processed, analysed and published well before any impact of the reform is detected in classrooms. Even so, policy makers usually react quickly attempting to bring about change to input specification (curriculum) and output measures (assessment) without considering fully the implications for teachers and teaching.

5.2 Teaching: specifying input, measuring output, changing processes

There is much policy effort focused on defining the structures and systems in which teaching and learning take place. For example, across nations there has been an increasing trend towards centrally defined learning aims, objectives and subject content throughout the curriculum. Although differently presented in individual nations, what teachers are expected to prioritise in terms of their students' knowledge, skills and understanding in mathematics and science is documented in a range of different publications that provide insight into how discipline domains as taught in schools have become reified by policy makers, with or without theoretical underpinning or the agreement of the academy. These policy documents indicate what is to be valued and how this is seen to be organised providing the official prevailing epistemology. For example, the teaching of science as an integrated discipline in primary school years is common across nations, whereas as students make their way through the later years of their education they are increasingly likely to find science reorganised and taught in separate subject disciplines. This is the common pattern of the organisation of science as a discipline across Europe (EACEA/Eurydice 2011b). At a discipline level we see curricula in mathematics organised around the main sub-domains as identified by PISA in developing its assessment framework (*Change and relationships, Space and shape, Quantity, Uncertainty*) (OECD 2003).

In general, we note that policy makers, exercised by the data they receive from both external sources such as PISA as well as from internal measurement of output, direct their energies towards (re-)defining input parameters and measuring output. Although there is a desire to effect a change in the processes of teaching, policy activity almost exclusively focuses on input and output with little about the teaching process. Unfortunately there often appears to be misalignment between the policies that affect input and output and what is intended to happen in the process of teaching and learning that provides the filling to the sandwich.

5.3 Students and output measures

The well-known adage 'wytiwyg' (what you test is what you get) (Burkhardt 1992) is particularly applicable as high-stakes assessment for both individual students and their educational institutions increasingly takes hold. In our world of instant information and data collection, processing and communicating what is measured can be increasingly both complex and meaningful, but often the complexity is reduced to headline numbers that provide sound bites. It is easier to ensure reliability in measuring student attainment with carefully designed assessment against nationally defined standards than to gain a richer overview that, for example, ascertains students' current and likely future engagement with learning in mathematics and science. The relationships that students have and develop with these subject disciplines and the influences that impact on their developing identities as young people and future citizens and workers are many, complex and rapidly changing at an important time in their lives (for an overview of such issues in terms of mathematics see Wake 2011b, and associated articles). Our analysis across the consortium in almost all cases pointed to assessment having a major and narrowing impact on teachers' classroom practice and, consequently, on students' experiences of learning. This raises our concerns that, for students to develop inquiring minds in mathematics and science, we need to measure *and value* more than merely attainment using tests as currently constituted and designed. These appear to be reliable in measuring outcomes rather than valid across the full spectrum of mathematical activity, producing gross distortion of the pattern of teaching and learning. Education has a wider spectrum of outcomes that we must seek to understand and value.

5.4 Lifelong learning of both the professional and the profession

Crucial for bringing about changes to teacher and learner practices is the professional development of teachers. As we have made clear there are many contextual issues, socially and historically developed, that impact on what it means to teach and learn in the schools of our different nations. These remain, often stubbornly, resilient in resisting change: current mathematics and science lessons, perhaps more so than those in some other school subjects, often seem to come from many decades ago. This is not always because teachers do not want change. An observer would see a system of professional development that is often ad hoc and, in some nations, almost non-existent after a period of ITE. It seems that only in rare cases is there a system of teacher professional development that focuses on the needs of the individual in relation to the community in

which they work and the profession as a whole. Although projects such as PRIMAS make valiant attempts to raise the profile of inquiry approaches to teaching and learning in mathematics and science, it is perhaps inevitable that this proves difficult when underlying systems and structures do little to ensure that professional development is deeply embedded within the profession as an expectation and right. It is perhaps worth reflecting on this situation by noting the contrast with the systematic professional development required of the medical profession. This is designed to support the individual's changing practice over their lifetime and the development of the profession as a whole as it responds to medical research and development. Our analysis at a national level of policy in relation to the development of the teacher as an individual and as a professional body suggests that this is one area where a policy rethink might make a substantial impact in support of the changes that are sought.

6 Summary and recommendations

Across the PRIMAS consortium nations, what is striking in relation to the many policy developments that we identified as having impact on the potential implementation of IBL methodologies? First, the wide range of different policies being implemented and the amount of effort that is currently being expended to support changes in teaching and learning of mathematics and science in schools. But perhaps what appears more significant in all nations is the apparent lack of strategic vision and coherence of policy development across the full range of potential areas of implementation. Given the strong rhetoric at a European level for the widespread use of IBL in schools and classrooms to support stronger student engagement with mathematics and science, it seems that many policy opportunities are lost. Policy implementation, whilst well-intentioned, is often fragmented rather than being carefully aligned; consequently, it is not supportive of work, like that of PRIMAS and other projects, that seeks to effect changes in pedagogies.

We point to the need for policy makers to question what is valued in mathematics and science learning, how this is specified and measured, and how teaching as a profession as a whole as well as the individual teacher might be better supported in pursuit of agreed objectives. Important in this regard is ensuring alignment of policies that support this across the different aspects of curriculum, assessment and pedagogy.

To ensure clarity our policy analysis leads us to recommend:

- At both European and national levels policy makers should consider how policy in relation to different aspects of education might be better strategically aligned towards ensuring key policy objectives are met.
- Policy seeking improved outcomes in terms of student achievement in mathematics and science should be proactive with clear vision rather than reactive to international studies. This requires a strategic approach over longer time-scales than the relatively short time-scales of political change and the frequency of international studies.
- Policy makers should consider how to better ensure that students' experiences of learning mathematics and science are positive and motivating. This requires careful consideration to be given to how inquiry-based teaching and learning processes can be developed and supported by the ways in which curricula are specified and how student achievement is measured.
- Policy development should be cognisant of, and sensitive to, the full range of students' learning experiences rather than focusing narrowly on achievement on narrowly conceived tests. In particular, promoting positive dispositions towards mathematics and science needs to be at the forefront of policy consideration.
- The lifelong professional learning of teachers, both as individuals and for the profession as a whole, should be supported by strategic policy interventions that make professional development an integral part of being a teacher.

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