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International Council of Associations for Science Education

*Supporting and promoting science education internationally*

**Editorial**

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This special edition of SEI was intended to bring together a diverse range of articles representing the state of the art in Inquiry Based Science Teaching/Education (IBST), and which were indicative of the dynamic nature of thinking about IBST at an international level. The articles provide a range of insights into the teaching and learning processes associated with inquiry, and also indicate some possible future directions for development work in IBST. Inquiry represents a philosophical and practical approach to the distribution of knowledge. In my view, we are seeing a convergence between education and research, two fields previously kept apart through having very different conceptions of their roles. Education comprised a continuum between the formation of fulfilled individuals (in the *bildung* tradition) and the provision of a trained workforce. Research was seen as the cutting-edge of scientific activity, "pushing back boundaries" and answering questions posed mainly by those in power, including, of course, 'powerful researchers' – those in control of their own funding or able to persuade funding bodies of their talent and relevance.

Inquiry in schools is, however, just as much about 'research' as it is about teaching and learning. Indeed, if we look closely at academic research, few would deny that all research involves a learning process, and a certain amount of teaching as well, as early career researchers are brought into professional communities, or funding bodies 'educated' about the latest findings in a specific field. What is different is not the relevance of the research, nor even its scientific rigour, but the power structures underlying it, which determine its questions and methods. A leading UK scientist recently described science as 'organised curiosity', which is clearly within the reach of most school classes!

We know from work in inquiry-based science teaching that students are capable not only of raising relevant and challenging scientific questions, but also of providing scientifically valid answers to those questions. We also know that seeing the relevance of school science is a major problem for many students. Tumebo (2013) describes students as " being frog marched across the landscape of science" and of course the destination is often unclear. Concepts of scientific literacy' do not really help, since current understandings of scientific literacy are about "the ability to debate socio-scientific issues" in a landscape where these issues are predetermined by others.

The real issue here is that the underlying purposes of education and research should be much more closely aligned, because the crises increasingly afflicting the planet can only be addressed by much more coherent action, involving both fields and involving them now. Education is currently conceived as a process taking up to twenty years (or more) from kindergarten to PhD. The classical cutting edge of scientific research, meanwhile, is equally far out – fusion power may take forty years[1]. We need a different kind of research, which serves several purposes simultaneously:

1) Engages pupils in purposeful activity
2) Produces learning about scientific processes
3) Produces results relevant to pupils and to the wider community
4) Addresses societal challenges such as economic failure and climate change

Before we suggest how this agenda could be taken forward, we need to consider the current situation in inquiry-based science teaching, and how we got there. In Europe, and especially following the publication of the Rocard Report in 2007 (EC, 2007), IBST was seen as a way of solving the problem of declining interest in science. Subsequently, a series of projects emerged to take forward the mission of spreading the IBST message across Europe. The most valuable contribution of such projects, in my view, is that they have created a European educational space in which the values, purposes and

[1] http://web.archive.org/web/20061107220145/http://www.iter.org/Future-beyond.htm

techniques of education can be discussed at a transnational level. The article by Vivien M. Chabalengula and Frackson Mumba (this edition) draws attention to the global importance of IBST and the importance of national context in mediating the implementation of inquiry. Meanwhile a different approach to inquiry, based on scientific practices, disciplinary core ideas and cross cutting concepts, is being promoted in the US by the National Research Council (Duschl et al, 2011).

Recently, a consensus has begun to emerge within this space that IBST is not the answer to all the problems of science education. Partly, this is due to confusion about the nature of IBST. In particular, there is a perception in certain quarters that it is a 'method', with fixed parameters, which can be plugged into existing systems in order to motivate students and achieve better results. An even more problematic pair of misconceptions is that inquiry is either completely structured or completely unstructured. The article by Zion and Mendelovici explains clearly the differences and implications of the various forms of inquiry, which clearly lie on a continuum. Within S-TEAM, we have used the concept of levels of inquiry proposed by Herron (1971) and developed by Smith et al (2013).

Inquiry as a set of teaching strategies definitely raises student engagement and understanding in most cases, but takes longer to cover the same curricular topics than conventional 'direct teaching'. Consequently, its usefulness is seen to decline as examination deadlines approach. This decline is also problematic in relation to the use of IBST in primary and lower secondary science, since any enthusiasm generated there is dissipated by the need to rush through 'overstuffed' curricula and 'past papers'. Furthermore, demonstrating that any potential success criteria for IBST have been met is not trivial. The current length of projects in this area is usually three or four years, which is not long enough to properly evaluate outcomes. If IBST is increasing engagement and motivation, is this increase sustained? If IBST is increasing the take up of science careers, the timeframe is too long, and the confounding factors too numerous to attribute these increases solely to specific teaching methods. We have good anecdotal evidence from teachers that IBST is useful in solving specific problems in the classroom, but as most of them also know, policy shifts in education are too frequent to sustain proper development of new methods or practices.

There are also misconceptions about the relationship of 'hands-on' or 'experimental' work to IBST, a point dealt with in the article by Seraphin et al, in this edition. As these authors point out, 'authentic' inquiry comprises a set of practices, which may or may not include actual lab work, field observations and so on. The point is that the practices of science, such as "analyzing and interpreting data" are followed actively, and that answers are not handed out in advance. On the other hand, inquiry is not characterized by a total lack of scaffolding, a misconception advanced by several otherwise reputable critics (e.g. Kirschner, Sweller & Clark, 2006). Science itself always builds on what is already known, and calls in specialist help when required.

A further emerging problem is that of 'mission creep'. It is very hard to describe 'good science teaching practices' without straying into the territory of 'good teaching' in general. The opposite approach is to head towards science didactics and detailed specification of how to teach a particular topic. The latter approach manifests itself in the tendency of EU projects to talk about 'materials' and 'resources', and to expend considerable effort on trying to produce transferable examples across borders. The indications are that this is not a good use of the European educational space. National systems are increasingly specifying a wide range of parameters surrounding teaching, curriculum and assessment, and are, in parallel, developing their own web-based resource systems to support teachers in their own national or regional contexts. The addition of a European layer of resource provision on top of these national systems is not particularly helpful, although it does promote international networking.

The debate about 'good teaching' in general is, meanwhile, being conducted in terms of concepts such as literacy, personalised teaching, formative assessment and low achievement. IBST is seen in EU circles as being a possible answer to the problem of low achievers in science and mathematics. The evidence from EU projects is that IBST can be used to improve the motivation of low achievers in science, but with the same caveats as with any application of inquiry – it takes more time and careful consideration of success criteria. Formative assessment, meanwhile, is becoming more prominent in the debate, but should not be regarded as a substitute 'magic bullet', but as fully complementary to IBST. The idea of literacy, in a wide variety of forms, is significant because it is clear that the ability to negotiate texts and numerical data is a prerequisite for being able to do science (Osborne 2012; Tiberghien et al 2011). Disciplinary boundaries have obscured this point, but it is now time to take seriously the literacy demands of science subjects.

This leads to consideration of inter-disciplinarity, which is a fruitful area for future collaboration. Feldman et al's article in this edition draws attention to the various possible framings of science in the classroom, on a continuum from 'science as inquiry' to 'science as culture'. These framings can, on the one hand, lead to the loss of science content in situations where the social component of science predominates, situations encouraged by the drive for scientific literacy. On the other hand, they can lead to collaboration between disciplines, developing different forms of literacy and mutually reinforcing learning, critical thinking and argumentation skills.

The articles by Chabalengula and Mumba, and Magee and Flessner in this edition demonstrate some of the complexity of involving teachers in facilitating effective inquiry. In the former case, the organization of the Zambian education system places constraints on the ability of teachers to engage with inquiry, whilst in the latter, the limiting factor is the availability of authentic experiences of inquiry for pre-service teachers. The article by Hakverdi-Can and Sönmez shows that there is much for pre-service teachers to learn about designing virtual environments for inquiry, another area where there is scope for overcoming the constraints of conventional teaching environments.

**The future of IBST**

A recent conference called "Together for Basic Skills: Comenius Thematic Meeting on Literacy, Maths and Science" (Brussels, 6-7 December, 2012) provided an opportunity to test the state of expert opinion on the direction and emphasis on future work in IBST. Many delegates identified that it was necessary to take a broader approach to improving achievement in literacy, maths and science, and that inquiry was only part of a wider 'repertoire of actions' to be deployed, including such concepts as formative assessment and personalised learning. There is thus a danger that inquiry, viewed narrowly as a fashionable method, will lose its attraction and be side-lined in the quest for better PISA results.

This would be a mistake. Inquiry is much more of a philosophical approach to education and culture, as well as being the essence of science. The essential components of inquiry are curiosity, scepticism and the use of evidence. Addressing the challenges currently facing the planet demands that we do much more inquiry in schools, not less. The article by Feldman et al shows, from a small beginning in a neighbourhood pond, that collaborative inquiry can do much more than raise test results. What is lacking in schools, and is currently undermining the potential of inquiry, is a lack of common purpose in applying it for public benefit, or for "progress-achieving" (Maxwell, 2012). Inquiry requires time and space for its implementation, but if this is provided, at all levels, transformative learning can take place, in communities of inquiry involving everyone from pre-school children to global policymakers. One potential concrete realisation of this involves schools taking part in real-world research projects, in conjunction with universities and the corporate sector.

In Europe, this would involve taking on the societal challenges of Horizon 2020[2], the successor programme to Framework Programme 7. These challenges include:

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture, marine and maritime research, and the bio-economy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Inclusive, innovative and secure societies;
- Climate action, resource efficiency and raw materials.

School science would then have a purpose, which is currently lacking, and pupils would, ideally, have the chance to work with science and industry professionals, thus learning about how science is done and opening up career opportunities. Assessment, in this scenario, would reflect the gains in a wide range of competences made through participation in multi-disciplinary projects.

It would greatly benefit school science in pursuing this inquiry-based agenda, and the work of citizen researchers in the context of 'open science' and (another EU priority) *Responsible Research and Innovation*[3], if existing restrictions on access to publications, both for readers and writers, were eliminated. This would also assist researchers and educators in the South, both in enabling them to publish freely without restrictive copyright and other restrictions, and to access their own indigenous knowledge bases as well as those of the North (Gray, 2010). In science education, we should be leading the way in opening up the distribution of knowledge, and reforming our own practices would be a good start in encouraging the curiosity of all.

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[2] http://*ec.europa.eu/research/horizon2020/*

[3] http://ec.europa.eu/research/science-society/document_library/pdf_06/responsible-research-and-innovation-leaflet_en.pdf

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