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Name of Coordinator: Dr. Eilish McLoughlin

Name of lead partner for this deliverable: AGES

A. Background to this report

This report is a deliverable of Work Package 2 (WP2) of the European FP7-funded project "European Science and Technology in Action: Building Links with Industry, Schools and Home" (ESTABLISH; 244749, 2010-2013). It meets the requirements of the Deliverable 2.2 by presenting an interim report on the key forces for driving change in classroom practice across participating countries of the beneficiaries of ESTABLISH. (See Table 1 below for beneficiary list).

The collection of data for this report was coordinated by participants from WP2 leader AGES, Anna Gethings (AGES), Jim Salisbury (AGES) and Rory Geoghegan (AGES). Data was gathered from participating countries by means of questionnaires and email correspondence, discussion at General Assembly meetings in Dublin (GA2) and Malta (GA3). A review of the relevant literature was also carried out to address the issues concerning science education, teacher training and school change as these are not just confined to Europe. The results presented in this interim report should not be taken to reflect national dictated policy. The report also contains material from other WP2 reports where such inclusion is relevant and informative.

The ESTABLISH participants who act as the WP2 contact points in each country were identified namely, Rory Geoghegan (AGES), Ewa Kedzierska (CMA), Nicos Valanides (UCY), Christina Ottander (UmU), Malgorzata Krzeczkowska (JU), Ewa Odrowaz, (JU), Zdeněk Drozd (CUNI), Annalise Duca (AL), Dušan Šveda (UPJS), Stefanie Herzog (IPN), Miia Rannikmae (UTARTU), Giovanni Tarantino (UNIPA), Maria Sandström (MaH) and Martin Lindner (MLU).

The analysis and presentation of this report was conducted by Jim Salisbury (AGES), Rory Geoghegan (AGES), Anna Gethings (AGES), Odilla Finlayson (DCU), Deirdre McCabe (DCU) and Eilish McLoughlin (DCU) and was approved for submission by the ESTABLISH Project Steering Committee meeting at its meeting in Umea, June 2011.

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For further information regarding ESTABLISH please contact:

Dr. Sarah Brady (ESTABLISH project manager)

Email: sarah.brady@dcu.ie

ESTABLISH website: http://www.establish-fp7.eu

B. The ESTABLISH consortium

Beneficiary short name	Beneficiary name	Country	Abbreviation
DCU	DUBLIN CITY UNIVERSITY	Ireland	IE
AGES	AG EDUCATION SERVICES	Ireland	IE
UCY	UNIVERSITY OF CYPRUS	Cyprus	CY
UmU	UMEA UNIVERSITET	Sweden	SE
JU	UNIWERSYTET JAGIELLONSKI	Poland	PL
CUNI	UNIVERZITA KARLOVA V PRAZE	Czech Republic	CZ
AL	ACROSSLIMITS LIMITED	Malta	MT
UPJS	UNIVERZITA PAVLA JOZEFA ŠAFÁRIKA V KOŠICIACH	Slovakia	SK
COUO	CARL VON OSSIETZKY UNIVERSITAET OLDENBURG	Germany	DE
UTARTU	TARTU ULIKOOL	Estonia	EE
UNIPA	UNIVERSITA DEGLI STUDI DI PALERMO	Italy	IT
MaH	MALMÖ UNIVERSITY	Sweden	SE
IPN	LEIBNIZ-INSTITUT FUER DIE PAEDAGOGIK DER NATURWISSENSCHAFTEN UND MATHEMATIK AN DER UNIVERSITAT KIEL	Germany	DE
CMA	CENTRE FOR MICROCOMPUTER APPLICATIONS	Netherlands	NL
MLU	MARTIN LUTHER UNIVERSITAET HALLE-WITTENBERG	Germany	DE

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1. Summary

This interim report is concerned with identifying the key forces that influence classroom practice across the participating countries in the FP7 ESTABLISH project. This report is a deliverable (Deliverable 2.2) of Work Package 2 (WP2) of this project whose objectives are the identification of key industrial partners (as reported in Milestone 2.1) and models of stakeholder cooperation in facilitating IBSE (as reported in Milestone 2.2). In this work, a review on how IBSE is implemented and assessed across participating countries has been reported (Deliverable 2.1). The key forces for driving change in classroom practice across participating countries are examined and findings from this work is presented in this interim report and in further detail in the final report of this project. The information gathered in these activities will inform the ESTABLISH project central objective of involving stakeholders in the task of supporting the use of Inquiry Based Science Education (IBSE) in second level schools. This engagement of key stakeholders is a defining feature of the ESTABLISH project. '*The rationale for this project lies in creating authentic learning environments for science by bringing together and involving all stakeholders that make change possible'* (ESTABLISH Annex I). In this work, these key forces are viewed as deriving from the actions of various 'stakeholders' groups and this report considers the following stakeholders influence or potential influence on school practice.

- Policy makers
- Teachers, teacher organisations and teacher training institutions
- Students
- Parents
- Public representatives
- School Management
- Industry

A review of literature and discussions with ESTABLISH consortium partners indicate that common difficulties are experienced in bringing about significant changes in educational practice. In particular, any attempt to introduce widespread use of new methodologies, such as IBSE, is thwarted by two inter-related items – the curriculum (in terms of syllabus content) and the associated assessment system. Consequently, these factors are identified as two critical forces in implementing IBSE in schools. As teachers play the central role in the delivery of education and the monitoring of student progress, these are also considered to be key players. Hence, the education of teacher is deemed to be a key factor. It is proposed that these three elements - curriculum, assessment and teacher education constitute the key forces for driving change in classroom practice.

However, since policy makers have the power to mandate IBSE and place it at the centre of science education through their control of both curriculum and assessment, they are a suggested to be the most influential category. School management, teacher organisations and teacher education institutions can bring influence to bear on policy makers as well as on daily classroom practice. Students and parents, as 'users' of the education service, have the potential to bring higher levels of influence than is currently the case. Since achieving a significant change in education systems takes considerable time, a long term strategy is imperative. Consequently, ESTABLISH will attempt to encourage policy makers to introduce the policy changes necessary by providing evidence of the benefits of IBSE. The most effective strategy in this regard is to disseminate IBSE through in-service and pre-service teacher education, and increase the use of IBSE by teachers in the classroom. In addition, all key stakeholders, as identified by the ESTABLISH project, will be mobilised to proactively promote and disseminate information about IBSE, to communicate with policy makers and to support local school initiatives in IBSE.

2. Forces That Influence Classroom Practice

The much cited Force Field Analysis model (Lewin, 1951) illustrates that a social situation is kept in 'equilibrium' under the influence of a number of 'forces for change' and 'forces for maintaining the status quo'. One example of a force for change in most work settings is 'technology' whereas 'lack of skill" is a restraining force. In this report the forces that affect classroom practice are taken for the most part, as deriving from the beliefs, values, motivation and activities of a group of stakeholders. A stakeholder is deemed to be 'an individual or group… that has a stake in and can influence an organisation's performance' (Dess et al, 2008 p 19).

The FP7 ESTABLISH project (ESTABLISH Annex I) identifies the stakeholders in second level science education as:

- Teachers and teacher educators of science including science teacher networks;
- The scientific community, both local enterprises and multinational industry as well as the science research community;
- The students of science in second level schooling;
- The parents of the students mentioned previously;
- The policy makers in science at second level, including curriculum developers and assessment agencies;
- National science education researchers.

Following discussion at ESTABLISH general assembly meetings it was suggested that school management be also included as a stakeholder group on the basis that a given school culture can determine the success or otherwise of any attempt to introduce and integrate new teaching practices. Two compelling reasons for the inclusion of this group were given:

1. Until curricula, teacher training and student assessment processes explicitly support IBSE by edict of the central authority (where such authorities exist) there is the danger that only individual or small quantities of teachers will undertake IBSE training. It is extremely difficult for teachers to introduce new methods in a school if the tradition and culture of that school is not supportive. Therefore, it is necessary for a critical mass of teachers in any given school to utilise IBSE methods. This will not happen unless support is offered by the school governing authorities and senior management of the school.
2. Where independent schools exist, such schools are free to decide critical processes and, therefore, may need to be convinced about the efficacy of IBSE. The Netherlands is an example.

Consequently, School Management is also considered to be a stakeholder. The term 'school management' here includes Boards, Management Committees, Head Teachers and any other form of school governance that has the power to determine teaching policy and practice.

It was also suggested that elected officials or public representatives who may not be in ministerial or other operational roles in government or may be in opposition to the governing parties, can still have significant influence on policy through lobbying and debate. Consequently, the impact of this group is also considered.

The ESTABLISH stakeholder groupings are shown in Figure 1.

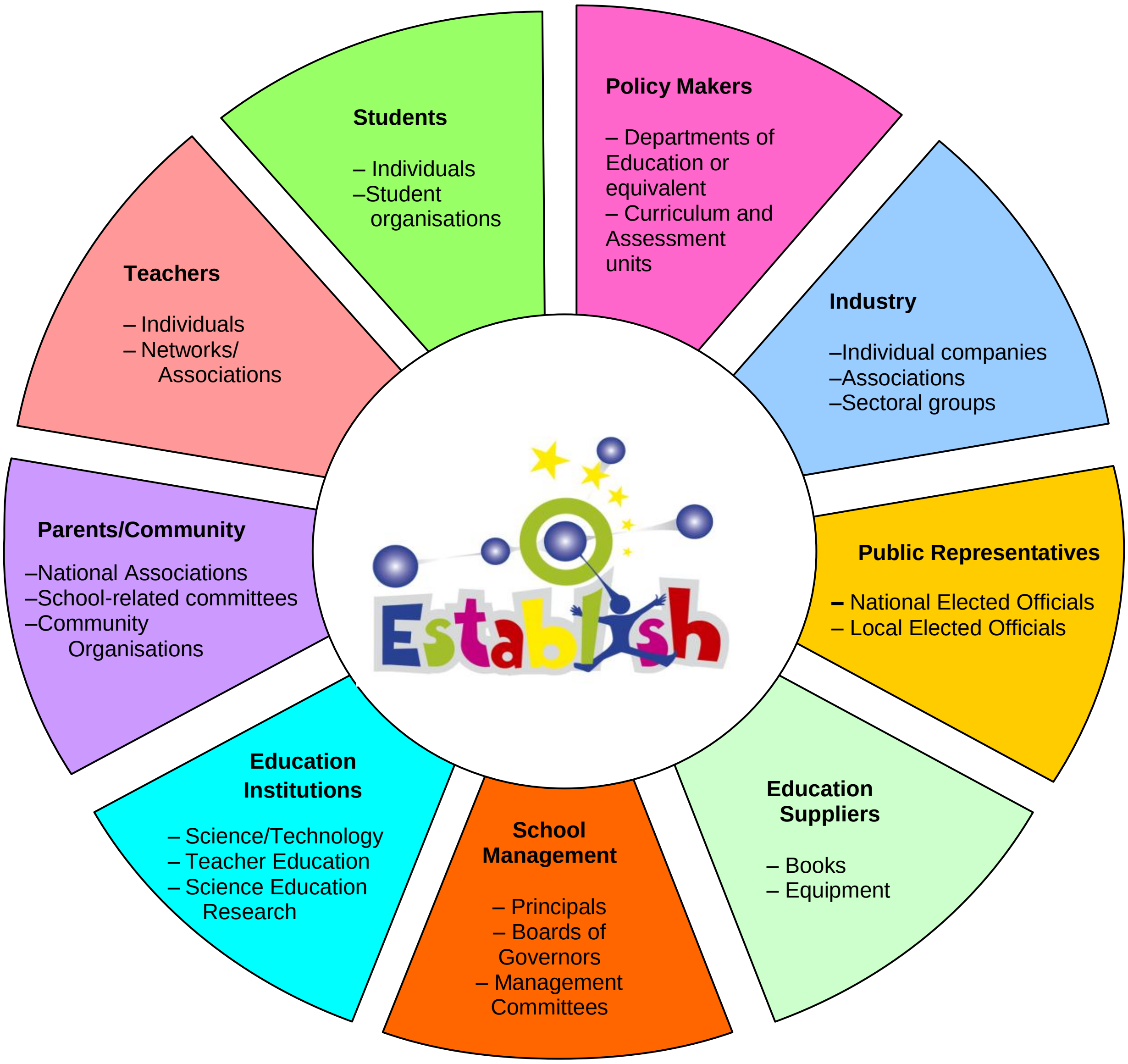

Figure 1: The ESTABLISH Stakeholders in driving change in classroom practice.

The 'media' (newspapers, TV, etc.) are not considered to be stakeholders as such. However, this cohort offer effective communication channels which can be used to deliver awareness campaigns to promote interest in, and support for, IBSE. ESTABLISH will consider the optimum way to use the media in support of its objectives.

3. Relative Importance of Stakeholders

All of the stakeholder groupings identified have a role to play in science education and have the potential to influence the widespread use of IBSE and its dissemination. It seems clear that, while each of these stakeholder categories can exert influence, some have greater impact than others. Indeed a discussion of the ESTABLISH General Assembly participants on the relative importance of the stakeholders revealed very differing opinions on this matter. For example, it was suggested that Education Suppliers have little influence on the uptake of IBSE. Nevertheless, since it can be claimed that such providers can encourage IBSE methods by making appropriate and, possibly, innovative materials available to schools, the category is an important one and therefore has been retained in the model.

Clearly, if policy makers were to mandate IBSE and ensure its place as an integral component of curriculum, in student assessment and in teacher education, there would be little need to engage in other influencing or promotional activities. Policy makers hold this power and, therefore, it is suggested that they are the most influential category.

School management, teacher organisations and teacher education institutions are also highly relevant since these categories can assert great influence on policy makers as well as on classroom practice. Teacher education institutions are staffed by educators and researchers whom can bring a large body of research in IBSE to the attention of policy makers. School management and teacher organisation exercise a high level of control over day-to-day classroom processes.

Students and parents represent the ‘users’ of services delivered by the education system and, if organised and coordinated, could exercise greater influence than they currently appear to do.

As part of this project, a WP2 ESTABLISH partner survey was completed by an ESTABLISH WP2 contact point in each participating country and the responses from this survey suggests that other stakeholders might become involved in supporting IBSE by influencing policy makers or by the provision of funding, expertise or other resources.

Tobin (1987, p289), identified five ‘assertions’ on forces which shape the implemented curriculum as part of his research in the US, namely:

1: Classroom management affected the quality of instruction.
2: The assessment system was used to motivate students and had a focusing effect on the implemented curriculum.
3: The academic work was strongly influenced by activities in the textbook.
4: Teachers endeavoured to cover the curriculum in the prescribed time whether or not learning occurred.
5: Target students dominated whole class interactions.

In summing up his findings, Tobin identified the amount of content that teachers feel obliged to cover as a major impediment to achieving curricula objectives. Content coverage is achieved at the expense of discussion and other modes of student involvement. He concludes that teachers do what they do because they believe that a rote learning approach is *'right for the learner'* and that their teaching style will not change until teachers are convinced of the value of changing.

> *'The major forces which influence instruction in high school science and mathematics appear to be associated with teachers' knowledge and beliefs'* (Tobin, 1987, p 287).

Change in schools systems takes time. Accordingly, it is imperative that policy makers and others in positions of power adopt a long term view. Mourshed et al (2010) reviewed the change process in 20 school systems from different parts of the world. They reported that '*significant improvement in educational attainment can be achieved within as little as six years*' (p 14). Six years may be little in terms of large system change but it is in excess of a government's lifetime in many countries. It is not unusual for large scale change in the business world to take, for example five to ten years and many change efforts actually fail (Kotter, 2001). Arguably, a national school system is more complex than even a multi-national business organisation with a single board of directors. Indeed, Saranson (1990) argues that it is virtually impossible to change a school system. This illustrates the necessity to find IBSE champions in the ranks of management and in every school.

In the following sections of this report each stakeholder category is considered and the nature of their involvement in science education is discussed.

4. Policy Makers

Policy, by its very nature can exist on a spectrum from very broad to very specific. A typical definition of policy is *'a deliberate plan of action to guide decisions and achieve rational outcome(s)*'. In effect, policy is a set of principles on which actions are intended to be based.

In addition, education policy can be developed at macro level such as a government body or agency and at micro level such as school management or even individual teachers. For the purposes of this report policy is understood as that developed at the macro level, i.e. policy that legally applies to the educational process in the schools located in the policy makers jurisdiction, whether regional as, for example, in Germany, or national as, for example, in Ireland.

In theory, such policies would be expected to encompass at least:

- the curriculum, by which we mean the content to be covered on the various science syllabi,
- the assessment processes and standards, by which we mean the examinations or other forms of testing that result in accredited educational awards.

Of course, policy can also specify other elements such as class hours, practical periods, learning objectives, learning outcomes and instructional methods. Some of these elements can implicitly or explicitly incorporate values that attempt to emphasise a preferred style of classroom management such as inquiry or collaborative learning. It is not unusual for official curriculum and syllabus documents to express such aspirations, while simultaneously, setting out timetables and content topic lists that make it difficult for educators to adopt anything other than a transmission mode of teaching.

The challenge for ESTABLISH, as a project dedicated to the use and dissemination of an inquiry-based teaching methodology, is to assess:

- how to persuade policy makers to introduce the policy changes necessary to support the widespread introduction and sustainable use of IBSE,
- how to ensure that such changes are put into operational effect in the classroom.

This issue is expressed succinctly by the President of the Educational Policy Institute in the USA. '*Policymakers require better tools and information in order to make prudent decisions about how best to spend taxpayer funds and also serve the public in the best manner possible.'*

(www.educationalpolicy.org/aboutus/default.htm)

At an earlier stage in the ESTABLISH project, the consortium participants identified the agencies/bodies responsible for the development of curriculum and assessment policies in the eleven participating countries[1] and these are shown in Table 1.

Partner Country	Curriculum	Assessment
Cyprus	• Ministry of Education and Culture	• Ministry of Education and Culture
Czech Republic	• Ministry of Education, Youth and Sport • The Research Institute of Education in Prague (VUP)	• Ministry of Education, Youth and Sport • Institute for Information on Education (IIE)
Germany	• Ministry of Education & Culture in each of the 16 States	• Ministry of Education & Culture in each of the 16 States
Estonia	• The National Examinations and Qualification Centre • Ministry of Education	• The National Examinations and Qualification Centre
Ireland	• National Council for Curriculum and Assessment • Professional Development Service for Teachers	• National Council for Curriculum and Assessment • State Examinations Commission
Italy	• Ministry of Education	• Ministry of Education • INVALSI
Malta	• Directorate for Education Quality and Standards	• MATSEC unit (University of Malta)
Netherlands	• Ministry of Education	• Central Examinations Board
Poland	• Ministry of Education	• Central Examinations Commission • Poland Regional Examinations Commission - Krakow
Slovakia	• National Institute for Education	• National Institute for Certified Educational Measurements
Sweden	• The Swedish National Agency for Education (Skolverket)	• The Swedish National Agency for Education (Skolverket)

Table 1: Bodies responsible for curriculum and assessment policies in each of the ESTABLISH participating countries

[1] Descriptions of European education systems and curricula are available on the Eurydice website at http://eacea.ec.europa.eu/education/eurydice/eurybase_en.php

Strong arguments need to be made to these identified policy makers to promote the use of IBSE. Indeed, there is much research evidence to support the use of constructivist methods in education. For example, several studies provide evidence for the efficacy of problem-based and inquiry approaches and some claim that students actually prefer such approaches over traditional 'chalk and talk' (Hmelo-Silver, Duncan, & Chinn, 2010; Doğru & Kalender, 2007; Kask, 2009). However, there is also a body of opinion stating that students may not respond to constructivist approaches if they do not possess the necessary cognitive (processing and representational) resources (Kirschner et al, 2006).

The scope of this report is not to analyse these arguments in any depth. The point to be considered is that policy makers will need to be convinced that the changes that ESTABLISH is advocating will deliver an appropriate pay-off for individual learners and for society in general. *'Since it can take many forms, it is critical that educators understand different forms of inquiry, and the value of implementing each*' (LaBanca, 2006, p 1). It will also be necessary to persuade them that such changes can be introduced without undue resistance from teachers and without institutionalised conflict with teacher representatives.

In a recent international report entitled "***How the world's most improved school systems keep getting better,***" Mourshed et al (2010, p 20) identify six interventions that occur across all instances of school performance improvement, namely:

- Technical skill building: (improved professional development).
- Student assessment.
- Data systems.
- Revised standards and curriculum: *('defining what students should know, understand, and be able to do, and creating the accompanying teaching content'*).
- Teacher and principal compensation (performance related reward schemes but only following significant progress).
- Policy documents and education laws facilitating the improvement.

It is obvious that policy makers are central to decisions on all of these points.

In recent years, with the growing influence of the EU, a shift from 'government' to 'governance' has commenced (Windzio et al. 2005, Türke 2008). This change implies a loosening of central regulatory control of schools and teachers and a strengthening of the role of the individual school in making adjustments to national standards. This change will place more responsibility on local decision makers while simultaneously offering more freedom to influence school practices.

4.1 Curriculum Content

As stated previously, it is not unusual for curriculum documents to contain terms that can be interpreted as supporting an inquiry approach. Such terms may appear in the prologue or introductory section of a syllabus.

For example, the current Irish science syllabi state that:

'… science syllabuses are designed to incorporate the following components:

- *science for the enquiring mind, or pure science, to include the principles, procedures and concepts of the subject as well as its cultural and historical aspects*
- *science for action, or the applications of science and its interface with technology*
- *science, which is concerned with issues – political, social and economic – of concern to citizens.'*

These documents do not specify how the topics should be taught but state that '*Teaching strategies should promote, in a positive manner, the aims and objectives of the syllabus'.*

Similarly, an official Polish document on the subject of the new core curriculum sates that:

> *'During classes pupils should have the opportunities to observe, study, inquire, explore laws and relationships, experience satisfaction and joy of independent learning.'*

However, teaching methods are not mandated.

> *'This allows the school to select teaching methods which … will ensure achieving learning outcomes described in the core curriculum in an optimum manner.'*

In Cyprus the curriculum also defines the educational philosophy of guided discovery and refers to students discovering science concepts for themselves as reported as part of the work of the FP7 S-TEAM project. (S-Team, 2010).

S-Team also report that, in the Czech Republic *'video studies show that there is little IBST actually practised in classrooms …'*

In Estonia, syllabi allude to '*making scientific observations'*, '*formulating hypotheses and verifying them through experiments'* and to activities such as laboratory work, project work and discussion. Again, it appears that these statements do not influence classroom practice to any significant extent. Some commentators believe that the new curriculum, to be introduced in the period 2011-2013, may improve this situation.

In Germany each Federal Stake produces its own curricula which, in line with national standards, are becoming competency based and include many aspects of inquiry.

The Swedish curriculum and syllabuses for science are goal oriented and state that students should develop knowledge not only in scientific content but also in knowledge '*concerning scientific activity'* and knowledge '*concerning the use of knowledge'*. A new curriculum will come into effect from July 2011 which contains clear IBSE goals.

One frequently cited reason for the apparent lack of adherence to curriculum aspirations is time.

'There is a very deeply held view on the part of educators, parents and other members of society that inquiry- based learning takes too much time and it is much ore efficient for students simply to be given the information they need to know. This point of view is strongly reinforced by the kinds of

things students are expected to know to pass the majority of testes they are given.' (Concept to Classroom, www.thirtenn.org)

These observations are echoed in a report from the IAP - the global network of science academies - Science Education Programme, (2010, p 13)

> *'The organisation of the school timetable presents an obstacle when, as is often the case, it provides no extended periods where students can study topics in depth or engage in problem-finding and problem-solving.'*

This is not surprising when the processes expected of an inquiry session are taken into account. The IAP report claims that students need to understand certain key ideas regarding the nature of scientific knowledge. Examples cited include concepts about cause and effect; the use of models to test hypotheses and the social, economic, political and ethical implications of science. Indeed, *'as well as describing major explanatory frameworks the curriculum should also include ideas about the nature of scientific activity and knowledge'* (p 12). In fact, the IAP report recognises that *'these statements look very like the aspirations expressed in many a curriculum document'* (p 12).

Millar and Osborne (1998) have suggested that a curriculum might be more effectively expressed in terms of '*narratives'* on the grounds that such narratives would allow students to choose topics to be studied. It is tempting to surmise that this suggestion is not going to appeal to teachers who are already pressed for time. As stated in the S-TEAM report, *'Many teachers cite the need to cover overcrowded curricula as a barrier to introducing inquiry-based methods'* (p 36).

A goal of the ESTABLISH project is to engage the support of policy makers and agencies responsible for setting national curriculum and assessment agenda, in order to ensure that the benefits of inquiry are recognised and supported in formal educational processes. It will also be necessary to ensure that various other initiatives in science education are co-ordinated effectively with the work of this project and this can only be achieved with the active involvement of these personnel.

4.2 Assessment Processes

The NRC (1996) identifies the obstacles to IBSE as including an overloaded curriculum that leads to lack of classroom time and the 'tyranny of testing'. However, many teachers have expressed their belief that, even if they were to honour the spirit of curriculum aspirations, their efforts would be undermined by the demands of official assessment processes. The IAP report also clearly identifies this concern:

> *'…the scheduling of lessons has some influence on teaching methods, but by far the greatest influence comes from the forms of student assessment that are used'* (p 13).

No one would argue that assessment is not necessary. The issue is around the purpose of the assessment and the assessment instruments used. As stated in *National Science Education Standards (NRC, 1996, pp. 5-6);*

> *'…assessments provide an operational definition of standards, in that they define in measurable terms what teachers should teach and students should learn'.*

Assessment can serve many purposes and can occur at many stages of the learning cycle. Teachers can set classroom tests and assign home work. Schools can organise tests that simulate the officially recognised examinations. The outcomes of such in-house assessments can be used for both formative and summative purposes and may result in adjustments to the teaching process. However, it is reasonable to assume that, in essence, such outcomes are measured against the standards set by the official assessment policy, i.e. that official assessment requirements are given priority by teachers when making decisions about teaching methodologies.

It is common to distinguish between formative assessment and summative assessment and it is generally accepted that both are central components of any effective assessment policy.

Even official assessment documentation may aspire to different forms of assessment. For example, the *AAAS Assessment Blueprint* (AAAS, 1998) urges teachers to ask questions that promote 'reflective', as opposed to 'reflexive', thinking. The *Guide for Teaching and Learning (Committee on Development of an Addendum to the National Science Education Standards on Scientific Inquiry)* suggests that IBSE assessment should be designed to measure three major learning outcomes namely:

- conceptual understanding,
- understanding about inquiry, and
- ability to perform scientific inquiry.

Black and Wiliam (1998), having reviewed almost 600 articles on formative assessment, and suggest that if students were trained in self-assessment, they could understand the purpose of their learning.

The AAAS suggests that:
'One way of involving students in assessment is to engage them in devising the scoring guide for a task or project. Their first person statements, "I explain my ideas clearly and in detail," and "I used words, numbers, drawings, tables, diagrams, or graphs to show my ideas," are the students' translations of the performance standards for inquiry abilities' (www.project2061, Ch 8).

In addition, an assessment system can include a number of different instruments. For example, the *New Standards Project* (New Standards, 1997) recommends a system with three elements - performance standards, examinations, and portfolios. One example of a performance standard is 'working productively in a group'. It is clear that this is best assessed by observation on the teacher's part. Indeed, certification forms for this are available for the teacher's use. Of course, this raises the central issue of schools assessments and their part in the summative conclusions for graduation awards.

The Assessment Reform Group (ARG) states: *'Assessment for Learning is the process of seeking and interpreting evidence for use by learners and their teachers to decide where the learners are in their learning, where they need to go and how best to get there'* (p 10). Clearly, this is a reference to formative assessment but it stresses the students' part in using such assessment, in discussion with their teachers, in order to further their own learning. No doubt many teachers would perceive that this process would demand a significant amount of classroom time.

It is clear that formal summative assessments are frequently used to make critical decisions on third level placement (such as in the Irish 'points system') and on career choice. As such, the reputation of teachers and schools may rest on such outcomes. Naturally, teachers will be reluctant to take any changes in teaching style on board if such changes are not proven to support the required outcomes since their own reputations and that of their schools will be at stake.

A basic tenet of inquiry is the claim that students learn best with a hands-on experimentation approach rather than being given information about outcome of an experiment. Nevertheless, the NRC review of high school practical work found that, even when official documentation calls for hands-on practical work, such work may not be carried out in the spirit intended. For example, it was found that, in New York State, lab work is carried out only because of possibility that laboratory reports might be reviewed by inspectors.

Also it is probably true that those who develop assessment systems are obliged to design measures that can be defended and that are relatively easy to apply. This must be particularly so in regimes where the outcome of examinations attracts rewards such as preferred access to third level places and better career prospects. Many countries publish school league tables in which the 'best schools' are those that achieve the best results in official examinations and those that supply most third level entry students.

4.3 The Curriculum and IBSE

How can IBSE be embedded in the curriculum so as to influence teaching and assessment practices? On the evidence available, and on current knowledge on the dynamics of change, it is reasonable to tentatively suggest that the necessary condition is to alter the official assessment systems so that the measures involved relate to the characteristics of inquiry. It then follows that the curriculum must also be changed to accommodate the timetable and scheduling necessary for the teacher to facilitate inquiry-based activities. It then follows that the teacher must be able to deliver such sessions and, therefore, must be provided with opportunities to develop the relevant competencies required. By 'competencies' here we mean the sum total of all the attributes necessary to be effective in the school and classroom e.g. 'knowledge, skills and disposition' (Kerr, 2009, p 164)). It also encompasses the concept of 'self efficacy' as applied to teachers' beliefs in their own abilities' (Leithwood & Beatty, 2008, pp 45-60).

Indeed, it can be reasonably claimed that the three factors, curriculum, assessment and teacher education, comprise both the necessary and sufficient conditions to drive change in classroom practice towards IBSE. However, as discussed later, the timescale for agreeing and implementing significant changes in curriculum and assessment is quite long. In alluding to the fact that science education research output is rarely implemented the ESTABLISH Annex I remarks that:

> '*This clearly indicates a mismatch between the knowledge gained by the researchers in science teaching and learning and the implementation of it by teachers, curriculum developers and assessment bodies.'* (ESTABLISH, p 6)

This mismatch is unlikely to be rectified in the short term. Accordingly, an appropriate way to promote inquiry approaches is through the mechanism of appropriate inquiry-oriented teacher education. At the same time, fundamental changes in curriculum and assessment policies and practices need to be pursued with the ongoing support of the other stakeholders.

4.4 Educational Continuity

An additional policy related issue that merits attention is educational continuity. The IAP report has drawn attention to *'... experience and research showing that the development of scientific ideas, skills and attitudes begins in the earliest years and is well advanced by the time students leave primary school'* (IAP, 2010, p8). In other words, it would be more likely that the output of scientifically able students from second level could be increased if the intake of such students from primary were greater than current levels. However, it may also be true that students who reacted well to primary level teaching are deterred by the styles adopted by teachers at second level. Either way, the question of educational continuity requires attention. This continuity issue has been deemed to be an important challenge for IBSE programs. As reported from the conference New Milestones for Inquiry-based Science Education in Primary Schools in Europe (Berlin, 2008) '*successful implementation of IBSE is a complex and long-term undertaking*' (www.oecd.org/document/4/0,3746,en_2649).

Why should this be so? One compelling reason is that education is a system with multiple sub-systems, including, curriculum, assessment, materials, teacher training, school management and various stakeholder interests. This complexity is illustrated by the findings of the IAP (IAP, 2010, p19) report which identified six issues associated with efforts to introduce IBSE into secondary schools where traditional teaching methods are used. These are:

- The demands of the curriculum content and lesson schedules.
- The impact of tests and examinations – particularly the use of results for 'high stakes decisions affecting students and teachers'. This 'creates pressure which distorts content and teaching methods, deters the use of inquiry and obstructs the formative use of assessment by teachers'.
- The relevance of science as perceived by students.
- Teachers' subject knowledge.
- The use of new technologies, which although it has many benefits can produce situations where students learn in isolation.
- The balance of continuity/discontinuity at transfer from primary to second level. 'An abrupt change in school culture, organisation of teaching and nature of science teaching at transfer from primary to secondary school can cause a decline in performance and in affective response to science'.

5. Teachers

Arguably, teachers play the central role in implementing IBSE since the delivery of teaching methodologies is critically dependent on the personal performance of the teacher in the classroom. Indeed the Rocard report (Rocard 2007, p8) identifies teachers as such, *'Teachers are key players in the renewal of science education'*. However, the central issue appears to be that IBSE demands a different style of teaching and this may be so different that many teachers would have to make significant shifts in style in order to accommodate it.

> *'It requires a mind-set change on the part of the teacher away from a deductive approach where the teacher often presents the concepts and information, including results of experiments* even *before the student carries them out, to a more inductive approach where the teacher creates the atmosphere to allow for student observation, experimentation, planning, and through teacher guidance, students can construct their knowledge'* (ESTABLISH, p 9).

Many commentators such as Postman and Weingartner (1969) believe that this is so. Accordingly, any significant move to inquiry-based teaching practice is dependent on teachers' willingness and ability to adapt to the requirements of IBSE. Teachers face a number of obvious challenges in this respect. Among such challenges are the different perspectives on IBSE; the significant shift in classroom management style required; the demands of the curriculum and related assessment processes; and the mixed abilities and interests of students in the average class.

5.1 Perspectives on IBSE

There are many varying perspectives on inquiry. Some viewpoints take the form of a definition containing a catalogue of processes such as 'diagnosing', 'critiquing', 'planning' and 'researching' (Linn et al, 2004), while others are more philosophical in essence, alluding to general areas of knowledge such as the 'Nature of Science' (NOS). 'Scientific literacy' is often quoted as a critical outcome of the inquiry-based approach (Osborne, 2002).

The S-TEAM report (S-TEAM 2009) observes that '*…there is no consensus regarding what productive inquiry entails, especially in early grades and it is not clear what teachers should be looking for and trying to promote'.*

Nevertheless, it seems to be generally accepted that it is possible to use an inquiry approach and that such an approach can be blended with other forms of pedagogy as set out in the Herron Scale (1971) which identifies different forms such as 'open' and 'guided'. La Banca (2006) recognises that the feasibility of introducing widespread use of open inquiry is low in view of curricular demands and teachers' lack of research experience. Apparently, in view of these difficulties teachers tend to use 'coupled inquiry', a blend of guided and open methodologies (Martin-Hansen, 2002).

5.2 Classroom Management Style

Essentially, even for guided inquiry, the teacher's role shifts to that of an advisor/facilitator. The demands on teaching style are then quite significant. Teachers must facilitate group work, argumentation, dialogue and debate, and provide for exploration and experimentation as described in the IAP report from the *Working Group on International Collaboration in the Evaluation of Inquiry-Based Science Education* programs (IAP, 2006).

In addition, more control passes to the student and this can be difficult for some teachers to cope with, especially teachers who have experienced years of successful traditional teaching (Brown, 1992). No doubt effective teachers are well versed in posing searching questions in the class for formative or other reasons. However, if IBSE requires strategies such as 'wait time' (Rowe, 1974) or decisions regarding 'discourse moves' (Tzialli et al 2007), the demands on flexibility and time may become significant. While doing all this, teachers should succeed in stimulating the student's curiosity.

> '*School practices sometimes diminish curiosity from the important goal it should be. Curiosity is a quality that serves the sciences well and is a key element in what makes a science-literate person…. A curious student is one we all want to have and foster in our classrooms, especially in the science classroom.'* (Glasgow et al, 2010, p 3)

5.3 Curriculum and Assessment

'*Much of the time, we teachers haphazardly meander through a maze of different topics, under the banner of "coverage."'* (Glasgow et al, 2010, p 2). There is no doubt that the requirements to cover content, as set out in many science syllabi, is seen as a severe impediment to the introduction of IBSE. This is exacerbated by the fact that most meaningful assessment processes (i.e. meaningful in terms of academic award status) do not reward attention to inquiry. These topics are discussed elsewhere in this report, but it is self-evident that teachers will not undertake innovative processes which damage their output as measured by the authorities or their peers.

5.4 Student Characteristics

IBSE based classes also present a challenge for many students. Many are not familiar with the concept of a hypothesis, cannot relate data to a hypothesis and avoid hypotheses that they feel have high chance of rejection (DeJong & Van Joolingen, 1998). They also tend to work with irrelevant variables, manipulate too many variables simultaneously and have difficulty with graphs (Guide for Teaching and Learning, 2000 p79). In addition, individual learning preferences vary considerably (Kolb 1984; Honey & Mumford 1982, 1983; Fleming, 2001). This implies that teachers should use different forms of inquiry teaching with different students, clearly not a very practical suggestion.

5.5 Teachers and Change

The topic of teachers undergoing change has been the subject of much research, as summarised by Loucke-Horsley et al (1998). A number of inherent features have been identified, including the following:

- Change takes time and persistence. Teachers need time to master new behaviours.
- As individuals progress through a change process, their needs for support and assistance change.
- To be effective, change must be clearly defined.
- There must be opportunities to collaborate. Ironically, the consultative and collaborative approach to change can result in long time scales for implementation. Lindner et al 200, in summing up research different approaches to school administration state that *'consultations could take nearly ten years before an innovation process is launched'*.
- Policies and administrators must support the change.
- Most systems and institutions resist change.

These principles have clear implications for the whole education system and must be taken into considerations when developing IBSE related professional development programmes for teachers. Laius et al (2009), following a research study in Estonia, specifically report on teachers' readiness to change. They found that one third of the chemistry teachers involved were not ready for change. The teachers found that changing the traditional classroom environment to a student-centred approach was the most difficult task and that the curriculum was an obstacle.

5.6 Teacher Education

Most teacher education programmes appear to inform their students about Inquiry Based Science Teaching (IBST) but it seems that most don't offer specific training in inquiry related techniques. For example, the S-TEAM report observes that in Germany '*the issue of wider dissemination of classroom IBSE is not a theme in most teacher education programmes'*. The report also remarks that in Estonia some programmes 'cover' IBSE while in the Czech Republic any IBST that does occur does not translate into classroom practice, while in Cyprus IBST may be taught in some teacher training programmes but is not mandatory. (S-TEAM p17).

If, as previously mentioned above, teachers require a new mind set in order to adopt IBSE as their normal approach, it is reasonable to state that teacher education programmes should be designed to develop this new attitude and persuade teachers of the value of inquiry methods. In addition, there is the question of what teachers should be taught. For example, it has been claimed that:

'... if the goal of science teacher education is to prepare teachers to teach for scientific literacy, then instruction on the nature of science (NOS) should be an integral part of teacher education'

(National Science Education Standards, www.nap.edu/openbook.php?record_id=4962).

Obviously, the goal of science teacher education will always be closely related to the role that teachers are expected to play in the classroom and this will be largely determined by curriculum and assessment requirements.

It is normally assumed that a change in belief precedes a change in behaviour. However, there is evidence that teachers will change their belief patterns if they try out a new mode of practice and see that it works.

'The conventional wisdom has been that changing teachers' thinking or beliefs will produce new behaviors. Research on teacher change, however, indicates that the process often works the other

way around: changes in attitudes or belief patterns often result when teachers use a new practice and see their students benefiting from it' (Guide for Teaching and Learning, 2000, p145).

Thus, tentative changes in teaching practice often result in new attitudes and commitment to the new approach. This suggests that it may be easier to convince teachers to experiment with IBSE on a small scale rather than attempt to convert them a priori at the levels of attitudes, beliefs or values. It has also been suggested that teachers progress through various cognitive and affective stages when confronted with the need to introduce a new teaching practice that demands significant changes in behavior. (Fullan,1991; Hall & Hord, 1987; Huberman & Miles, 1984). These 'stages of concern' are presented in Table 2. It is claimed that being aware of these stages can enhance the change facilitation process (Lieberman & Miller, 1991; Joyce & Showers, 1990).

Stage of Concern	Expression of Concern
6. Refocusing	I have some ideas about something that would work even better.
5. Collaboration	How can I relate what I am doing to what others are doing?
4. Consequence	How is my use affecting learners? How can I refine it to have more impact?
3. Management	I seem to be spending all my time getting materials ready.
2. Personal	How will using it affect me?
1. Informational	I would like to know more about it.
0. Awareness	I am not concerned about it.

Table 2: Teachers Expressions of Concern extracted from Inquiry and the National Science Education Standards: A Guide for Teaching and Learning (2000); adapted from Hord et al., 1987. *Taking Charge of Change.* Alexandria, VA: ASCD

Teacher education has been called 'the best solution but the worst problem' (Fullan,1993). It is reasonable to state that teachers will not attend a professional development programme unless (a) they are motivated to do so and (b) have reasonably easy access to the programme. The first is a matter of awareness and conviction about the value of IBSE and the second is about time and, possibly, funding. All of these areas could be addressed by official policy. Indeed, it will be absolutely necessary for policy makers to consider these points if the necessary critical mass of IBSE teachers is to be generated.

No doubt there are many effective science teachers in all schools – teachers who engage and enthuse students who then go on to third level in pursuit of science careers. However, it seems to be generally accepted that many teachers lack the skills required to deliver IBST effectively in the classroom. ESTABLISH partners were asked to estimate the level of influence that teachers and teacher educators have on science/technology education in their countries. It is clear from the responses given that most respondents feel that the level of influence is high. The level of expertise that educators have is the in valuable resource that they offer with funding being the most serious obstacle to their involvement.

5.7 Teacher Organisations

The Rocard report (Rocard 2007) states that '*... being part of a network allows them* (teachers) *to improve the quality of their teaching and supports their motivation.'* Lindner, (Linder 2008, p8) in discussing the SINUS programme in Germany, also stresses the *'positive effects of teamwork, of sharing ideas and classroom materials'*.

Teacher organisations offer a powerful networking capability and, accordingly can do much to propagate the IBSE message among members. They can also play a lobbying role in raising awareness among policy makers, administrators, school management and industry. Barnett & Kitto (Barnett & Kitto 2004) identifed a 'research-practice gap' in science and mathematics education. They believe that this gap exists because teachers have little interest in the findings of educational researchers. Teacher organisations can be the conduit for bringing IBSE related research to the attention of members, thereby going some way to filling this research-practice gap.

Accordingly, ESTABLISH will seek to develop more effective intra- and inter-country teacher networks. This effort will be assisted by the existence of relatively strong existing science teacher associations in some ESTABLISH countries (Poland, Estonia, Ireland, Netherlands, Germany) and mutual membership, such as the International Council of Associations for Science Education (ICASE).

6. Students

Students are considered to be central stakeholders in the education system because they are the primary users of the educational system. Although the quality of teaching can have significant effects on the student's performance, and hence on later career decisions, a student has little influence on teaching styles or general classroom management. Research by Delpit (Deppit 1995) suggests the importance of students receiving explicit instruction in the skills they need to engage in science inquiry and learn from inquiry experiences. However, students are unlikely to realise that that they need such things and are likely to accept what they experience in a science class as the accepted norm.

Undoubtedly, while individual teachers may have engaging personal styles, there are also many other factors that influence student performance. The concept of 'context' appears important to student learning. Bransford et. al. (1999) suggest that activities that are perceived by the student as being 'in context' are critical to learning. Roth and Roychoudhury (1993) suggest that students could develop integrated science process skills in an environment of 'situated cognitive context'.

Not surprisingly, the 'key success factors' associated with student learning are identified as 'interest and motivation' (*Tytler*, 1992). So it is pertinent to ask what the necessary conditions for interest and motivation might be. Some insight may be gained from the five research findings reported by the ACC in a chapter titled *How Students Learn Science.* These are described as:

1. Understanding science is more than knowing facts.
2. Students build new knowledge and understanding on what they already know and believe.
3. Students formulate new knowledge by modifying and refining their current concepts and by adding new concepts to what they already know.
4. Learning is mediated by the social environment in which learners interact with others.
5. Effective learning requires that students take control of their own learning.

Of course it is accepted that students display many different learning preferences but as stated in the Rocard report:

> *'...IBSE and traditional deductive approaches are not mutually exclusive and they should be combined in any science classroom to accommodate different mindsets and age-group preferences.'* (p 7)

Effective teacher education is needed to develop the skills needed to produce this blend in the classroom and thereby, meet the needs of the science students of the future.

The ESTABLISH project believes that the implementation of IBSE, supported by the influential stakeholders, will serve to increase the intrinsic motivation of students, improve scientific literacy and stimulate more informed science career choices. Although it is not expected that student representative bodies can exert much influence at policy or school level it will be necessary to raise awareness among such bodies around the IBSE debate and its benefits. ESTABLISH consortium members have been asked to identify student organisations in their countries. While it seems that such organisations do not exist in all countries, steps will be taken to engage those that do exist e.g. Estonia, Ireland, Slovakia.

7. Parents

It is self-evident that parents, guardians and other primary carers are interested in the efficacy of children's' education. *'Parents want their children to 'do well', 'go to college' or 'get a job…'* (ESTABLISH, p 7). However, in addition to such outcomes it is recognised that parents can also influence their children's learning performance. Drawing on the research cited below, the *National Science Teachers Association (NSTA)* in a Position Statement titled *Parent Involvement in Science Learning*, state that:

> *'...the involvement of parents and other caregivers in their children's learning is crucial to their children's interest in and ability to learn science. 'Parents and other caregivers have a critical role to play in encouraging and supporting their children's science learning at home, in school, and throughout their community. Teachers also play an important role in this effort and can be valuable partners with parents in cultivating science learning confidence and skills in school-age youth.'* (www.nsta.org/sciencematters/qualityscience.aspx#3).

The NSTA claim that children achieve greater success and are more engaged and confident as learners, when parents are involved in science education. This claim is supported by research which identifies many positive outcomes of parental participation including, self-esteem, academic achievement, and positive attitudes to school (Henderson & Mapp 2002; Pate & Andrews 2006; Cotton & Wikelund, 2001).

Most modern schools attempt to engage parents via channels such as newsletters, consultation, membership of parent/teacher groups or management boards and involvement in school events In addition parents are frequently expected to sign homework.

These modes of engagement fit one or more of the six types of involvement defined by Epstein (1992), as summarised below:

- Parenting: 'Help all families establish home environments to support children as students'.
- Communicating: **'**Design effective forms of school-to-home and home-to-school communications about school programs and children's progress.'
- Volunteering: 'Recruit and organize parent help and support'.
- Learning At Home: 'Provide information and ideas to families about how to help students at home with homework and other curriculum-related activities, decisions, and planning.'
- Decision Making: 'Include parents in school decisions, developing parent leaders and representatives'.
- Collaborating with Community: 'Identify and integrate resources and services from the community to strengthen school programs, family practices, and student learning and development.'

Of course, there are parents who do not have the motivation to become involved. Even among those who are motivated, it can be difficult to allocate sufficient time to school-related pursuits. Indeed, the *Family and Parenting Institute* in the UK advise schools to be aware that *'only a very small number of parents will want to be actively involved in formal mechanisms like Parent Teacher Associations (PTAs) or as school governors'*. It is also recognised that many parents have had negative experiences during their own schooling (www.familyandparenting.org).

Even though small numbers of parents may wish to be actively involved, they still constitute an important stakeholder group. Parents can be very influential at community level and many are involved in other youth development activities and other local pursuits. Above all, they are interested in the quality of education and the future welfare of their children.

ESTABLISH partners were asked to estimate the level of influence that parents and parents associations have on science/technology education in their countries. Responses indicate that in many countries parents and associations are deemed to have some influence. As with other stakeholder groups, this is taken as a sign of a fund of goodwill among parents that can be drawn on in support of ESTABLISH and related IBSE programmes. Consequently, parent organisations (e.g. Irish Parents Association; the Parents' Union in Estonia and the AKS in Malta) will be informed of the benefits of IBST and encouraged to engage in the debate and to promote the initiative through their network of local branches and through communication with local teachers and political representatives. Again, any relevant European umbrella organisations will also be included.

8. School Management

The literature on organisation change frequently emphasises the systemic nature of the change setting, whether that setting is a business organisation, a voluntary body or a school. (Cummings and Worley, 2009) Of course, it is generally accepted that some individuals will always be reluctant to change. Indeed Lawrence (1969), in a paper since considered to be a 'classic', claims that individuals are the primary source of resistance because the change threatens the embedded social relationships that provide certainty and meaning in the work setting on a daily basis. It is sometimes difficult to alter the habits of a lifetime.

A school is a social system and, as such, has developed a particular culture over time. Behaviors that have proven to be functional over and that have delivered results (by some accepted measures or measures) cannot be easily changed. The S-Team countries reported that new teachers find it difficult to introduce innovative teaching practices and that they generally revert to the traditional culture of the school. (p8). This is not surprising since, in most organisations, new employees are usually not empowered to introduce novel practices. Culture is not usually malleable and this suggests that systems must be 'unfrozen' (Lewin, 1951) before they can be changed. This unfreezing is unlikely to happen without the full support of school management.

'School principals, district administrators, and teacher leaders (including department chairs) are essential links in the adoption of inquiry as a way of teaching and learning.' (Olson et al, 2000, p 143).

Leadership from principals or other influential teachers is known to be critical to the quality of teaching and learning in schools (Fullan, 1991; Prather, 1996). It is also possible that, in many cases, those in authority in a school do not perceive the need for any change in the way science is taught. A record of excellence and history of good exam results do not motivate any desire for a change in teaching styles. Of course, this is closely related to the assessment debate which is discussed elsewhere in this report. However, if progress is to depend on a revolutionary change in national assessment processes, the advocates of IBSE might be in for a long haul. In the interim, it is critical that principals and other in-school influencers be persuaded of the benefits of IBSE for their students and for society at large. They might be encouraged to undertake some of the following suggested tasks.

- Become familiar with the research on IBSE in order to understand its implications.
- Encourage science teachers to attend an IBSE familiarisation and training programme.
- Actively support a teacher who returns from such a programme and encourage the incorporation of IBSE methods in the classroom. The difficulty in transferring skills from the training environment to the workplace (from the 'workshop to the workplace') is a familiar phenomenon. (Heaven et al, 2006; Singh et al, 2003).
- Chair a staff discussion on IBSE – such a debate might be carried out under the umbrella of active learning or cooperative learning in order not to isolate science teachers as the sole focus of attention.
- Support regular feedback sessions on in-class experiences.

In those countries with a school principals' representative association it may be advantageous to communicate an IBSE message through that organisation. For example, in Ireland the *National Association of Principals and Deputy Principals* represents senior second level school managers. Even in the absence of national policy, leaders can drive significant change in organisations (Kim & Mauborgne, 2011). A school is a relatively complex social system and as such requires strong leadership if it is to be effective.

'Growing consensus on the attributes of effective school principals shows that successful school leaders influence student achievement through two important pathways - the support and development of effective teachers and the implementation of effective organizational processes' (Davis et al, 2005, p 8)

With reference to the Pollen project, Jarvis et al reported that *'teachers who felt supported by school management were generally more positive about the project'* (p 48).

ESTABLISH recognises that significant progress will not be made without the energetic and active support of school management who carry prime responsibility for the development of a positive professional work culture and the evolution of the school as a dynamic learning organisation. Such schools have been defined as those that:

' employ processes of environmental scanning; develop shared goals; establish collaborative teaching and learning environments; encourage initiatives and risk taking; regularly review all aspects related to and influencing the work of the school; recognise and reinforce good work; and, provide opportunities for continuing professional development'(Silins et al, 2002, p 24).

9. Industry

There are a number of reasons why industrial partners might wish to support the dissemination of IBSE practice in second level schools. A continuing stream of STEM and other graduates with high levels of science literacy is important to the sustainability, competitive positioning and research capability of many organisations. In fact, industry often attempts to influence educational practice when a skills lack is perceived. For example, there is a strong industry presence in the US 'Educate to Innovate' initiative. Senior industry executives frequently comment on the education system. For example, in Ireland, a senior Google manager has spoken of the challenge in recruiting STEM graduates (www.siliconrepublic.com).

In addition, many companies profess a corporate social responsibility (CSR) policy which supports involvement in education and community related projects and activities. For example, in the last decade, Intel has invested more than $1Bn educational programmes across more than 70 countries. (Roth 2010). In the UK, Shell sponsor many science education activities including science workshops in schools, family science days and teacher training. The CASCADE teacher training programme is designed to *'help trainee teachers extend their portfolio of teaching styles and support them with delivering the Science Enquiry strand of the National Curriculum'* (www.shell.co.uk).

In the ESTABLISH Work Package 2 survey, WP2 contact points in the participating countries were asked to estimate the strength of influence that the various categories of stakeholders exert on science/technology education. The findings from these responses are outlined in Appendix 1. Some interesting findings are noted from these responses.

Respondents were asked to assess the level of influence the industry has on science/technology education in their countries on a scale of 1 (Little Influence) to 5 (major influence). Scores were generally low except in Netherlands and Slovakia where certain industries/companies seem to have greater influence.

Respondents were also asked to provide the names of the industrial stakeholders that have supported change in science education and to rank the level of such support under four categories, namely:

- Funding
- Lobbying policy makers
- Providing educational resources/ programmes
- Expertise

Responses indicate that there has been some level of support from individual companies or institutions in most countries. This may indicate a positive base on which further involvement can be built by well conducted promotional exercises.

Respondents were also asked to select the factors that 'might prevent industrial stakeholders from supporting the introduction or implementation of IBSE' from the following list:

- Lack of funding
- Lack of commitment
- Lack of interest
- Lack of short-term return
- Lack of expertise.

Each of these factors was considered to be relevant but no specific patterns emerged. It would seem reasonable to infer that all probably apply. It is also probably true that most respondents may not be familiar with the mission or the corporate perspectives on science education of the individual business enterprises in their respective countries.

In a report entitled *Encouraging Student Interest in Science and Technology Studies* (2008), the *OECD Directorate for Science, Technology and Industry* states that, to encourage interest in science and technology (S&T), it is necessary to tackle a number of issues outside the education system in order to improve the image and knowledge of careers. Industry can part a significant part in this effort.

Science and Technology in Action and ***Spirit of Enterprise*** are two Irish examples in which the classroom lessons and cases published are financially supported by private and state companies. Many companies also offer site visits, provide speakers or sponsor 'science quizzes' in schools in the local community. As part of the work in ESTABLISH, organisations currently partnering in the

Science and Technology in Action school resource in Ireland (e.g. Intel, Dell) will be asked to link with their corporate branches in the other partner countries and with all relevant local and European businesses in their supply chain. The objective here is to develop a broad European industry network of firms that will promote the cause of IBSE in their spheres of influence. Similarly, those private and public organisations with a science research mandate will be encouraged to support the project and to network with their equivalent organisations in the partnering countries in the promotion of IBSE.

10. Engaging the Stakeholders

Mitchell et al (1997), having reviewed the current state of stakeholder theory, claim that stakeholders can be categorised in term of relationship attributes. Two such attributes are *power* and *legitimacy*. Although their research relates to the field of management we suggest that these attributes can be usefully applied to the ESTABLISH stakeholders and their relationship with education. It seems reasonable to claim that all these stakeholders possess a high level of legitimacy but that power is distributed unevenly.

There are many models of power such as those set out Yukl (1998) and Green & Elfres (1999). Yukl identifies three types of stakeholder power:

- Position power, which derives from legal or other formal authority
- Personal power, which derives from relationships, influencing skills or charisma
- Political power, which can arise from formal or informal control over decisions or resources.

As applied to the ESTABLISH stakeholders and their capability to influence the future course of science education, it is suggested that:

- Policy makers possess a high position and political power base.
- Teachers have some personal power and potential political power through their representative bodies.
- Teacher Education Institutions have potential political power if they are based in prestigious institutions.
- Parents have political power in their communities and on an larger scale through a representative organisation.
- Students have little power but can mobilise support via parents and through a representative body.
- School Management has high position locally and can mobilise high political power through representative bodies.
- Industry, as employer and focus of much local commercial activity possesses a high level of political power.

Of course, there is a difference between potential power and power as actually exercised in practice. By engaging with stakeholders the ESTABLISH project will attempt to persuade those with high power (policy makers) about the merits of IBSE, and encourage those with potential power (industry, parents, teacher organisations, school management) to play their part in bring about the necessary changes.

11. Types of Engagement

Stakeholders may be engaged in several different modes. One model (www.dse.vis.gov) that has been identified for this is as follows:

- Inform: *'...know you are trying to reach and how they are most likely to access and understand the information…'*
- Consult: *'…ensure that purpose of the consultation is clear, including what is being consulted on and what is non-negotiable…'*
- Involve: *'…work with the community to ensure their concerns are directly reflected in alternatives and solutions…'*
- Collaborate: *'…there must be clarity about the extent of decision making power that is delegated, and, in particular, what is not …'*
- Empower: *'…empowered communities share responsibility for making decisions and accountability for the outcomes of these decisions…'*

It is clear that these types of engagement are designed for government relations with the community. Nevertheless, models such as this have much to offer projects such as ESTABLISH which are attempting to co-opt communities to the use of IBSE. All ESTABLISH stakeholders will be asked to undertake certain actions which will, for example, proactively promote and disseminate information about IBSE and support local schools in introducing any innovative pedagogical processes that may emerge from the project.

12. Support of ESTABLISH IBSE Units

A key objective of the ESTABLISH project is to engage relevant industries in support of the IBSE units being developed in this work. For this purpose, a report entitled the "***Engagement of Industrial Partners"*** has been prepared which outlines the number of ways that an industrial partner may contribute to these IBSE materials. These include:

- Exercising influence on policy makers e.g. writing to local or national representatives about the relevance of IBSE.
- Provision of funding e.g. for the dissemination of a unit to schools.
- Provision of resources e.g. materials such as a company video that is relevant to a given unit; publishing relevant information of their website.
- Provide expertise e.g. classroom visits by practising scientists.

However, a particular industry will need to know exactly what is required of them and this will depend on local conditions. For example, it is unlikely that a company can provide class visits on a national basis.

13. Synergy with Other Projects

'The current initiatives in Europe actively pursuing the renewal of science education through "inquiry-based" methods show great promise but are not of the scale to bring about substantial impact, and are not able to exploit fully the potential European level support for dissemination and integration' (Rocard, p7). This situation was recognised in a statement in an earlier report *Increasing Human Resources for Science and Technology in Europe (*2004, p 186). '*There is an urgent need for a comprehensive European strategy for enhancing the development of scientific culture across Europe.*'

Appendix 2 lists five FP7 projects concerned with teacher education in IBSE. A total of 32 countries with a total of 99 partner organisations are involved in them with 15 of the countries involved in three or more of the projects. One of these recent projects (PROFILES) aims at raising the 'self efficacy' of science teachers and will do this through '*an inspired longitudinal training programme reflecting stakeholder views'*. The concept of longitudinal programmes is key to effective introduction of sustainable change in teaching norms. Many teachers feel this is true, as reported by Jarvis et al, (following research relating to the Pollen programme on teacher confidence and attitude) who recommend *'staged long term in-service over several years'*. Of the 20 countries represented in the PROFILES project, eight are also participating in the ESTABLISH project.

In the classroom, the teacher is the change agent. As such, like all change agents, they must have the vision, the certainty and the energy to work through the inevitable difficulties that accompany most worthwhile change efforts. The only intervention capable of creating a critical mass of teachers committed to IBST is teacher education, which has been referred to as *'the best solution but the worst problem'* (Fullan 1993). The most effective way to deal with this challenge is dynamic and continual inter-project co-operation between these project partners.

In addition, there are other projects which have much insight to offer in terms of stakeholder engagement, notably Sinus, Sinus Transfer and Pollen. As stated in the ESTABLISH Milestone 2,2 report (*Identification of Models of Stakeholder Cooperation in Facilitating IBSE*):

> *'Many of the projects are multi-country and involve a range of tertiary educational institutions in the conduct of the project. In many instances, different institutions in the same country are involved in different IBSE projects. This would seem to offer scope for powerful inter-project cooperation when targeting the stakeholders in a particular country*.'

In fact, ESTABLISH is a founding member of the EU-wide initiative Project Coordinators Netwrok (ProCoNet). This initiative brings together the Coordinators of IBSE related projects to discuss matters of mutual concern. Currently 16 international projects are involved. The overall purpose of this network is '*to improve levels of pupil engagement with science, increasing scientific literacy and the numbers of pupils choosing science-based careers so as to reach the objectives of Europe 2020*' (ProCoNet Interim Report, June 2011).

14. Conclusions

This report has described those elements that influence classroom practice and claimed that these forces derive their effect through the actions of various categories of stakeholders. This indeed is the rationale for the wider collaboration with stakeholders towards meeting the goals of this project – the widespread implementation of IBSE in the classrooms of Europe. While these stakeholders can be addressed in parallel and, indeed, it is the mission of ESTABLISH do so, it is also necessary to make any short term gains that might move the system in the required direction. Therefore, it is necessary to ensure that IBSE in introduced to as many teachers as possible without waiting for fundamental changes in national curricula and assessment policies. These required changes will not be introduced quickly. Accordingly, it is reasonable to propose at this stage that most energy should be focused on teachers (awareness and skills training) and, where possible, on school management, without whose influence school cultures might remain static. In this way, ESTABLISH may be able to influence the *'... small number of critical factors that go together to create the chemistry of widespread improvement'* (Mourshed et al, 2010, p 6).

Indeed, there is evidence that change can be effectively managed by building on existing strengths rather than by concentrating on perceived 'problems'. The approach known as *Appreciative Inquiry* is a 'non-deficit' model of change (Cameron et al, 2003). Such an approach would recognise the current abilities of teachers and develop those abilities in the context of existing environmental facts such as curriculum, assessment and mixed ability classes. This is not to suggest that efforts should not be made to influence the curriculum and assessment authorities. This must also be done. However, if teachers are willing and capable of introducing inquiry with existing curricula and still achieve effective results, students and parents will be likely to respond more readily. Of course, these things would be easier to achieve if Continual Professional Development (CPD) were compulsory in all countries and the relevant teacher education institutes were supported in delivering sufficient numbers of IBSE programmes. Since these conditions are not met, it is necessary to persuade teacher education institutions to produce dynamic and attractive programmes, and also to attract large numbers of teachers to them.

The report of the *Working Group on International the Evaluation of Inquiry-Based Science Education (IBSE) programs* (IAP 2006) has called for the establishment of local evaluation teams in all countries implementing IBSE programs to monitor and assess the impact of such programmes. The teams referred to are national teams and, accordingly, it is likely to be some time before such institutions and processes are set up. Nevertheless, the concept of monitoring is attractive and it may be more viable to establish teams at a sub national local level, similar to the Pollen model. In the interim, ESTABLISH will consult with all stakeholder groups in order to raise awareness around IBSE and secure the engagement and support of these groups.

As the work of ESTABLISH is engaged in a major change exercise and, accordingly, it can be instructive to consider models from this literature. Most such models for change recognise the need for stakeholder support, as illustrated in the following Table 2 (Cummings & Worley, 2009, p 164) which defines the various components of change management.

Motivating Change	• Creating Readiness • Overcoming Resistance
Creating a Vision	▪ Describing the Core Ideology ▪ Constructing the Envisioned Future
Developing Political Support	▪ Assessing Change Agent Power ▪ Identifying Key Stakeholders ▪ Influencing Stakeholders
Managing the Transition	▪ Activity Planning ▪ Commitment Planning ▪ Managing Structures
Sustaining Momentum	▪ Providing Resources ▪ Building a Support System for Change Agents ▪ Developing New Competencies and Skills ▪ Reinforcing New Behaviours ▪ Staying the Course

Table 2: Components of Change Management, extracted from Cummings & Worley, 2009, p 164.

It should be noted that change is not usually the linear process implied by such models. There is often much iteration involved, more typical of the *Action Research* model (Shani & Bush, 1997). It is also relevant that the different stakeholder groups may not share a common perspective on IBSE and will require different forms of attention. Indeed, it will be obvious that ESTABLISH is simultaneously active at several of these stages; e.g. vision creation, influencing stakeholders, resource provision and competency building.

It may also be useful to consider the model derived by Mourshed et al (2010, p18)) during the McKinsey research on improving school systems. Their model identified the following phases in what the authors describe as the improvement 'journey'.

- Ignition – motivation to start the improvement process.
- Establishing the current performance stage.
- Identifying the relevant set of interventions.
- Contextualising – adapting the interventions to the prevailing context.
- Sustaining – ensuring continuous improvement.

This WP2 interim report supports the concept that the optimum way forward is to deliver high quality teacher education programmes in IBSE in the participating countries. This action will increase the number of teachers/schools in which inquiry approaches are used and the number of students who experience IBSE activities. Simultaneously, in collaboration with willing stakeholders, influence should be brought to bear on curriculum and assessment authorities to make the fundamental changes that will embed inquiry in the everyday practice of the whole science education system. In addition, cross-project collaboration will accelerate the formation of the required critical mass of IBSE expertise. This interim report forms the basis of a deeper analysis of the stakeholder actions necessary to drive change in classroom practice in the ESTABLISH participating country, which will be presented by the end of the ESTABLISH project.

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Appendix 1: Overview of ESTABLISH Work Package 2 Surveys

ESTABLISH Work Package 2 surveyed the nominated representatives in the project participating countries on aspects of science education. These data were gathered by means of questionnaires and templates over an extended period.

1. In March 2010 a comprehensive questionnaire was used in order to:
   - gather information about science education policy and practice in each country or region,
   - gain insight into the key stakeholders that influence policy and drive change in the area of science education, and
   - establish the extent to which inquiry is embedded in the curriculum and assessment policies and practice in each country.
2. In September 2010, at the General Assembly meeting in Dublin worksheets were completed by each participating team. Its purpose was to identify actions to influence stakeholders
3. In January 2011 a short questionnaire was emailed to each contact person in order to identify supports for IBSE and barriers to its implementation.

It is noted that the questionnaires used were not subject to any statistical reliability or validity testing and that the data returned reflect the personal opinions of the representatives of the ESTABLISH participating countries. However, these are the opinions of experienced professional science teacher educations and may be considered as reflections of the realities observed by these professionals in the course of their activities.

One important consideration is the extent to which these views coincide with the findings from the literature as reported in this document and the following selection of respondent views illustrates a close correlation with some comments.

- Although IBSE is recommended or specified in the curricula in most (ESTABLISH) countries it is not explicitly assessed in most countries.
- IBSE implementation is not uniform within or between countries.
- Of the eleven countries represented by ESTABLISH, just five implement national teacher education programmes for in-service teachers, some of which began as early as the 1970s.
- The main barriers to the implementation of IBSE perceived are insufficient time, lack of resources, the overloaded curriculum and insufficient training.
- Although there is divided opinion as to whether the current curriculum is appropriate for IBSE, there is general agreement that IBSE would require a different kind of curriculum
- IBSE requires more time than traditional methods.
- New forms of assessment are needed which do not disadvantage IBSE.
- Teachers are not confident in using IBSE methods.
- Many teachers need deeper understanding if they are to facilitate students' engagement with challenging tasks.

- Many teachers appear to perceive inquiry-based approaches as an ‘add–on’ which would demand more time, rather than an integrated part of their teaching.
- In general, teachers have not received adequate training in IBSE methods.
- Opinion was divided on whether teachers are generally convinced of the value of IBSE.
- Students require a good foundation in order to benefit from IBSE.
- Where IBSE is the norm students have more positive attitudes to science.
- Industrial stakeholders can and do influence science/ technology education policy.
- Student and parent organizations not be expected to commit substantial financial resources to supporting the implementation of IBSE but, because they represent a large fraction of the population, they can influence change in other ways.

Appendix 2: European countries involved in some of the current FP7-funded IBSE projects

Country	S-TEAM	ESTABLISH	Fibonacci	PRIMAS	PROFILES
Austria			√		√
Belgium			√		
Bulgaria			√		
Cyprus	√	√		√	√
Czech Republic	√	√			√
Denmark	√		√	√	
Estonia	√	√	√		√
Finland	√		√		√
France	√		√		
Germany	√	√	√	√	√
Greece			√		
Hungary				√	
Ireland		√	√		√
Israel					√
Italy		√	√		√
Latvia					√
Lithuania	√				
Luxembourg			√		
Malta		√		√	
Netherlands		√		√	√
Norway	√			√	
Poland		√	√		√
Portugal			√		√
Romania			√	√	√
Serbia			√		
Slovakia		√	√	√	
Slovenia			√		√
Spain	√		√	√	√
Sweden	√	√			√
Switzerland			√	√	√
Turkey					√
United Kingdom	√		√	√	√