Conceptualisations of science and mathematics education in Early Years education

In science and mathematics it is possible to consider both knowledge and the processes involved in gaining that knowledge. Duschl et al. (2007) identify four strands of scientific proficiency that are interwoven in learning and teaching:

1. Know, use and interpret scientific explanations of the natural world;
2. Generate and evaluate scientific evidence and explanations;
3. Understand the nature and development of scientific knowledge;
4. Participate productively in scientific practices and discourse.

These strands reflect an increasing recognition of the importance not just of pupils' engagement with scientific concepts but also of the need to develop their understanding of the 'nature of science' and 'procedural understanding' (Duschl et al., 2007; Eady, 2008; Harlen and Qualter, 2004; Kallery, Psillos, and Tselfes, 2009). According to Gago et al., (2004):

> "*The 'nature of science' has become an important concern in the curriculum. This often means the rejection of the stereotypical and false image of science as a simple search for objective and final truths based on unproblematic observations. The recent emphasis on understanding the nature of science is related to the attempt to give more attention to its social, cultural and human aspects. Science is now to be presented as knowledge that is built on evidence as well as upon arguments deployed in a creative search for meaning and explanation.*"
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> (Gago et al., 2004: 138).

In this context procedural understanding refers to an understanding of the processes in which science knowledge is acquired. The perceived importance of procedural knowledge is reflected in moves toward more inquiry based learning approaches, epitomised in IBSE, that emphasise children's understanding and skills in finding out and evaluating information around them (European Commission, 2011a). As argued by Drayton and Falk (2001) an inquiry-based approach to learning is not only a means of fostering understandings and skills associated with scientific procedures, but is a means of learning content. Greater procedural knowledge may be informed by, and in turn inform, conceptual understanding (Rittle-Johnson, Siegler and Alibseli, 1999); knowledge of content can provide the context for developing process skills, which in turn can help learners develop further concepts (Harlen and Qualter, 2004). Rather than attempt to evaluate their relative importance, it is perhaps more productive to consider their interdependence and how the relationship plays out in learning at different phases in education.

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Debates about content and process are also echoed in mathematics education; however, it is important to acknowledge differences in terms and focus. In mathematics, a major tension that is discussed is between ‘conceptual and procedural’ knowledge. Procedural knowledge in this context refers more to the skills in applying the right procedures to solve problems. This is contrasted with children’s understanding of the concepts involved. However, it has been argued that this debate unfairly promotes conceptual understanding by taking a narrow, superficial view of procedural knowledge (Star, 2000). This tension is similar to that between ‘instrumental’ and ‘relational’ knowledge discussed by Skemp (2006), where instrumental knowledge refers to the ability to carry out specific procedures or repeat facts, whilst relational knowledge is more concerned with understanding the significance of this information; how it relates to other ideas. In contrast to science, the terminology ‘nature of mathematics’ has not gained the same currency, although it is possible to draw parallels with debates around children’s understanding of formalism in mathematics and how this can seem disconnected from children’s informal experiences.

There is an emerging understanding in both mathematics and science education that the dichotomisation of ‘process’ and ‘content’ may obscure the relationship between the two, with arguments being made for efforts toward considering their interdependence (Harlen and Qualter, 2004).

Another aspect increasingly emphasised in science education is the role of emotive factors such as motivation and attitudes that affect engagement and quality of thinking (Brown and Campione, 1994, Duschl et al., 2007). Furthermore embodiment theories of education argue that it is not possible to separate thinking from perceptual and emotional experiences (Clark, 1999; Dourish, 2004; Lakoff and Nunez, 2000).

Science and mathematics in the Early Years offer opportunities to foster and draw together processes, concepts and attitudes in building on children’s curiosity and concern to investigate and explain the world around them from their earliest years. As outlined in a later section, through participation in play, exploration and dialogue with others, children are engaged in generating, testing out and evaluating ideas.

Capabilities in science education

In science there are opportunities for the use and development of a range of process skills involved in the linking, generation and testing and evaluation of ideas, many of which are noted within IBSE. Lists vary, but common elements suggested include:

- Questioning, predicting and planning
- Gathering evidence by observing and using information sources
- Interpreting evidence and drawing conclusions
- Communicating and reflecting

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(Harlen and Qualter, 2004: 66)

These processes Duschl et al. (2007) suggest can be grouped according to different phases in an inquiry or investigation. The first phase involves generating evidence through asking questions, formulating hypotheses and designing experiments, the second observing and recording and the final phase evaluating evidence.

Similarly, it is possible to identify a number of mathematical processes. Artz and Armour-Thomas (1992) develop a cognitive-metacognitive framework identifying six categories in problem solving; reading, analysing exploring; planning/implementing, and verifying. In a further framework, Mayer (1985) identifies four components of mathematics problem solving: translation, integration, solution planning, and execution.

The mathematical processes identified above can be linked to science; indeed, various authors (e.g. Harlen, 1993) describe the relationship between science and mathematics, presenting mathematics as a grammar for science, or that mathematics helps science to derive models, develop formalisms and to approach conceptualisation. Reflecting on debates about content and process as above, there is widespread recognition that these processes are inextricably linked with the contexts and concepts associated with their application and that they involve both action and thinking in linking and developing ideas. However, there may also be significant differences in the processes behind problem solving in mathematics and the science processes involved in IBSE.

With mathematics, children tend to be presented with certain problems. This is done so as to draw children's attention to particular mathematical aspects of the problem, for example, the need to count or add amounts. In a way, the mathematics problem supports children's thinking by reducing the messiness and difficulty of mathematics in the world around us. Whilst children are aware that mathematics plays a role in their everyday lives (Abraham, 2009), such as paying for goods (with cash) or working out how much time remains, these involve quite difficult concepts or amounts. There is a tension therefore between presented problems that are manageable but may lack links to personal experience and meaning, and everyday experiences, which may be difficult for children to interpret mathematically (Zacharos and Koustourakis, 2011). This tension is arguably different in science that allows more scope to question and reflect on more everyday experiences rather than specific problems.

Affective factors also play a significant role in the Early Years; science and mathematics provide a context for developing important attitudes and dispositions as a foundation for future learning. These include curiosity, motivation and confidence to engage in inquiry and debate, willingness to change ideas, flexibility and respect for evidence and more widely positive attitudes to learning and respect for the

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environment. There is a growing recognition that the “affective dimension is not just a simple catalyst, but a necessary condition for learning to occur” (Perrier and Nsengiyumva, 2003: 1124).

The importance of supporting young children’s early motivation and enjoyment for science and mathematics has also gained significant attention in light of the growing concern about older children’s choice not to continue studying these subjects in study. In other words, negative attitudes to science and mathematics may stem from earlier school experiences. Consequently, a key objective of science and mathematics education should be to increase motivation and foster positive attitudes (e.g. Fensham and Harlen, 1999; Kallery, Psillos, and Tselfes, 2009; Millar and Osborne, 1998).

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