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Pupils Attitudes Towards Technology
Technology Education and Research: Twenty Years in Retrospect

Conference Paper Submission of

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Paper Title:

The need to change pedagogies in science and technology subjects: a European perspective. Implications for Initial Teacher Education.

Abstract

This paper evolves out of a consultancy which was carried out with the European Commission over a two year period.

At a meeting of European Union Ministers held in Uppsala (2001), the importance of increasing recruitment to scientific and technological disciplines of education was highlighted.

A working group, comprising representatives from member states, stakeholders and social partners involved in science and technological education, was subsequently set up. Its remit was to identify good practice in science and technology education across Europe and to make recommendations for policy makers in the area. One important theme which emerged at this stage was a perceived need to develop the type of pedagogies which would encourage the active involvement of pupils in authentic and meaningful learning experiences within these subject domains. A series of questions relating specifically to this area was therefore incorporated into the second phase of the investigation. Qualitative analysis of these questionnaires was carried out

Using the results of these analyses, along with information from discussions, this paper considers the situation in Europe in respect of the introduction of what are essentially social constructivist pedagogies in the field of science and technology. It explores some of the attempts which have been made to implement such pedagogies and, more importantly, the barriers to their introduction which have been identified in a number of countries across Europe. A consideration of research literature in the field is then used to promote the argument that teacher beliefs or theories are a crucial factor in preventing change. The role of these theories in presenting barriers to change are discussed and the implications for the education of teachers across Europe are discussed.

A European strategy for technology and science

Whilst this paper is not an exploration of technology education in Europe over the past twenty years, it will examine important changes in thinking about both technology and science education from a European Union point of view. More importantly it will explore the barriers which are perceived to exist at the level of practice in relation to implementing policy changes.

European-wide concern with the diminishing recruitment to courses and careers in the disciplines of mathematics, science and technology resulted in a meeting of Ministers of Education in Uppsala, Sweden in 2001.

There was a general recognition that scientific and technological advancement is fundamental for the continued development of a competitive knowledge society. It was further recognised that since general and specialised scientific or technological knowledge is increasingly required in professional and daily life, in public debates, decision making and legislation, the acquisition of at least a basic understanding in these areas is increasingly necessary for all. If Europe is to improve its position in the world, there must be strenuous efforts made to encourage children and young people to take a greater interest in the disciplines of technology and science in particular. It was concluded that only by achieving this can the aspirations of Europe to become a

major competitive and dynamic knowledge economy, capable of sustainable economic growth and greater social cohesion be realised.

It was consequently seen as essential that all countries in Europe should both encourage children and young people from the earliest possible age to take a greater interest in science and technology, and ensure the satisfaction, and consequently the retention, of those who had already embarked on careers in the field. It is with issues relating to initiatives that attempt to introduce new pedagogies for science and technology at school level, therefore that this paper is concerned.

Initial findings of the Working Group

An expert group was subsequently set up in September and a consultancy later established. This consultancy involved liaison with the European Commission at regular meetings in Brussels along with the expert representatives of the extended European Union Countries (including the new accession countries).

Although all three areas of mathematics, technology and science were the focus of this group, this paper will focus on technology and science only. Although recognising that these are distinct and separate subjects, the predominant number or experts from the domain of science in the group, along with the conflation of science and technology on many school curricula, resulted in generic issues relevant to both subjects being considered in tandem.

One dominant theme which emerged during the initial discussions, was the importance of changing pedagogy in order to develop more effective and attractive teaching methods. This was seen as a crucial factor in raising interest and achievement in the technological and scientific domain.

There was a recognition that successful learning involves active engagement in the learning process and that in all areas, but particularly in the area of science and technology, education must be "more concerned with interpretation and understanding than in the achievement of factual knowledge or skilled performance." (Olson and Bruner, 1996: 19) The identification of pedagogies which moved away from the transmission of facts or the demonstration of skills towards the development of active, autonomous learners was therefore considered an important area for exploration.

In the initial stage a number of examples of policy initiatives which were attempting to introduce more interesting, active and authentic learning approaches into the technology and science curricula were considered. Some of these were aimed at encouraging interest from an early age through the introduction of authentic hands-on learning experiences in both science and technology at the elementary stages of schooling. (see for example, Barlex; 2003; Benson, 2003). Although science was a mandatory part of the primary school curriculum in virtually all areas of Europe, however, there was less evidence of technology being a mandatory subject at this stage. Where it was included in the curriculum, moreover, it was often integrated with science although in some cases imaginative attempts to integrate both science and technology with other areas of the curriculum, such as language and numeracy had been made. (See for example, Ginns *et al*, 2005)

At secondary level, attempts had been made to introduce team work and communication into the subjects through the development of collaborative working and the forging of stronger links with industry. (see for example, Dakers,2004; Head and Dakers, 2005; Hill and Smith, 2005). Autonomous learning was to be encouraged through the opportunity for pupils to make a choice of topics, the use of library research work and the provision of material suitable for different learning styles. (See for example, Hill and Smith, 2005). The opportunity to work on research projects with university staff was also an important feature of policy in this respect. New subjects such as biotechnology, perceived as having greater relevance to twenty first century curricula were in the process of being introduced. Above all, the need to develop motivated and autonomous learners was clearly recognised through the focus in policy on the development of higher order thinking skills. Hypothesis formation, collation of evidence, synthesis, analysis and problem solving therefore were all identified as important skills to foster in this area. (See for example, Dow, 2005; McCormick, 1997).

In the development of higher order thinking, the importance of the types of goals identified by both pupils and teachers was recognised as being of crucial importance. Interestingly, it was noted in the evaluation of one initiative that pupils who were most concerned with performance demonstrated by good results were found to benefit from and to prefer a more traditional teaching approach. This is consistent with research conducted by Ames (1992) and Dweck (1999) into the differential effects of the adoption of performance or learning goals. Both Ames and Dweck suggest that in situations where performance goals are encouraged, the main concern of pupils is the appearance of competence and the avoidance of appearing incompetent. Competence is equated with good results. This focus on performance, however, is more likely to lead to a subsequent avoidance of tasks which are perceived as challenging. The product of learning (in this case the grade) is considered more important than the process of learning. Pupils who adopt (or are encouraged to adopt) performance goals are therefore less likely to persevere when difficulties are encountered. They are more likely to engage in surface learning and to focus on rote learning. Where learning goals are adopted, however, pupils are more likely to take risks, to welcome challenging tasks, and to develop effective strategies for learning. They are more likely to persevere in the face of difficulty and to be intrinsically motivated to learn. Pedagogies which promote learning goals rather than performance goals, and which take into account the different learning styles of individuals were therefore generally regarded as important in increasing understanding and as having an important potential for increasing levels of interest and attainment for all. It was recognised that although the traditional approach may give the appearance of short term success for some, the promotion of pedagogies which promote the adoption of learning goals were regarded as being more likely to result in more meaningful learning, more active involvement, and consequently greater increases in both achievement and interest over time

Most countries also clearly recognised the importance of teacher support in affecting change. Some had therefore set up either national or regional resource centres both to supply resources and to assist with pedagogy. (See for example, Dakers, 2004). In other areas more informal support was provided through resources such as CD ROMS, and informal networks to provide advice and support for teachers. There was a recognition that Higher Education Institutes and Teacher Training Institutions had

an important role to play in developing confident staff well educated both in subject content and in modern educational theory.

Pedagogy
As the implementation of effective pedagogy in the scientific and technological disciplines emerged as an important issue, a set of questionnaires was devised to explore, in greater detail, the realities of translating policy into practice.

Participating countries were therefore asked to provide information in three broad areas. The first involved the extent to which there was a clear recognition at the level of both practitioners and decision makers, that more effective and attractive teaching methods should be introduced in the disciplines. The second concerned the measures taken to support the development of teaching methods and to describe the role of any collaborative partnerships in this development. The third was the identification of any challenges or difficulties which had been encountered in the attempts to implement changes in pedagogy. It is with this third area that this paper is concerned.

Barriers to effective pedagogy
Whilst it had been clear in the first phase of the analysis that the majority of participating countries were attempting to address the issue of pedagogy in a number of interesting and innovative ways, it became apparent at the second stage that there were significant barriers to change. In almost all cases, moreover, the main barrier identified was the reluctance of teachers at all levels to change. Although the adoption of more attractive and effective pedagogy had been identified as necessary at policy level, there was a clear perception that a problem exists at practitioner level with the representatives from Austria, Belgium (Flemish Community) Cyprus, the Czech Republic, Denmark, Estonia, France, Germany, Hungary, Ireland, Italy, Luxemburg, Norway, Slovakia, Slovenia and Sweden all identifying this as an important area of concern.

The current pedagogical model
It became apparent, both from the questionnaires and from subsequent discussion sessions with the working group, that the legacy of behaviourist, transmission, whole class teaching, in which the teacher is expert and the student merely a passive recipient of knowledge, remains the dominant model in science and technology across most of Europe today.

The mechanistic processes which underly this model reduce knowledge to small discrete components which are learned and subsequently tested in situations completely devoid of any meaningful context. This type of instruction results in a depersonalisation and fragmention of the child's experience, and in its "whole class", assembly line production of skills, estranges children from not only the subject and each other, but from themselves as well. (Grumet. 1992)

"*Within this behaviourist inspired metaphor, the learner is a passive being whose repertoire of behaviours is determined by rewards and punishments encountered in the environment. The metaphor…has straightforward implications for instruction, namely, creating situations that elicit responses from learners and providing appropriate reinforcement for each response. Drill and practice is the epitome of instruction within this view of learning*." (Mayor 1992: 407)

It was a conclusion of the working group, therefore, that a major shift in pedagogy was essential in order to motivate schoolchildren across Europe to participate in an active and meaningful way in technology and science education. The emphasis for this change has its genesis in socially constructed learning which has at its centre the concept of mediation. (See for example, Engestrom *et al*, 1999; Rogoff, 1990; Vygotsky, 2000).

The role of mediation in the learning process

The transmission model is by its nature a monologue in which interaction between teacher and pupil is a one way process. There is, however, a growing recognition in modern educational thought, that effective learning involves active participation in the learning process. Meaning cannot be transmitted but is rather constructed through the process of interaction and inquiry. This necessitates communicative action. (Bruner, 1996; Vygotsky, 1978; Freire, 1970; Dewey, 1974).

Learning does not take place in a vacuum. Humans do not learn simply by constructing their own realities, separate from the cultural, historical, and social environment into which they were born.

According to Vygotsky (2000), the nature of learning or mental processing involves four areas of development: an evolutionary process (phylogenesis); a sociocultural historical process; individual development (ontogenesis), and development through interaction with specific sociocultural settings (microgenesis). (Wells. 1999). It is social in that it involves the interaction of others. It is culturally and historically orientated through community structures which give rise to identity. A society's cultural identity is thus formed through links with its past, mediated through forms of discourse where meaning is co-constructed and reconstituted from one generation to another. This clearly moves far beyond the didactic transmission of facts which is perceived by practitioners as the dominant model of teaching in Technology and Science today. It also highlights the importance of encouraging different cultures to retain their distinct and separate identities and militates against any European wide "one-size-fits-all" solution to the problems of recruitment in the field. What is perceived as good practice in one culture may not easily translate to another.
It was clear in relation to the issue of pedagogy, however, that this was a common concern which in this instance cut across cultural differences.

Perceived reasons for resistance to change
The transmission, mastery model of teaching has its roots in the passive, mechanistic, reductionist theories of behaviourism which strongly influenced educational theory and practice in the 1950s. Despite cultural changes, curriculum reform, policy development, scientific and technological advances and developments in theories of what constitutes effective learning, the prevailing model of pedagogy in schools across Europe has clearly remained in many ways essentially unchanged for more than fifty years. A crucial question for the working group therefore concerned the possible reasons for the persistence of this model in twenty-first century European schools.

Many different potential reasons were explored, both within the questionnaires and at discussions during subsequent meetings of the expert group, in an attempt to account for teacher resistance to change.

The nature of the teaching population

One issue that was common to a number of countries was the existence of a predominantly aging teaching population. In this cases it was felt that an alleviation of the problem might well occur naturally as large numbers of the current teaching force reached retirement and were replaced by a younger, more energetic, motivated and dynamic population of teachers who would be more willing to embrace the necessary change. It this were the case, then changes in pedagogy would occur naturally over a period of years.

There is evidence from research, to suggest, however, that this may in fact be too optimistic a view. The greater influence of the practices encountered by newly qualified teachers in schools over the academic theories encountered in teacher education courses has long been recognised as a barrier to change (e.g. Denscombe, 1982, Zeichner & Tabachinick, 1981) More recently, moreover, Long, 2004, has highlighted the almost insurmountable difficulties experienced by new teachers who attempt to introduce innovative methods into a system in which attempts at innovation are met with either lukewarm support or outright resistance. Although Long describes the situation in the USA, her concerns also find resonance across the European Union.

" Because they are weary of the constant battle to find a place to learn and grow, too many teachers join the status quo or leave teaching altogether. They lose hope, confidence, and, most frighteningly, a sense of themselves as knowledgeable professionals" (Long, 2004: 142)

By these processes, today's potential innovators simply become tomorrow's subvertors of innovation and the whole cycle of resistance to change continues.

Assessment

In attempting to account for the fact that so many new, enthusiastic and innovative teachers are first sucked into and subsequently maintain the status quo, Long, (2004) among other issues, highlights the problem of assessment. This was an area which again found resonance within the expert group, with Cyprus, Estonia, France and the Republic of Ireland all identifying the examination system, especially at the upper secondary levels as an important barrier to change in this respect. The feeling was expressed that as long as examinations concentrate on the reproduction of previously learned facts, the transmission model would prevail. As long as the main function of assessment is perceived by teachers to be a means of accountability, teachers will be reluctant to take the risk of abandoning tried and tested traditional methods and adopting those which essentially involve a relinquishing of control to pupils.

In an attempt to address these difficulties, the Republic of Ireland has made some changes to the system of assessment at junior secondary level with some progress being made by shifting focus from formal examinations to ongoing assessment, with thirty five percent of the final mark being allocated to course work at this stage. Although this example perhaps only defers rather than radically changes the impact of

assessment, France described a more radical approach in the assessment of science at Baccalaureate level with a shift in emphasis from written theory towards the inclusion of assessment of practical work.

Both these initiatives, however, still allow for an emphasis to be placed on summative assessment. It was felt that it may be necessary to focus on the development of more formative assessment procedures in order to allow for a move towards the development of higher order thinking skills now considered important in technology and science education.

This was an area which it was felt required to be addressed at policy level. As long as governments remain obsessed with measurement for accountability purposes, the culture of mastery learning seems likely to remain. Teaching to the test in order to inflate results sends out false messages with its focus on performance rather than processes of learning. Pupils, under these conditions, simply become more and more sophisticated in developing strategies to circumvent the epistemological error of this narrow mastery system. (Friere, 2001). Until this is recognised it seems likely that this particular aspect of teacher resistance to change will persist.

Top-down methods

"Top down" methods of promoting innovation were identified as another contributory factor to teacher resistance to change. Austria, for example noted the scepticism of teachers to "top-down" models of reform, the lack of coordination between government driven and practitioner driven initiatives, along with a deterioration in the working conditions of teachers as important factors in this respect.

That initiatives developed at policy level either do not translate into practice at classroom level or are short lived is well known within the field of education. There is a growing recognition, therefore, that for teachers to have a sense of ownership of new initiatives, it is necessary to include them at the discussion and planning stage. Although Scotland had no representation on the expert working group, there may be valuable lessons to learn from a recent Scottish Executive funded " Assessment is for Learning" initiative which has adopted just such a bottom up approach and which appears, to date, to be having an effect on changing, not just assessment, but through this, the pedagogy of teachers across the curriculum in primary and secondary schools. (Hallam *et al*, 2004) While ongoing evaluation of the programme will be necessary to determine its impact on pedagogy in the longer term, there may well be valuable lessons from this approach for the development of more effective pedagogies in science and technology across Europe.

Teacher education

A lack of appropriate support in the form of pre-service education, in-service training or suitable resources was identified as a barrier by the Czech Republic, Denmark, Estonia, the Belgian Flemish Community, Germany, Hungary, Italy, Slovakia, Slovenia and Sweden. Whereas some countries such as Estonia, Hungary, Slovakia and Slovenia particularly emphasised the need for resources in the form of new, up-to-date text books and materials, there is again evidence that this may not be sufficient to ensure a change in practice. The Belgian Flemish Community, for example noted that even where good practice materials were provided, the difficulty of convincing

teachers of their effectiveness remained. In Norway, moreover, the perception existed that it was difficult to persuade teachers that the use of different methods would result in more motivated and competent students in the field of science and technology. As the status quo was perceived to be successful, there was little impetus for change.

The role of implicit theories

It seems clear that teacher resistance to change is perceived as a real and persistent problem across Europe, at least in relation to pedagogy in technology and science.

This problem of translating educational theory into practice is one which has been long recognised and which has attracted much research. Differences in the extent to which teachers will adopt new practices are well documented. Miles (1981) for example suggests that whereas some teachers will actively seek out change, others will remain dominant preservers of the status quo for long periods of times

A significant part of resistance to change may be attributed to the underlying assumptions which are held about the nature of effective teaching and learning. There certainly appeared to be evidence to support this from a number of countries across Europe. The importance and enduring nature of such assumptions, moreover, is reflected in the wide range of terminology used to describe these in the research literature. Whereas Sternberg (1990); Runco (1993); Kennedy (1997) and Dweck (1999), all refer to these underlying assumptions as implicit theories, Eraut (2000), uses the term private theories, Gibson (1984), refers to structures of feeling, Bruner,1996, intuitive theories or folk psychology, Kelly (1955), personal constructs and Argyris and Schon (1976), tacit theories. Argyris and Schon, moreover, emphasise the importance of the impact of tacit theories which are often evident only *in* action over espoused theories which are generally based on academic theories and which are used to *explain* action. Thus there appears to be an important distinction between those theories developed through experience and the type of theories developed through research and critical engagement in a particular area, with the former deeply embedded and determining action.

The role of these intuitive, tacit, private or implicit theories has been investigated in a number of areas with direct relevance to the classroom. Kennedy (1997), suggests for example that the types of beliefs held by teachers influence fundamental issues such as the reasons given for variation in academic performance, the role of education, effective pedagogy, and notions of right and wrong in the classroom. Dweck (1999) has explored the importance of implicit theories of personality, and both Dweck and Sternberg have investigated the differences between implicit and explicit theories surrounding the constructs of intelligence and personality. Sternberg (1985), has explored the difference between expert and laypeople's identification of creativity in areas such as engineering and science. Just as theory suggests that opinions cluster to form attitudes which in turn cluster to create ideologies (Eysenck, 1944) it may be that implicit theories about various aspects of teaching technology and science cluster to form an implicit ideology or what Schon refers to as a "psychology of everyday life." (1976: 8) If this is the case, then the difficulty in affecting change in pedagogy in the area can perhaps be more readily appreciated.

Investigating implicit theories

Whereas Dweck (1999), has provided some evidence to suggest that implicit theories can be changed, at least temporarily under laboratory conditions, the findings of others would appear to contradict this. Argyris and Schon, for example, stress the difficulties involved in changing implicit or tacit theories as new ideas emerge

" …the trouble people have in learning new theories may stem not so much from the inherent difficulty of the new theories as from existing theories that people have that already determine practice" (1976: viii preface)

The enduring nature of implicit theories is also highlighted by Kennedy (1997) who stresses their role in the evaluation of new ideas. Implicit theories form frameworks of ideas under which new information is selected and constructed. Kennedy suggests therefore that while new ideas which are compatible with an overall existing framework will be easily and unconsciously assimilated into this framework, ideas which appear challenging or incompatible with the framework will be dismissed without consideration. Not only do past experiences create beliefs, but these beliefs, once generated, create frameworks by means of which further experiences are constructed.

The impact of implicit theories in resistance to change is also given clear emphasis in the contention that "teachers belief systems can be ignored only at the innovators peril" (Clarke and Peterson, 1986, cited in Yerrick et al 1996).

This suggestion that implicit theories both impact upon teaching practices and may prove extremely resistant to change has important implications. It suggests that teachers have their own deeply embedded beliefs about the nature of successful teaching based not upon policy or academic theory but upon " eclectic aggregations of cause-and effect propositions from many sources, rules of thumb, generalisations drawn from personal experience, beliefs, values, biases and prejudices" (Clark, 1988: 5)

Much of the literature describing attempts at affecting changes in practice emphasises the importance of first making implicit theories explicit. A range of methodologies has consequently been employed in an attempt to bring implicit theories into consciousness. These include standardised questionnaires specifically devised to address particular areas such as intelligence and personality (eg Dweck, 1999; Sternberg, 1985), the use of concept generation exercises such as the Kelly Repertory Grid (Solas, 1992; Hillier, 1998) narrative studies (Beattie, 1995), learning journals (Johnston, 2004), exploration of the metaphors that people use to describe education and teaching (Bullough, 1991; Inbar, 1996; Yero 2002) in-depth stimulated recall interviews (refs) observation to explore theory in action and case studies involving multiple methods of investigation.

That the elicitation of implicit theories by whichever means does not necessarily result in significant changes in practice over time, however, has been clearly demonstrated by Yerrick, Parke and Nugent (1997). Recognising the lack of impact on one-day courses on teacher practice, Yerrick *et al* explored the effect of an intensive two week course on the thinking and practice of science teachers. Implicit theories were first elicited by means of intensive interviews during which teachers were asked to reflect on the nature of teaching and their own past experiences. The

overwhelmingly predominant belief elicited was that of science as a factual list of concepts. Items to be taught were based on what was already known, supporting a transmission model of teaching. This was further backed up by discourse analysis in which the language used to describe teaching was strongly supportive of teaching constructed as the transmission of facts to be learned.

The intensive two week workshop in which participants became learners in inquiry sessions while tutors modelled the use of dialogue and similar transformational teaching methods was specifically designed to affect changes in both thinking and pedagogy. The intended outcome was the promotion of independent, autonomous learning and a deeper understanding of concepts by situating learning within authentic and current contexts- exactly the outcomes desired by policy makers across Europe. The findings suggest, however, that despite evident changes in teacher *talk* about teaching, curriculum content and assessment at the end of the two week period, implicit beliefs not only remained intact, but had been used, as Kennedy (*op cit*) has suggested to construct new knowledge within the existing framework of beliefs.

" …. we believe that an intricate set of resolving and rationalising mechanisms allowed our participants to assimilate the messages … without changing fundamental views of science and teaching. …….we believe that teachers have found ways to assimilate portions of reform visions and to view potentially contrary messages in ways that accentuate their own beliefs" (Yerrick *et al* 1997: 154)

Implications

If change in practice is to be effected across Europe, it will clearly not be enough either to simply elicit or explore the implicit theories held by entrants to courses in Initial Teacher Education or teachers who attend in-service courses intended to promote pedagogical reform. Whilst such measures may help to make implicit theories open to examination and question, this on its own will not necessarily affect any deep or lasting change in practice. This is clearly partly because of the deep rooted nature of beliefs which act as filters for incoming information, the strength of which cannot be underestimated:

" While…. educators embrace the replacing of factual treatment of knowledge and objective testing with more inquiry-based teaching steeped in learning theory and philosophical treatment, teachers' belief systems can keep teachers from even recognising these differences. Teachers who are targets for upcoming reform efforts may enter embracing a transmission model of teaching that filters other messages out and makes change highly unlikely. Even more disturbing is the tendency for teachers to interpret a departure from the norm as anything other than 'something I always do…..just not every day" (Yerrick *et al*, 1997: 156).

Wells (1997) suggests, moreover, that the situation is made even more complex because of the further conflict that may arise between teacher beliefs and perceived external requirements. He sees further difficulties arising when teachers try to adopt innovatory practices which are in keeping with their implicit theories but which are not supported by external administrators, and indeed the wider community.

This viewpoint was also apparent in perceptions of technology and science education across most of Europe. Teachers are being expected to change their practice within a

context where instructive discourse seems to shape the educational world. The Scottish curriculum document 'Teaching for Effective Learning' (HMI 1995) neatly sums this up "If you think there is only one answer, then you will only find one" (9) This epistemological framework emerged as perhaps one of the most serious challenges to the delivery of a modern and exciting technology and science curriculum.

Possible solutions

Perhaps the most effective way ahead lies in the type of solution suggested by countries such as Ireland, France and Austria. A first step might be to consider an even more radical change in assessment than that so far introduced with a move towards the adoption of a system in which the focus is on assessment of the processes rather than products of learning, where assessment is used to inform students of their present level of understanding of scientific and technological concepts and processes rather than the present focus on knowledge and understanding translated into the recall of previously learned facts.

By removing, or at least reducing the pressures of assessment on teachers this would perpaps in turn allow for the important elements of uncertainty, experimentation and creativity to be incorporated into the technology and science curriculum. Instead of demonstration and replication of already known processes, a spirit of true scientific and technological inquiry and exploration could be allowed to develop. In this context, teachers, instead of being the transmitters of existing knowledge could be encouraged to become, along with their pupils, part of a community of enquiry, a team which explored the unknown and uncertain together. A parallel change in the curriculum towards a focus on relevant current events and issues in the technology and science fields, would perhaps not only ensure that teachers and students were learning together but also help students develop the important idea that technological and scientific endeavour is an uncertain and tentative process.

"….it is highly unlikely that students will come to understand the nature of scientific fallibility if they are never informed of scientific mistakes or experience error themselves since the class has been oriented around what has already been discovered" (Yerrick *et al*, 1996: 140).

Also important is the development of a combination of top-down and bottom up models of change identified by Austria and presently being developed in Scotland as part of the Assessment is for Learning Project. When change is perceived as imposed from above, it is more likely to be rejected. When teachers form part of a community of enquiry along with policy makers and researchers and where all are perceived as learners with important contributions to make to the process, reform becomes something which is no longer imposed but actively pursued. Apparently powerful changes in both assessment and pedagogy can ensue, although it is important to note that long term and lasting change will take time to be established. As Torrance and Pryor (1998) suggests, formative assessment can be used in a behaviourist as well as a social constructivist manner and this may well be dependent upon the implicit beliefs held by particular teachers. Black *et al* (2003) also demonstrate that changes in practice, when affected by such means of collaborative enquiry can exist at different levels. At the deepest level, change permeates all aspects of a teacher's thinking and consequently has a profound impact on all aspects of pedagogy. Not all teachers

achieve this level, however. With some, change remains at the level of the adoption of one or more particular strategies and deeper structural changes in thinking do not automatically occur. This difference again may well be a function of implicit theories held.

The role of Initial Teacher Education

Clearly not all the changes necessary can be affected at the level of teacher education courses. Changes in policy are also necessary. The experience of the majority of countries across Europe indicated, however, that policy measures in themselves are insufficient to affect change. A number of countries were therefore giving serious consideration to how both pre-service and in-service provision for teachers could be improved to facilitate changes in thinking.

One important way may be to give pre-service (and in-service) teachers opportunities to explore and make explicit their deeply embedded tacit theories thus enhancing self knowledge and making a critical self analysis of practice more possible. As previously noted, literature in the field suggests a wide range of ways in which this can be achieved, and these should be built into courses. Although, this in itself is unlikely to be sufficient, as previously discussed, it is an important first step in exploring the impact of past experience on practice. Further research into whether and to what extent implicit theories involving different aspects of learning such as, for example, creativity, motivation, intelligence, subject knowledge etc combine to form an overarching pedagogical ideology may be an important development both in determining the strength of resistance to change and exploring the development of potential interventions.

One such intervention may lie in the development of educational structures which encourage the formation of communities of learners. Although the importance of the development of reflective practitioners is seen as an important element of teacher education courses, there is still perhaps too much emphasis on the development of the teacher as an individual. Dakers (2005) for example provides an interesting model of a community of practice in relation to architecture. As an architect cannot claim to know all there is to know about his subject, before he can design, for example an hotel or an airport there is a requirement to " learn about the culture that constitutes the meaning behind hotels or airports. To do this necessitates taking the skills of architecture into a newly formed community which is in the business of designing and building….. Likewise, many other communities of practice, such as civil engineers, electronic engineers, airport specialists etc., come together to form this macro community." (Dakers, 2005; 14)

Similarly in teaching, the individual teacher cannot know everything there is to know. The ultimate outcome of a pupil's progress through the school system will depend upon many micro communities involving parents, neighbourhoods, peer groups, policy makers and the various professions directly involved in the education process. The extent to which these micro communities form a macro community will play a large part in determining that outcome. The extent to which learning is promoted as a truly collaborative activity in teacher education courses has an important part to play in this process. The development of closer and more meaningful links with industry and other outside agencies at all stages of the education process will have an important role to play in this.

Another issue which teacher education can address is that of the locus of control. External control is central to the transmission model of teaching and can be difficult for teachers to relinquish. Black et al (2003) found, for example, that teachers involved in developing formative assessment techniques were often reluctant to relinquish their control over assessment by utilising peer and self assessment methods, even when policy allowed and indeed encouraged this approach. This is an aspect which requires to be addressed through analysis of the degree of control which is imposed upon students in courses of initial teacher education and through discussion and support. Educators of student teachers must explore their own implicit theories in this respect. Although social constructivist methods were espoused in all examples of Initial Teacher Education initiatives across Europe, it is extremely likely that factors such as a lack of subject choice for students, the use of whole class lectures, the emphasis on assessment and the tight control of timetabling, all combine to transmit a very different message of what teaching and learning is all about.

Changing pedagogical practice in technology and science within the European context will clearly not be an easy task. It became evident through the discussions of the working group, however, that until some of these important issues are addressed, increasing recruitment to technology and science subjects across Europe through the development of more attractive and effective teaching methods suitable for the twenty first century may prove to be an elusive dream.

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