



## **IMPORTANCE OF INTEGRATION OF PEDAGOGY AND TECHNOLOGY IN TEACHING SCIENCE**

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### **Abstract**

*This paper addresses the integration of pedagogy and technology in science teaching. Science teaching is such a complex, dynamic profession that it is difficult for a teacher to stay up-to-date. For a teacher to grow professionally and become better as a teacher of science, a special, continuous effort is required (Showalter, 1984, p. 21). To better prepare students for the science and technology of the 21st century, the current science education reforms ask science teachers to integrate technology and inquiry-based teaching into their instruction (American Association for the Advancement of Science, 1993; National Research Council [NRC], 1996, 2000). Good teaching “begins with an act of reason, continues with a process of reasoning, culminates in performances of imparting, eliciting, involving, or enticing, and is then thought about some more until the process begins again” (Shulman, 1987, p. 13). Thus, to make effective pedagogical decisions about what to teach and how to teach it, teachers should develop both their PCK and pedagogical reasoning skills. In recent years, many researchers in the field of educational technology have been focused on the role of teacher knowledge on technology integration (Hughes, 2005; Koehler & Mishra, 2005, 2008; Mishra & Koehler, 2006; Niess, 2005). This paper discusses the role of science education in 21<sup>st</sup> Century, the aim of science education, purpose of science education, changing trends in science education, meeting the changing needs in science education, role of ICT in transforming teaching and learning, the link between ICT and pedagogy. At the conclusion it states that though integration of technology and pedagogy is essential for better science teaching but a balance between pedagogy and technology is required to avail the greatest benefit.*



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## **INTRODUCTION**

Science teaching is such a complex, dynamic profession that it is difficult for a teacher to stay up-to-date. For a teacher to grow professionally and become better as a teacher of science, a special, continuous effort is required (Showalter, 1984, p. 21). To better prepare students for the science and technology of the 21st century, the current science education reforms ask science teachers to integrate technology and inquiry-based teaching into their instruction (American Association for the Advancement of Science, 1993; National Research Council [NRC], 1996, 2000). The *National Science Education Standards* (NSES) define inquiry as “the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work” (NRC, 1996, p. 23). The NSES encourage teachers

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to apply “a variety of technologies, such as hand tools, measuring instruments, and calculators [as] an integral component of scientific investigations” to support student inquiry (p.175). Utilizing technology tools in inquiry-based science classrooms allows students to work as scientists (Novak & Krajcik, 2006, p. 76). Shulman argued that teachers not only need to know their content but also need to know how to present it effectively. Good teaching “begins with an act of reason, continues with a process of reasoning, culminates in performances of imparting, eliciting, involving, or enticing, and is then thought about some more until the process begins again” (Shulman, 1987, p. 13). Thus, to make effective pedagogical decisions about what to teach and how to teach it, teachers should develop both their PCK(Pedagogical Content Knowledge) and pedagogical reasoning skills .

In recent years, many researchers in the field of educational technology have been focused on the role of teacher knowledge on technology integration (Hughes, 2005; Koehler & Mishra, 2005, 2008; Mishra & Koehler, 2006; Niess, 2005). The term TPACK (also known as TPCK; Koehler & Mishra, 2005) has emerged as a knowledge base needed by teachers to incorporate technology into their teaching. Koehler and Mishra (2005) discussed TPACK as a framework for teacher knowledge for technology integration. Their TPACK framework is based upon Shulman’s conception of PCK. In Koehler and Mishra’s model of TPACK, there are three main components of teacher knowledge: content, technology, and pedagogy. They described TPACK as a combination of these three knowledge bases. According to the authors, TPACK is the ...basis of effective teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of problems that students face; knowledge of students’ prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. (Koehler & Mishra, 2008, p. 17-18)

The complex and counter-intuitive nature of scientific concepts and processes mean that opportunities for discussion reasoning, interpretation and reflection are very important for knowledge building. Introducing technological tools and resources which students can use interactively potentially offers further opportunities for expressing, evaluating and revising their developing ideas as they visualise the consequences of their own reasoning.

## **SCIENCE EDUCATION FOR THE 21ST CENTURY**

21<sup>st</sup> Century Science will require teachers to adapt and a different set of pedagogic practices. Its goal of fostering ‘scientific literacy’ involves developing a knowledge not only of the broad explanatory themes of science but also of some of the discourse and practices of scientists, including the processes of theory construction, decision making and communication, and the social factors that influence scientists’ work, albeit highly simplified. Another force for pedagogic change in science education is the new modes of enquiry afforded by computer-based tools and resources, now known collectively as ‘Information and Communication Technologies’ (ICT). The advent of this educational technology, and its more widespread access in schools, potentially has an important part to play in re-shaping the curriculum and pedagogy of science. In particular, it offers easy access to a vast array of internet resources and other new tools and resources that facilitate and extend opportunities for empirical enquiry both inside and outside the classroom .Thus, in a very real sense, it offers opportunities to dissolve the boundaries that demarcate school science from contemporary science by facilitating access to a wide body of data, such as real-time air pollution measurements, epidemiological statistics, or providing direct links to high quality astronomical telescopes, and providing ready access to a wealth of information about science-in-the-making. Access to such secondary resources and data, however, places greater emphasis on the need to provide a science education which gives pre-eminence, as its ultimate goal, to developing the higher order cognitive skills of evaluation and interpretation of evidence requiring critical assessment of the validity of theories and explanations. Such an education would seek to support and develop students ’scientific reasoning, critical reflection and analytic skills. What, then, is the potential of using ICT to support and nurture such a science education? In the following sections of this review, we now examine this potential – particularly that envisioned by the current trend in science education which seeks to develop scientific literacy. We also explore the teacher’s role in exploiting this potential, and the outcomes .

## **THE AIMS OF SCIENCE EDUCATION**

Thomas Huxley and others, in contrast, saw the function of science education as a means of intellectual development providing opportunities to engage in the exercise of reasoning by analyzing and interpreting data, and using evidence-based arguments for appropriate

scientific theories. In addition, it also permitted the testing of speculation. For Huxley then, science offered a discoverable order revealed by the application of standard processes. What mattered was not so much the content of any science education but the unique capacity that science offered for a training of the mind –in short that the process of engaging with scientific enquiry was much more significant than the content .Such debates, between the value of the content of science versus its processes, i.e. scientific modes of thinking, were to play themselves out repeatedly in debates about the function and purpose of science education. They can be seen in Armstrong’s advocacy of the significance of process (Armstrong 1891), in particular, in his advocacy of an approach to teaching which came to be known as ‘guided discovery’, and were to emerge again in the 1980s (Millar & Driver 1987) and) technological education for the development of a rounded individual (Barnett 2001

### **THE PURPOSES OF SCIENCE EDUCATION**

Current research would suggest, however, that there are four common rationales for science education:

- **The Utilitarian:**

the view that a knowledge of science is practically useful to everyone. However this view is increasingly questionable in a society where most technologies are no longer remediable by any one other than an expert.

- **The Economic:**

The view that we must ensure an adequate supply of scientifically trained individuals to sustain and develop an advanced industrial society

- **The Cultural Argument:**

The view that science and technology are one, if not the greatest, achievement of contemporary society, and that a knowledge there of is an essential prerequisite for the educated individual

- **The Democratic:**

The argument that many of the political and moral dilemmas posed by contemporary society are of a scientific nature. Participating in the debate surrounding their resolution requires a knowledge of some aspects of science and technology. Hence,educating the populace in science and technology is an essential requirement to sustain a healthy democratic society.

## **THE CHANGING CONTEXT**

Two factors have led to calls for change in the nature of school science education.

### **1. The changing relationship between science and society.**

The past 30 years have seen a transformation in society's view of science. 30 years ago, we witnessed 'white heat of the technological revolution', men were landing on the moon, and iconic symbols such as Concorde heralded a new dawn. In contrast, today, after a long experience environmental and technological disasters such as Chernobyl, global warming, ozone depletion, Bhopal, and more, science is seen as a source of threat as well as a source of solutions. In addition, recent research has transformed our understanding of science by highlighting the ways in which culture and values impact upon the development of scientific ideas and practices. The perception of scientific progress today is, therefore, more ambivalent than 30 years ago both in terms of its 'impacts' on society, and in terms of its claims to act as a value-neutral domain

2. In the 1980s, the economic case for science education was successful in arguing that science should be a compulsory part of all school science curricula in many countries across the globe. The outcome, however, was the imposition of a model of science education designed for the small minority of children who would go on to become scientists. In recent years however, it has been increasingly argued that compulsory science education can only be justified if it offers something of universal value to all. Hence, in the last decade the democratic and cultural arguments have come to the fore to argue that a complete science education should give a much more holistic picture of science, concentrating less on the details and more on the broad explanatory themes that science offers. In addition, a much more comprehensive treatment of a set of ideas about how science is done, evaluated and functions is required. The most significant product of this debate so far has been the development of a new curriculum entitled Science for Public Understanding which has attempted to articulate a model of school science which meets these two challenges.

## **MEETING THE CHALLENGE OF CHANGE**

The changes embodied in these courses are radical. Traditionally school science has ignored any treatment or exploration. Hence, the pedagogy of school science has tended to be didactic, authoritarian and non-discursive with little room for autonomous learning or the development of critical reasoning. In addition, science teachers, themselves the product of the

standard model of science education, often have naïve views about the nature of science. Teaching about science rather than teaching its content will require a significant change in its mode of teaching and an improved knowledge and understanding in teachers.

### **POTENTIAL ROLE OF ICT IN TRANSFORMING TEACHING AND LEARNING**

While there are changes in the views of the nature of science and the role of science education, the increasing prevalence of Information and Communication Technologies (ICT) also offers a challenge to the teaching and learning of science, and to the models of scientific practice teachers and learners might encounter. ICTs, for example, offer a range of different tools for use in school science activity, including:

1. Tools for data capture, processing and interpretation – data logging systems, databases and spreadsheets, graphing tools, modeling environments
2. Multimedia software for simulation of processes and carrying out ‘virtual experiments’
3. Information systems
4. Publishing and presentation tools
5. Digital recording equipment
6. Computer projection technology
7. Computer-controlled microscope.

These forms of ICT can enhance both the practical and theoretical aspects of science teaching and learning. The potential contribution of technology use can be conceptualized as follows:

1. Expediting and enhancing work production; offering release from laborious manual processes and more time for thinking, discussion and interpretation
2. •Increasing currency and scope of relevant phenomena by linking school science to contemporary science and providing access to experiences not otherwise feasible
3. Supporting exploration and experimentation by providing immediate, visual feedback
4. Focusing attention on over-arching issues, increasing salience of underlying abstract concepts
5. Fostering self-regulated and collaborative learning
6. Improving motivation and engagement.

The use of ICT changes the relative emphasis of scientific skills and thinking; for example, by diminishing the mechanical aspects of collecting data and plotting graphs – particularly beneficial for low ability pupils – while enhancing the use of graphs for interpreting data,

spending more time on observation and focused discussion, and developing investigative and analytic skills (Hennessy 1999; McFarlane & Friedler 1998; Rogers, in press-b; Rogers & Wild 1996). Research also suggests that using computer modelling and simulation allows learners to understand and investigate far more complex models and processes than they can in a school laboratory setting (eg review by Cox 2000; Linn 1999; Mellar et al 1994).

Use of ICT, especially the internet, can open up access to a broader range of up-to-date tools and information resources, and increase the currency and authenticity of schoolwork far beyond that which textbooks and other resources can offer. It allows pupils to relate their work more closely to the outside world – to obtain live news or real data, for example concerning an earthquake. Pupils can even ask questions of ‘real’ scientists, or collaborate or pool results with peers elsewhere. A topical example of reported use was accessing the Roslin Institute website during a research project on the cloning of ‘Dolly’ the sheep ([www.globe.gov](http://www.globe.gov)) involving 12,000 schools collaborating with a community of scientists to collect, analyse, validate and interpret shared research data concerning climate change. Such exploration of pressing global questions promotes students’ awareness of environmental issues and the Earth as a dynamic system.

A further example is the Jason Project ([www.jasonproject.org](http://www.jasonproject.org)), a series of real-life and real-time internet-based science explorations designed for students who can engage with the work of research scientists exploring the geology and biology of dynamic and eco-systems throughout the planet.

Contact with wider ideas can extend high ability pupils and is perceived to increase opportunities for learning beyond that anticipated by the teacher or prescribed by the curriculum. One recent application, a CD-Rom called ‘Ideas and Evidence’, uses ICT to raise pupils’ awareness of the

Uncertainties which surround the construction of scientific knowledge, especially the validity and consequences of different scientists producing different results and interpretations.

This tool can be used to support role play and group discussions of topical social and ethical issues, including media bias and oversimplification in presenting science news stories (eg concerning health scares such as BSE or mobile phone transmissions).



Tools like this may, therefore, support teachers in rising to the new pedagogical challenges emerging as the curriculum begins to shift. Using ICT can provide access to new forms of data previously unavailable.

Data logging can offer measurements of transient phenomena, remote and long term monitoring and increased sensitivity; for example, it is commonly used to measure the speed of a moving object by measuring the time taken to pass through a light gate and combining this with manual

Measurement of its stopping distance.

Using ICT further allows teachers and pupils to observe or interact with simulations, animations or phenomena in novel ways that may be too dangerous, complex or expensive for the school laboratory.

Use of a data logger can facilitate otherwise impossible demonstrations, such as measuring energy transfer as a hot liquid cools. Digital video capture offers an alternative to data logging; repeated and slow motion playback allows phenomena which are difficult for a whole class to view, or events otherwise too slow (eg plant growth) or fast (eg sound waves or the behavior of two different masses dropped from the same height), to be captured.

The internet also offers some unique opportunities for pupils to experience phenomena such as viewing the Earth from a moving satellite. A particularly accessible and popular way of exploiting the power of visual representations to develop understanding – particularly of abstract phenomena like electricity flow – is the direct use of video clips from interactive simulation CD Roms. Examples include ‘seeing’ an electron going around a nucleus or a white cell ingesting bacteria, simulating launch of a space shuttle, and rotating a 3D model of molecules and atoms in motion.

Another multimedia tool is the ‘Interactive Microscope Laboratory’ (Baggott & Nichol1998), which facilitates active investigation of the sub-optical living world (eg measurement of the heart rate of a water flea) through simulating the functionality of advanced microscopy.

Virtual reality ‘field’trips (eg to remote animal habitats) and surrogate walks (eg through a rainforest) are beginning to offer further possibilities which other local resources cannot provide. Interactions with virtual phenomena can be repeated as often as necessary for the learner – impossible during a live practical



.Supporting exploration and experimentation the interactive simulations described above, use of these tools offers immediate feedback to pupils, and introduces a more experimental, playful style in which trends are investigated and ideas are tested and refined. Through providing an immediate link between an activity and its results, the likelihood is increased that pupils will relate the graphical or diagrammatical representation of relationships to the activity itself. In particular, the key pedagogical technique of Predict – Observe – Explain is greatly facilitated through viewing a graph or model on screen soon after making a prediction .Rapid data presentation and interactive computer models representing a scientific phenomenon or idea not only provide immediate opportunities for study and analysis; they can also encourage pupils to pose exploratory questions and to pursue these by conducting follow-up activities (Barton 1998; Finlayson & Rogers 2003; Newton 2000; Wardle, in press), to access ideas more quickly and easily, to formulate new ideas and transfer them between contexts.

.Thus, computer analytic facilities are advantageous over manual methods in allowing a more holistic and qualitative approach to pupil analysis of trends and relationships between variables in a graph

### **The link between use of ICT**

Current research would suggest, however that it is not appropriate to assume simply that the introduction of such technologies necessarily transforms science education. Rather we need to acknowledge the critical role played by the teacher, in creating the conditions for ICT-supported learning through selecting and evaluating appropriate technological resources, and designing, structuring and sequencing a set of learning activities. Pedagogy focusing ICT effectively includes:

1. Ensuring that use is appropriate and ‘adds value’ to learning activities
2. Building on teachers’ existing practice and on pupils’ prior conceptions
3. Structuring activity while offering pupils some responsibility, choice and opportunities for active anticipation
4. Prompting pupils to think about underlying concepts and relationships; creating time for discussion, reasoning, analysis and reflection
5. Focusing research tasks and developing skills for finding and critically analyzing information

6. Linking ICT use to ongoing teaching and learning activities
7. Exploiting the potential of whole class interactive teaching and encouraging pupils to share ideas and findings. Opportunity to greatly enhance the quality

Teachers' motivation to use ICT in the classroom is, at present, adversely influenced by a number of constraints including: lack of time to gain confidence and experience with technology; limited access to reliable resources; a science curriculum overloaded with content; assessment that requires no use of the technology; and a lack of subject-specific guidance for using ICT to support learning. While this technology can, in principle, be employed in diverse ways to support different curriculum goals and forms of pedagogy, such constraints have often stifled teachers' use of ICT in ways which effectively exploit its interactivity. Consequently, well-integrated and effective classroom use of ICT is currently rare. Research shows that even where technology is available, it is often underused and hindered by a set of practical constraints and teacher reservations. Whole class interactive teaching is also under-developed. At present, effective use of ICT in science seems to be confined to a minority of enthusiastic teachers or department. On the whole, use of ICT in school science is driven by – rather than transformative of – the prescribed curriculum and established pedagogy. In sum, teachers tend to use ICT largely to support, enhanced complement existing classroom practice rather than re-shaping subject content, goals and pedagogies. However, teacher motivation and commitment are high and practice is gradually changing. The New Opportunities Fund (NOF) scheme for training teachers in using ICT in the classroom appears to have had more success in science than in other subjects.

## **CONCLUSION**

To conclude, teachers are currently working towards harnessing the powerful potential of using ICT to support science learning as far as possible, given the very real operational constraints. Further development depends on providing them with more time, consistent access to reliable resources, encouragement and support, and offering specific guidance for appropriate and effective use. Assessment frameworks (and their focus on end products) may also need to change in order to evaluate – and thereby further encourage – ICT-supported learning. We can conclude integration of pedagogy with technology in science teaching may facilitate

### **Improving motivation and engagement**

ICT offers the opportunity to greatly enhance the quality of presentation, incorporating the use of movement, light, sound and colour rather than static text and images, which is attractive and more authentic. Above all, using ICT can increase pupils' persistence and participation through enhancing the appeal of laboratory activity, not only in terms of novelty and variety, but by providing immediate, accurate results and reducing the laboriousness of work.

### **Structuring activity and supporting active, reflective learning:**

The teacher's role is critical in structuring tasks and interventions in ways which prompt pupils

using ICT to think about underlying concepts and relationships .

### **Developing an investigative approach**

“Pupils might be encouraged to compare sets of data; they can look at each other's graphs, discuss the differences and similarities or compare their graph with that of sample data. Hopefully... they might take a broader view of what constitutes relevant and useful information. **Linking ICT use to ongoing teaching and learning**

It is important to stress that although simulations and other tools can provide a virtual alternative to practical work in some situations, using ICT is not perceived – by pupils, teachers or educators – as a replacement for other activities. The balancing and integration of use of ICT resources with other teaching and learning activities, is desirable in many situations; indeed it often provides the greatest benefits.

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