A COMPARISON BETWEEN CURRENT INITIATIVES TO PROMOTE SCIENCE AND TECHNOLOGY EDUCATION IN SWEDEN AND THE ASPIRATIONS FOR SCOTLAND

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ABSTRACT

This paper evolves from work carried out during a consultancy for the European Commission. This consultancy involved liaison with the European Commission at regular meetings in Brussels with representatives from the extended European Union comprising 30 Countries (including the new accession countries). These formed a 'working group' which was set up to explore examples of initiatives aimed at increasing recruitment into the fields of Mathematics, Science and Technology and to draw up reports based upon the discussions.

As part of the remit a study visit to Sweden was organised to enable evaluation of some of the established and ostensibly, successful initiatives which had been set up to promote greater interest in science and technology.

An analysis of recruitment to the field of Science and Technology education in Europe will be shown to be gaining political impetus. The implications of this for both Sweden and Scotland will be considered. Following a brief overview of the Swedish school system, an examination of the current situation in both countries will be explored. Three Swedish initiatives which closely relate to current aspirations for Science and Technology education in Scotland, will be discussed and analysed.

A EUROPEAN STRATEGY FOR SCIENCE AND TECHNOLOGY

An important conclusion reached at a meeting in Lisbon of the European Council of Ministers in March 2002, was that the Union was currently confronted with what was termed a quantum shift resulting from globalization and the knowledge driven economy. From this meeting a strategic target evolved which had at its heart the desire for the Union to become the most competitive and dynamic knowledge based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion. This set of initiatives is targeted for 2010.

Initiatives which were considered to be crucial in achieving this dynamic economy were recorded by the European Council as involving scientific and technological development. General and specialised scientific or technological knowledge is increasingly called upon in professional and daily life, in public debates, decision making and legislation. The Council goes on to emphasise that all citizens require a basic understanding of mathematics, science and technology and that this should be acquired as part of the necessary package of basic skills.

A major and significant focus of this programme is a modernisation of the various current educational systems set within the extended European Union. The focus will, however, respect the various national diversities of the thirty countries involved.

On this basis, and following a report to the European Council of Ministers meeting in Barcelona in March 2002, the role of education and training was identified as being fundamental to the enhancement of the level of qualification of people in Europe, and hence to meeting not only the Lisbon challenge, but also the broader needs of citizens and society.

In particular, scientific and technological development was seen as being fundamental for a competitive knowledge society. All citizens, it is argued, should have a basic understanding of science and technology. In order to improve its position in the world and to meet the Lisbon targets, it is consequently seen as essential that Europe encourage children and young people to take a greater interest in science and technology, and to ensure that those already in scientific and research careers find their careers, prospects and rewards sufficiently satisfactory to keep them there.

An informal Meeting of Ministers of Education and Ministers of Research in Uppsala, Sweden, in March 2001 underlined the importance of increasing recruitment to scientific and technological disciplines, including a general renewal of pedagogy and closer links to working life and industry throughout the entire educational and training system.

Science and Technology was therefore one of the three priority areas in which the Education Council decided on 28 May 2001 to start work, as highlighted in the conclusions of the Stockholm European Council. In the context of the implementation of the detailed work programme on the objectives of education and training systems also known as the "objectives process", the Commission established a working group for increasing recruitment to Maths Science and Technology, which formed one of the thirteen objectives.

It is issues relating to initiatives which explore new pedagogies for science and technology at school level that this paper will address. However, the first problem encountered by the working group was how to differentiate between the concepts of science and technology.

UNPACKING THE RELATIONSHIP BETWEEN SCIENCE AND TECHNOLOGY

In the context of the 'Canberra Manual' (1995) science is described as, at its widest, '…"knowledge" or "knowing"; in a narrower sense it is understood as being the kind of knowledge of which the various "sciences" like mathematics, physics or economics are examples. In ordinary English usage science is often synonymous with the natural sciences…' (p 16). Technology on the other hand is described as '…"the application of knowledge", and more narrowly dealing with tools and techniques for carrying out the plans to achieve desired objectives' (p 16).

There exists in this context, a clear and distinct difference between science and technology. Moreover, the 'Canberra Manual' classifies six broad fields of science and technology, the first two being the natural sciences including mathematics and computer science programmes, followed by engineering and technology, which includes trade, craft and industrial programmes together with engineering programmes, architectural, transport and communications programmes. Other fields include medicine, agriculture and social sciences.

Once more a clear distinction is made between science and technology where technology has now been aligned to engineering. The tension inherent in the distinction between science and technology was a strong and recurring issue which emerged at the various working group meetings. The widely held perception was that technology was an applied form of science and that science, in a school sense, comprised Physics, Chemistry and Biology. It was generally thought that these subjects effectively subsumed technology. This is not a new misunderstanding and in terms of school education, a consensus was eventually reached which highlighted the distinctive natures of science and technology and clearly identified their unique and distinguishing features, at the same time recognizing that each is constituted within each other. This distinction is supported by many authors such as Kline (1985); Staudenmaier (1985); Black and Harrison (1992); Layton (1993); Benne and Birnbaum (1978); Gardner (1994); Harlen (2000); Barlex & Pitt, 2000).

The working group agreed that, for the purposes of the consultation, science would be classified as the natural sciences; physics, chemistry and biology as taught at school level and technology would be classified as technology education, once more, as taught at school level. Science in this sense, has more common features throughout the various countries, and is considered to be a more important subject area than technology education which demonstrates a wide variation in both its delivery and status.

The study visit to Sweden was, however, exclusively related to science education. The Swedish initiatives discussed do have similar ones that are exclusively geared towards technology education. These, however, did not form part of the study. The term science and technology is used throughout the paper in order to take account of the technological perspective which is certainly reflected in the Scottish Science Advisory Committee report.

This paper is based upon a case study visit to Sweden which coincided with the publication of the Scottish Science Advisory Committees first report; Why Science Education Matters: Supporting and Improving Science Education in Scottish Schools (SSAC, 2004).

ASPIRATIONS FOR SCIENCE AND TECHNOLOGY IN SCOTLAND

The aspirations for Science and Technology in Scotland are clearly illustrated by the following quotation from the SSAC report.

> "Above all, the SSAC [Scottish Science Advisory Committee] wishes to see that support is forthcoming for excellent science carried out by talented individuals, to ensure that Scotland remains at the forefront of internationally competitive science. To achieve this goal it is also important that we have a society that has a confident relationship with science. For this reason, we are keen to ensure that access and opportunities are given to all those who wish to learn about science generally and new scientific breakthroughs in particular. We must seek to identify innovative and more effective ways of teaching and promoting science both formally in our schools and informally via our network of science centres." (SSAC, 2004:3)

It is perhaps interesting to note that whilst the report does give some mention to technology education, the same perception as discussed earlier is evident throughout the report regarding the distinction between science and technology. The emphasis in the above quotation is exclusively geared towards science.

ASPIRATIONS FOR SCIENCE AND TECHNOLOGY IN SWEDEN

The similarity to the aspirations for Scotland may be seen by the following statement from the Swedish Ministry for Education.

> "Scientific and technical development play a crucial role in competitive knowledge societies. An increasing amount of both general and specialised scientific and technical skills are needed at work, in daily life, in the public debate, in decision making and the legislative process. All citizens need to have a fundamental understanding of technology, mathematics and science if Europe is to maintain or preferably improve its position in the world and achieve the overall, shared goals. More young people need to be stimulated in different ways to apply for technical and scientific studies" (Ministry of Education and Science in Sweden, 2003:5).

Sweden includes technology in the above quotation; however, this report followed the establishment of the agreed classification by the working group, on which, as is usual for devolved areas of EU member states, Scotland had no representation. As consultant I was not at liberty to contribute the Scottish experience, only the UK representative was entitled to do that; that representation was poor in terms of attendance and certainly only gave an English perspective.

It became evident at the various working group meetings that whilst uptake in science and technology subjects was generally in decline at school level, all countries were unanimous that these subject domains were essential to the economic wellbeing of Europe.

Both Scotland and Sweden clearly hold Science and Technology in high regard, or at least they do so politically. The reality in both countries, however, appears to be somewhat different. Students at school level are rejecting courses in both subjects. Whilst at the political level, knowledge in Science and Technology is seen to be commensurate with a strong economy, university students seem, in spite of these political aspirations, to be more interested in taking courses in Media Studies, Computing or Business Management. Science and Engineering have, it would seem, lost their appeal. This may be due in part to modern conceptual perceptions of the subjects. "For some, Science gives us agricultural self sufficiency, cures for the crippled, a global network of friends and acquaintances; for others it gives us weapons of war, a school teacher's fiery death as the space shuttle falls from grace, and the silent, deceiving, bone-poisoning Chernobyl" (Collins and Pinch, 1998:1). "In recent years public confidence in Science has decreased due to events such as the BSE and Foot and Mouth crises" (SSAC, 2004:8).

Science and Technology are, however, regarded as the main forces behind social and cultural change. In this knowledge economy world we now inhabit, it is Science and Technology that have become the required capital for economic competitiveness and national identity. Japan was regarded as the most technologically advanced nation on earth in terms of electronics; it was also highly developed economically.

Science and Technology are therefore seen as the most important areas for development in industry and in terms of the future, at both school and tertiary level. Recruitment into these areas is now seen, politically and culturally, to be of crucial importance.

In 2000, the PISA (Programme for International Student Assessment) saw Scientific and Technological literacy as being "the capacity to use scientific knowledge, to identify questions and draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity" (p3).

The SSAC (2004) has subsequently shown recognition of "the relationship between science, science policy and wider society as crucially important for the future development of science in Scotland and seeks to foster a greater literacy in science among the Scottish population" (p7).

Significantly, the emphasis can be seen to be shifting from a "transfer of knowledge" model, to that of a more discursive, socially constructed model, where the impacts of science and technology upon society are seen to be crucial aspects of a curriculum which will attract more interest.

This paradigm shift is taking place in science and technology curricula around the developed world including Sweden and Scotland (SCCC, 2000; Ministry of Education and Science in Sweden, 2003; SSAC, 2004). This new 'literacy' emerged, principally from the USA but quickly spread, in the late 1970s, as a response to the new and emerging global marketplace. International comparisons at the time revealed that USA students were lagging behind their global competitors in science and technology achievement. Moreover, the image of science and technology, as mentioned above, was reaching an all time low (Waks, 2004).

Emphasis in the 70s was more about positive recruitment together with an emphasis on the correlation between the number of scientists and engineers, and a strong economy. The emphasis has now changed, however, to that of the social aspects of science and technology, delivered within a more authentic pedagogy. This was a major conclusion which emerged from the working group.

THE NEED FOR A CHANGE IN PEDAGOGY

The working group established that there is a growing recognition, which is implicit within the ideology set out in the SSAC (2004) and the Ministry of Education and Science in Sweden (2003) documents, as well as similar documentation in other European countries, that for children to learn, they have to be actively involved in the learning process. They construct meaning through the process of interaction and inquiry, which is fundamentally constituted through their relations with the world (Lave, 1993; Lemke, 1997; Walkerdine, 1997; Wenger, 1998).

Learning, however, does not take place in a vacuum. Children do not learn simply by constructing their own individual realities in isolation from the cultural, historical, and social environment into which they were born. Without those factors there is no conceptual framework to work from. (Resnick, 1987)

Vygotsky saw human development as an interaction between the social and the material environment. Significantly, he saw this environment as constantly changing. This state of change was due to a fusion between past and present, and the present is seen in light of history. "To study something historically means to study it in the process of change" (Vygotsky, 1978:64–65, original emphasis). Human beings are not limited to their biological inheritance, as other species are, but are born into an environment that is shaped by the activities of previous generations. In this environment, they are surrounded by artifacts that carry their past into the present (Cole, 1996). Scientific and technological literacy involves teachers and pupils, developing together in a community of understanding which investigates, amongst other things, the way that science and technology impacts upon us as human beings in a technologically mediated globalised world. In this way, more relevant and authentic understanding of the scientific process can be taken forward in an informed and meaningful way, rather than the abstract 'make up a problem' paradigm (Dakers, 2002).

Central to Vygotsky's theory of cognitive development is that a child's metacognitive, or intrapersonal processes have their roots in interactions with others. They learn by internalising external dialogue. For Vygotsky, language and thought are intimately and inextricably related (Sternberg and Williams, 2002).

The development of scientific and technological literacy, as well as life skills, is accelerated through the use of language skills such as debating, justifying an opinion, weighing up conflicting points of view and analysing disagreements. These skills which are linked to problem solving skills, can be assessed, formatively, in dynamic and exciting ways, such as observation, interaction, group work and challenge from the teacher. Furthermore, learning and understanding the design process, is not seen as the acquisition of isolated skills, or as items of information transferred from an expert and deposited, or "banked" into the pupil (Freire, 1970). It is seen as involving an interactive process where concepts are deliberated in a safe, social context, which encourage a synthesis between opposing views and perceptions.

The case study to Sweden was set up to explore initiatives which applied these new pedagogies to teaching science in schools.

THE SWEDISH SCHOOL SYSTEM

The Swedish public school system comprises both compulsory and non compulsory schooling. Compulsory schooling is for all children between the ages of seven and fifteen. Municipalities have, moreover, an obligation to provide a place for all six year olds in a pre school class if their parents so wish. Compulsory education is free of charge, nor is there normally a charge for teaching materials, school meals, health services and transport. Non compulsory schooling includes pre school and upper secondary school which takes children from the age of sixteen to eighteen. Significantly, 98% of school leavers from compulsory school make the transition to upper secondary.

Municipalities must also provide places for all students who complete compulsory schooling. Upper secondary education is also free of charge. In principle, students have the right to study towards their first choice of national programme, of which, since 2000, Sweden has offered seventeen. All are of three years in duration, and have a total rating of 2,500 upper secondary credits. These programmes are designed to provide a broad general education and provide eligibility to study at university or post-secondary school level.

All national programmes include eight core subjects: English, the Arts, Physical Education and Health, Mathematics, General Science, Social Studies, Swedish (or Swedish as a second language) and Religion. These core subjects account for 750 upper secondary credits. The remainder of the credits are accounted for in the seventeen programmes which give the upper secondary course its own character. These programmes are:

- Child and Recreation/Recreation, Educational and Social Activities
- Construction/Construction, Building, Painting, Metalwork
- Electrical Engineering/Automation, Electronics, Electrical and Computer Technology
- Energy/Operation and Maintenance, Marine Technology, Heating, Ventilation and Sanitation
- Arts/Art and Design, Dance, Music and Theatre
- Vehicle Engineering/Aeronautics, Coachwork, Motor Vehicle Mechanics and Engineering, Transport
- Business and Administration/Business and Services, Travel and Tourism
- Handicrafts/Various Trades and Crafts
- Hotel, Restaurant and Catering/ Hotel, Restaurant and Catering Services
- Industry/ Local Specialisations, Country wide recruiting
- Foods/Local Specialisations, Country Wide recruiting
- Media/ Media Production, Printing Technology
- Use of Natural resourses/Local Specialisations
- Natural Sciences/Mathematics and Computer Sciences, Environmental Science, Natural Sciences
- Health Care/ No National Specialisations
- Social Science/ Economics, Liberal Arts, Social Sciences, Languages
- Technology/ Local Specialisations.

By combining specific subjects from different programmes, each municipality can put together specially designed upper secondary programmes to meet local and regional needs. In upper secondary school, subjects are divided into courses which may have 50, 100, 150 or 200 credits. Grades are given for every course completed. A grade of Pass always gives the number of approved upper secondary credits for the course, regardless of whether the student requires fewer or additional hours to achieve the course objectives.

At the end of the upper secondary school programme, students receive a final grade (leaving certificate), which is a compilation of the grades for all the courses included in the study programme (Skolvereket, 2004).

THREE SWEDISH INITIATIVES

The Swedish Government, in partnership with authorities and private actors, has been striving for many years to increase interest in Technology, Mathematics and Science in school and higher education. Several long-term initiatives have been introduced with the aim of improving general conditions. An important aim of these measures has also been to create a positive attitude to these subjects among children and young people.

All upper-secondary pupils must take Science as a core subject, regardless of the programme they are following. The Science programme now incorporates a broader range of different courses in Mathematics and other scientific areas. An upper-secondary programme in Technology with several specialisations has also been introduced.

National measures have also been implemented to promote and develop experiments and laboratory work as part of compulsory school education. Local Science Centres have been established across the country with some help from government grants. A government Mathematics delegation has been established to develop a plan to determine how interest in, and attitudes towards Mathematics can be improved among students at all levels, from pre-school to higher education.

Every institute of higher education receives a specific educational task stipulating targets for the minimum number of degrees in related disciplines to be awarded in the long term. Examples of such degrees are civilingenjör (MSc in Engineering). These degrees provide a qualification for teaching at primary and secondary school level. Funding for undergraduate education is provided by the government on a per capita basis, up to a fixed maximal amount.

THREE EXAMPLES OF GOOD PRACTICE IN SWEDEN

Three examples of good practice aimed at different sectors of the education system were examined as part of the case study. These were:

- the SciTech project: aimed at stimulating interest in the primary sector
- the five national resource centres: aimed at stimulating interest in the primary and secondary sectors.
- the SciTech Basic Year: aimed primarily at increasing recruitment of students from upper secondary into higher education in science and technology related areas.

THE SCI-TECH PROJECT

The aim of the SciTech Project is to develop teaching methods which will enable children to approach Science education in an active and participatory way. A guiding principle of the pedagogy is that the working methods adopted in schools should attempt to be connected, as far as possible, with the reality of the pupils' own experiences and to accommodate a range of learning styles. Traditional transmission models of teaching have therefore been replaced by the imaginative use of narrative, drama, outdoor education and model construction in an attempt to develop in children the interest and understanding of scientific concepts. These concepts are set within a context that the children can relate to. In this way a much greater emphasis is placed on the need for real world investigation in developing the interest of children. Encouraging dialogue with children, moreover, encourages them to realise that not all their implicit ideas about the world necessarily fit with all the evidence presented This type of pedagogy therefore "will keep them puzzling about it" (Harlen 2000:73). Evidence suggests that by using this model, children are motivated to discuss issues relating to the ways in which Science and Technology impacts upon their lives and the society that they are involved with from a local, national and global perspective.

Modelling the teaching entirely around children's 'big' questions about their own experiences and excluding any abstract scientific fact can, however, become extremely complex, especially for the teacher (Harlen, 2000). On the other hand, the transmission model tends to demotivate the pupil. Vygotsky (2000), however, suggests that concept formation, or making sense of the world is a synthesis of the two. He sees spontaneous learning going from the child's everyday concrete experience of its environment, where thought is non-deliberate and based upon natural curiosity. School based instruction, on the other hand involves initial verbal definitions which are of themselves, initially, abstract constructions. However, when these are applied systematically, with unambiguous links being developed, they gradually become more concrete in formation. The type of pedagogy being applied in the SciTech project therefore attempts to synthesise these opposing methods into a more coherent and enjoyable whole from the child's point of view by moving it towards a state where she can develop an increasingly articulate understanding of her environment.

The SciTech project personnel are actively involved in providing training sessions for established teachers with little or no scientific background to enable them to present Science and Technology activities in a stimulating and motivating manner. The emphasis is very much directed towards the primary sector teachers who are considered to have very low confidence levels in the teaching of Science and Technology. They also have input into Initial Teacher Education courses where they offer help and advice to student teachers and to ITE Tutors.

Furthermore, a SciTech Newsletter is published four times a year and distributed to all involved in the SciTech field. These newsletters include activities designed to promote active enquiry into such areas as young people's attitudes towards Science and Technology and offer up to date information on teaching aids in Science and Technology education.

NATIONAL RESOURCE CENTRES

A measure designed to complement the SciTech programme is the establishment of five National Resource Centres for the various Science and Technology subjects. Such Centres exist for Chemistry (established in 1994 and situated in Stockholm), Physics (established in 1997 and situated in Lund), Technology (established in 1997 and situated in Norrköping), Mathematics (established in 1998 and situated in Göteborg) and a centre for Biology and Biotechnology (established in 2002 and situated in Uppsala). Each of these Centres receives some funding from the Government and is attached to a major university which also offers financial and academic support.

The five Centres have a somewhat different profile of activity, depending partly on the nature of the subject. For the purposes of this paper the most recently established Centre for Biology and Biotech will be considered.

The Centre for Biology and Biotechnology is based at Uppsala University. The work of the centre is primarily directed towards supporting teachers in the Science domain at all levels of the education system. An emphasis is placed upon practical work. The focus, once more, is upon connecting Science to real life experiences and contexts with examples of Biology used in everyday conditions. The centre designs experiments which actively encourage student discussions relating to aesthetic and ethical arguments about scientific issues. These issues can range from considering the preservation of nature to the use of genetics.

Here again there is a clear emphasis on cross curricular links and these are made by encouraging teachers to use topics in different subject areas. Teachers are thus encouraged to explore a range of ways in which pupils may acquire scientific literacy, such as engaging with a story which started in a nature study. Multiple pathways are then formed which lead to Science or lead from Science to other areas of the curriculum.

One problem identified by the Centre was that of reaching teachers. As stated earlier, a regular newsletter is sent out to schools and teachers can take out individual subscriptions to this. However, whilst some evidence does exist that this initiative is having some impact on science teaching, the newsletter is not reaching and influencing as many teachers as the Centre would wish.

The resource is free to schools and it is necessary for the Centre to work with other organisations in order to ensure sufficient further resources, principally human resources. Government funding is sufficient to provide only 2.5 FTE for the running of the centre. This places a strain on the dissemination of information and particularly staff time. In order to have the desired impact on teachers' attitudes and practice, it is considered preferable to have face to face meetings with teachers, and where this is achieved it is found that they are generally very responsive to the new ideas and teaching methods promoted. Given the small scale of the Resource Centres and the high demand made upon them, therefore, it would seem that without further funding these will never be able to fulfill their aspirations which also include establishing links between industry, schools and universities.

SCI-TECH BASIC YEAR

An initiative which has had a very positive impact on recruitment to higher education is the establishment of the SciTech Basic Year. The objective of this project is to allow young people, who have completed their upper secondary studies in other fields such as Arts or Social Sciences, to effectively change their minds by encouraging them to have second thoughts about their future careers. The SciTech Basic Year is an intermediary year during which students are given the opportunity to study courses in Scientific disciplines which will in turn allow them entry to a university course specialising in a related Scientific or Engineering discipline. This initiative started in Luleå in the late 70's and is now established in the majority of universities in Sweden.

Enrolment on The SciTech Basic Year at a specific university is generally attached to a guaranteed place in one of the Engineering, Science based or Initial Teacher Education programmes at that university. The student has the right to financial support during the basic year although the course does not entitle the student to any further academic credits.

Students attend university as part of the Sci-Tech basic year which does not form part of any undergraduate programme, but is seen as an intermediary year. The SciTech BasicYear is therefore regarded as a way to broaden the base of recruitment for Science and Technology courses at university level. Every year, approximately 7,000 students from the Social Science program or from the various vocational programmes in upper secondary school study opt to take up the opportunity of the SciTech basic year. Most of these then enter higher education by progressing to a Science or Technology related course. Significantly, about fifty per cent of these students are female. Approximately one third of the students take up Initial Teacher Education for primary school by this route.

Informal interviews with participating students on the course indicated a high level of enjoyment of the university environment. However, teaching strategies such as university-style lectures were considered to have a demotivating effect on these students. Recognising that they were undertaking an intensive year of study in an alien subject area, tutors on the course chose to adopt styles of teaching more closely related to school than university. It was felt that students were more responsive to this methodology and this was certainly reflected in the student retention and success rates.

COMPARISONS WITH THE SCOTTISH SYSTEM

"The Scottish Science Advisory Committee (SSAC) is an independent Committee, established under the auspices of the Royal Society of Edinburgh with funding from the Scottish Executive, to provide advice to Scottish Ministers on Science strategy, Science priorities and Science policy" (SSAC, 2004:2). Whilst the emphasis may be seen to favour science, the SSAC recognise and consider Technology as a complementary discipline.

Explicit in the Swedish case study, and SSAC documentation is a recognition that training for teachers in Science and Technology is much needed at primary level. In Scotland primary teachers have continually expressed low confidence levels in the teaching of Science (Harlen and Holroyd, 1996) and even lower confidence levels in the teaching of Technology (Dakers and Dow, 2001; Dakers, 2001). "It is vital to improve the experience that primary school pupils have of Science and to make sure that their interest in Science is sustained and developed across the primary-secondary transition" (SSAC, 2004:9). This is very much in line with the rationale behind the Scottish 5–14 "Environmental Studies" documentation which also emphasizes the importance of developing authentic, meaningful learning environments (SCCC, 2000).

The principles behind the Swedish Sci-Tech project are, moreover, very much in line with the proposals set out for Scottish education in "Science for Citizenship", as outlined by SSAC (2004), and "Technological Capability" as outlined by the SCCC (1996).

Scientific and Technological development, as is clear in the Swedish initiative, involves a process of socialisation. Humans are not born in isolation but into communities, or cultures, which are mediated today, almost entirely, by science and technology.

Whilst the SSAC does not directly tackle issues relating to the need to change pedagogies, it does recognise the need for some change in the delivery of the Science curriculum. "The present Science curriculum both at Standard and Higher grade is too content-dominated, with virtually no scope for individual teachers to include topical or innovative material to inspire their pupils" (SSAC, 2004, p9). Perhaps the pedagogical realignment adopted in the Swedish Sci-Tech initiative may offer some guidance on this matter.

The SSAC has, however, on the other hand, recommended that "SEED should provide resources to sustain the Improving Science Education 5-14 Programme" (SSAC, 2004:4). By so doing, it is embracing a pedagogy founded upon a 'scientific method' of delivery. It does this by aligning itself with the methodologies espoused by HMI, who recommend that teaching Science will be improved by adopting pedagogies which are in direct opposition to those discussed earlier. This opposition is apparent in the following quotation:

> "The TIMSS [Third (now Trends) in International Mathematics and Science Study] researchers collected data about teaching and learning in Science from pupils and teachers in all the participating countries. Scotland was unusual in a number of ways compared with higher achieving countries. It had the smallest Science classes in secondary schools, with 99% of classes in S1 and S2 containing 20 or fewer pupils. Less time was spent in whole-class teaching of Science in primary and secondary schools than in all other participating countries. Further, less Science homework was set, both in primary and secondary schools. Given that frequent whole-class teaching and homework are characteristics of high performing countries, teachers of Science in primary and secondary schools should review their teaching approaches to ensure they take account of the characteristics of effective science lessons" (HMI, 1999, Paragraph 3.4)

This emphasis on 'frequent whole class teaching' and 'high performing countries' resonates with instrumentalist overtones. It supports a pedagogy which leans disturbingly towards a knowledge acquisition model based upon Lyotard's somewhat dystopic postmodern condition (2001):

> "We may thus expect a thorough exteriorisation of knowledge with respect to the "knower," at whatever point he or she may occupy in the knowledge process. The old principle that the acquisition of knowledge is indissociable from the training (Bildung) of minds, or even of individuals, is becoming obsolete and will become ever more so" (p4).

SCIENCE CENTRES

The Science Centres in Sweden differ quite dramatically from the type of Science Centres established in Scotland. These are supported by the SSAC which recommends that "The Scottish Executive should find a means to provide financial support to ensure the sustainability of the Scottish Science Centres as a network which fulfils a cultural and educational role" (SSAC, 2004:7). Despite such support, in February 2003 the Scotsman newspaper reported on concerns about the viability of the relatively new Science Centre in Glasgow. In August last year, moreover, the same newspaper reported the closure of the Big Idea Science Centre in Irvine. This was apparently due to a serious decline in visitor numbers. It was suggested that this must also raise new fears about the viability of Scotland's other fledgling Science Centres. It may be that these Science Centres, whilst purporting to engage visitors in scientific enquiry, are regarded simply as places of entertainment where evidence of children's delayed gratification in trying to solve some of the 'hands on' experiments is somewhat lacking. Unlike in Sweden, the pedagogy upon which they are based tends to be constructivist rather than social constructivist, with children being encouraged to interact directly with the environment rather than through a process of scaffolding or social mediation. The Swedish Centres' emphasis on subject areas and their connections with universities may also be factors which contribute to their perceived viability.

SCI-TECH BASIC YEAR

There is no comparative initiative to this in Scotland. Given that it is proving to be very successful in Sweden, it may be that the SSAC may wish to consider this as a viable recommendation to SEED.

DISCUSSION

The pedagogy used in the Swedish initiatives is based on social constructivist principles in which building on prior experience, and the active construction of knowledge with mediation from more expert others emerge as important features. It is significant that tutors in all of the initiatives did not regard themselves as transmitters of knowledge but that the learning process was a "meeting of minds."

The importance of connecting scientific principles to the real world was also an important aspect of all courses, with tutors emphasising the importance of authentic and meaningful learning experiences for students. The need to build on the prior experience of students, to express concepts in a language which is accessible to them, to make scientific and technological concepts relevant by presenting them within authentic learning contexts was highlighted as a crucial element in the success of the initiatives at every stage of the education process.

An ability to cater for a range of learning styles and to harness the creative power of narrative, drama, art, models etc is closely related to this and must be considered an important element in raising and maintaining interest.

Whilst the Swedish initiatives were impressive, there were several problems which emerged as part of the study. Finance was either limited in the amount granted, as was the case for the development of the Centres which received very limited budgets and relied to a large extent on subsidies from the host universities, or budgets being stopped before projects could become established, as was the case with the SciTech primary project. The SciTech basic year relied on the exceptional teaching talents of two retired university science professors, without whom it was quite clearly stated, the project might not have been able to run. Moreover, some of the students who opted to enroll for this year did so for strategic purposes. When interviewed, some admitted to electing to study social subjects in upper school because they were easier to do than science subjects, however, they knew that they could enroll in the basic year thereby getting into science subjects 'by the back door' so to speak.

One of the major problems associated with any of these initiatives at school level, is that of teacher resistance to change. This was seen overwhelmingly to be the case in all countries. This may suggest that for any new initiative to succeed teachers should be involved in the planning rather than have initiatives 'thrust upon them'.

It is clear that no single initiative can change the recruitment to the Science and Technology areas, but the Swedish initiatives discussed warrant close attention because of their potential influences on several of the problems that need to be addressed. Whilst the most recent Scottish initiatives are clearly intent on addressing similar issues, there may be much of value to be learned by Scotland exploring initiatives from other parts of Europe where successful, albeit problematic, innovation has been implemented with at least some evidence of success.

REFERENCES

Barlex, D. and Pitt, J. (2000) *Interaction. The Relationship Between Science and Design and Technology in the Secondary School Curriculum*, London: Engineering Council.

Benne, K. and Birbaum, M. (1978) *Teaching and Learning about Science and Social Policy*. Boulder, CO, USA: ERIC Clearinghouse for Social Studies/Social Science Education/Social Science Education Consortium.

Black, P. and Harrison, G. (1992) in McCormick, R., *et al*. (Eds) *Teaching and Learning Technology.* Wokingham: Addison-Wesley Publishing Company, in association with the Open University, Milton Keynes.

Canberra Manual (1995) *The Measurement of Scientific and Technological Activities. Manual on the Measurement of Human Resources Devoted to S&T. 'Canberra Manual'*. OECD and ECSC-EC-EAEC, Brussels. Luxembourg (1995) www.oecd.org/dataoecd/34/0/2096025.pdf (accessed July 27 2004).

Cole, M. (1996) *Cultural Psychology: A Once and Future Discipline*. Cambridge, MA: The Bellknap Press of Harvard University Press.

Collins, H. and Pinch, T. (1998) *The Golum at Large: What you should know about Technology,* Cambridge: Cambridge University Press.

Dakers, J. (2001) Primary Teachers Confidence in Delivering Technology Education. In: (Eds) Benson, C., Martin, M., Till, W., Third International Primary Design and Technology Conference Proceedings. Birmingham, CRIPT, pp 50–54.

Dakers, J. (2002) *Dialectical Methodology. The Impact of Incorporating a Neo-Vygotskian approach to Design and Technology*. In E.W.L. Norman (Ed.), *DATA* International Research and UK Education Conference (pp 45–50).

Dakers, J. and Dow, W. (2001). Attitudes of Secondary Teachers of Technical Subjects and Home Economics Towards Curricular Continuity at the Transition between Primary 7 (11 years) and Senior 1 (12 years). Third International Primary Design and Technology Conference Proceedings. Birmingham, CRIPT, pp46–49.

Freire, P. (1970) *Pedagogy of the Oppressed*, New York: Herder and Herder.

Gardner, P. (1994) Representations of the relationship between science and technology in the curriculum. *Studies in Science Education*, 24: 29–47.

Harlen, W. (2000) *Teaching, Learning & Assessing Science 5–12*, London: Paul Chapman.

Harlen, W. and Holroyd, C. (1996) Primary Teachers' Understanding of Concepts in Science and Technology. *Interchange Nr 34*. Research and Intelligence Unit.

HMI (1999) Improving Science Education 5–14. A Report by HM Inspectors of Schools. Scottish Executive Education Department) www.scotland.gov.uk/library2/doc09/imse-00.asp (accessed 15 March 2004).

Kline, S.J. (1985) What is technology? *Bulletin of Science, Technology and Society,* 5 (3): 215–18.

Lave, J. (1993) Situated Learning in Communities of Practice. In: L. B. Resnick, J. M. Levine, S. D. Teasley (Eds.) Perspectives on socially shared cognition, *American Psychological Association*, Washington, pp 17–36.

Layton, D. (1993) *Technology's Challenge to Science Education – Cathederal, Quarry or Company Store,* Buckingham and Philadelphia: Open University Press.

Lemke, J. (1997) Cognition, Context and Learning. A social semiotic perspective. In: D. Krishner & J. A. Whitson (Eds.) *Situated cognition, social, semiotic, and psychological perspectives*, New Jersey: Lawrence Erlbaum Associates, pp37–56.

Lyotard, J. F. (2001) *The Postmodern Condition: A Report on Knowledge*, (Original published 1973), Manchester: Manchester University Press.

Ministry of Education and Science in Sweden (2003) *A Report on Education and Training in Sweden and the shared European Goals*, Regeringskansliet: Government Offices Sweden.

PISA (2000) www.pisa.oecd.org/knowledge/chap3/c2.htm (accessed 15 March 2004).

Resnick, L.B. (1987). Learning in school and out, *Education Researcher*, 16, pp12–20.

SCCC (1996) *Technology Education in Scottish Schools: A Statement of Position from Scottish CCC*, Dundee: Scottish Consultative Council on the Curriculum.

SCCC (2000) *Environmental Studies: Curriculum Guidelines,* Dundee: Scottish Consultative Council on the Curriculum.

Skolvereket (2004) *The Swedish School System*, Regeringskansliet: Government Offices Sweden.

SSAC (2004) Why Science Education matters: Supporting and Improving Science Education in Scottish Schools, Scottish Science Advisory Committee. Report available at: www.scottishscience.org.uk/main_files/pdf/Publications/final_Annual_Report.pdf (accessed 11 March 2004).

Staudenmaier, J. (1985) *Technology's Storytellers*: *Reweaving the Human Fabric,* Cambridge, Mass., USA and London: Society for the History of Technology and the MIT Press.

Sternberg, R.J., & Williams, W.M. (2002) *Educational Psychology*, Boston, MA: Allyn & Bacon.

Waks, L.J. (2004) Globalisation and the renewal of technological literacy. In: J. Dakers (Ed), *Technology, Design and Society*, New York: Palgrave (In press).

Walkerdine, V. (1997) Redefining the subject in situated cognition theory. In: D. Krishner & J. A. Whitson (Eds.) *Situated cognition, social, semiotic, and psychological perspectives*, New Jersey: Lawrence Erlbaum Associates, pp57–70.

Wenger, E. (1998) *Communities of Practice: Learning Meaning and Identity*, Cambridge: Cambridge University Press.

Vygotsky, L.S. (1978) *Mind in Society: The Development of Higher Psychological Processes*, Massachusetts: Harvard University Press.

Vygotsky, L.S. (2000) *Thought and Language*, (Twelfth printing, Original 1986), Alex Kozulin (Ed.), Massachusetts: MIT University Press.