Integration: An Approach to Science in Primary Schooling[1]

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HISTORICAL BACKGROUND: 1960s TO 1990

Science in relation to primary schooling was first generally acknowledged in the 1960s (Osborne and Simon, 1996). Well-funded large project teams were established in a number of countries to develop curriculum materials for use in these early years of schooling. In this remarkable period of science curriculum reform, it is, however, important to note that these primary projects followed, rather than led, earlier projects that were developing, or had developed materials for the sciences in secondary schooling. Thus these secondary projects had already clearly defined what characteristic of Science these new materials would promote in the secondary years. Science was essentially to be a body of conceptual knowledge.

What then could these second phase projects define as the characteristic of Science for the primary years? The answer that triumphed on both sides of the Atlantic, and in many other countries linked to these sources, was what became known as the "processes of science". **Science-A Process Approach** in the USA and **Science 5 to 13** in England and Wales epitomised this emphasis on content-free processes among which were *observing, classifying, measuring, hypothesising, inferring and predicting*. This decision may, in part, have been deferential to the fact that teachers in primary schools in general had (and still have) weak conceptual backgrounds in the sciences. In addition, they lacked (and still lack) confidence about teaching it.

In perhaps another deference to these teachers concerns about science and its teaching, several countries placed science into their curriculum of primary schooling in a new subject that was a combination or an integration of science with the social sciences. In Thailand the subject was called **Life Experiences**, and in the Scandinavian countries it was called **Orienteering** (as in the sport with the same name), which was meant to refer to the ways the natural and social science can contribute to *making one's way in the world*.

In other countries, Science could be either a distinct and separate subject or it could be taught in a manner that described by those teachers as an "integrated" way, which again usually meant an association with social studies.

During this first period of recognition of Science in primary schooling there was, in many countries, no strong pressure for schools and teachers to make Science a central or core feature of the primary child's learning. Enthusiastic teachers with confidence about Science did teach science, and found its

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topics could attract great interest among their students. For them, the processes were learnt naturally as they engaged their students in questions of inquiry about the particular natural phenomena they were able to introduce into their classrooms. For most primary teachers, for whom Science did not have positive associations, science education became more and more marginalized in the students' learning experiences. Furthermore, the definition of primary science as a set of essentially content free processes encouraged a number of teachers, who did take their science education responsibilities seriously, to recognize that these could be fulfilled by engaging their students in familiar social contexts, just as well as by using natural science ones about which they personally felt less confident. Even when these social contexts did also have natural science aspects, teachers did not find it easy to shift the focus of their teaching to these aspects, and this may be because the science in real world human situations is, in fact, often very complex.

Support from the system

It was not that education systems ignored primary science. Over these twenty five years there is a long record in many countries of efforts by the system to encourage more teaching of science. New materials to assist teachers were periodically developed. A variety of professional development models were tried, from large scale, short intensive sessions, to longer training of small numbers of exemplary teachers who were then be the trainers of others in their own and neighbouring schools. The emphasis on Science in some initial teacher training programs was increased, but the science intentions of their graduates seemed to disappear quickly once the laissez faire attitude about science in schools was encountered.

In 1988/89 I was commissioned with some others to conduct a National Review of Teacher Education in Science - both pre-service and post-service. This involved an extensive study of all the programs and outcomes of the 52 universities and teacher training institutions who were involved in these two levels of teacher education. Most of these institutions did prepare primary teachers. For someone like me, who knew the many efforts and very considerable resources over the years that had been put into trying to lift the level of primary science education, it was a depressing two years.

The general place of Science in primary schooling in Australia was still so bad, after so much effort, that we, as reviewers, briefly considered recommending abandoning Science as part of the primary curriculum. This would, however, have been to deny Australian young children any prospect of learning in, and from the exciting world that Science has opened for

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humankind. So we did our best to recommend yet another set of ways in which Science could gain a higher profile in the life of primary schools.

Nor was this dismal scene peculiar to Australia. Reports from England, USA and Canada, continental Europe, and many Asian countries were finding the same thing.

> *Science, after 25 years since it was officially acknowledged, had only a marginal presence in primary schooling.*

Glimmers of new integrations

During these years there were, however, occasional voices who argued that Science in the primary school had a great potential to contribute to language development. At a Commonwealth Workshop in Cyprus in 1982 for mathematics and science curriculum representatives, I also recall that both groups found they had a great interest in the teaching and learning of *Measuring* as a topic of great importance for all young learners in the primary years.

Finally, the 1980s saw the beginnings of serious recognition of the environment and of technology by education systems. Both of these had obvious links with science. The brave teacher pioneers, who tried to introduce such topics into their primary classrooms, found very warm receptions from their students who related easily to the idea of using science to take care of (or to nurture) both natural and human environments in order to improve their life's quality. Similarly, the design and making that were at the heart of technology had such an appeal to many primary learners, that teachers could open the science door by focusing on the Science of the materials and the processes involved in construction with them.

These glimmerings of new possibilities for integration were, however, soon to be extinguished by much grander curricular forces.

THE 1990s

New status for primary science

As the decade of the 90s began, a very different perspective of Science in the primary years appeared. During the 1980s for a variety of reasons country after country had given official assent to the notion that school science should be for all students and not just for those with intentions to enter science-based careers. As the decade ended, **Science for All**, as the slogan had been replaced by **Scientific Literacy**, placing Science alongside the already established literacies for language and number, that are so often used as the hallmarks of educated societies, and that politicians are so

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extremely sensitive about. The 1990s heralded the first responses of education systems to these new external presses for a new role for Science in schooling. The new National Curriculum in England and Wales declared Science to be one of three core subjects alongside Language and Mathematics. Then detailed lists of topics and concepts were prescribed in three disciplinary strands together with a strand of scientific skills (NCC, 1991). Without distinction in kind between primary and secondary schooling, many of these science learnings were to be taught in the first two stages of the curriculum plan that coincided with the primary years. The American Association for the Advancement of Science (AAAS, 1993) published its **Benchmarks for Scientific Literacy** in which a great number of science learning targets, now set out in seven strands, were associated with the primary years.

A number of other countries and states followed these leads, and compiled their own long lists of intended science topics and conceptual learnings. The Scandinavian countries, had been concerned for some time that Science within their integrated subjects was being poorly represented. Norway and Sweden thus now listed Science as a separate subject, again spelling out lists of intended science content learnings. Denmark, however, produced a subject in which Science and Technology were kept together and, even more surprisingly, did not prescribe any topics or conceptual content. Rather, its curriculum emphasized Science as ***Ways of Working*** and ***Ways of Knowing*** in investigations of science and science/technology situations, that teachers and their students could find in the school's near and further, natural and human-interacted environments (Andersen and Sørensen, 1995). It was argued by this curriculum's designers that, if these investigations were properly carried out, good and worthwhile science content would be learnt. This notion of Science as extended open-ended investigations of mutually-chosen situations that can involve Science provides, as I shall argue later, a much easier curricular context for successful and integrated learning to occur.

In many of these 1990s reforms, Technology emerged as a new and separate subject, making the previous promising explorations of integration between these two fields almost impossible to maintain.

The idea of curriculum focus

The international curriculum review that was carried out as part of the Third International Mathematics and Science Study (TIMSS), described countries with long detailed lists of content for learning as having a "diffuse" curriculum for science. In these curricula, in any year of schooling, a large number of different topics were to be taught, placing great demand on the

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primary teachers, and raising a likelihood of incoherent, superficial learning. Those countries, like Japan, which in contrast had relatively few topics per year, were described as having a "focussed" curriculum. The demand on teachers was less in terms of topics to be covered, but more depth was required, if the opportunity for deeper more coherent learning was to be realized. A focussed curriculum, we shall see, is another important curricular feature for the advantages integrated teaching of science can have.

Some educational systems reinforced these new intentions for primary science by specifying time per week to be spent on science, commissioning new support materials, instituting standardized regular tests of learning progress, and providing varying degrees of professional development for primary teachers. At least officially, it looked as if primary science was at last established. In practice the problems of actually implementing these now much more demanding intentions were even greater than they were with the more modest suggestions I outlined in the previous section.

Thematic integration

Nevertheless, some creative work was done by individual teachers and by some developers of support materials for these new curricula. Their aim was to reduce the diffuseness of the long lists of science learnings by choosing larger themes or real world contexts that would enable a number of the discrete pieces of content to be studied in an integrated way. This is a sense of *integration within a science curriculum itself*, instead of the other more usual meanings of integration that have a cross-curricular sense. The use of a thematic approach in primary science was an example, at that level, of a curriculum design that had already been promoted in secondary science in the later 1980s. This was termed the "*Concepts in Contexts*" design. It was promoted because of its potential to present science concepts to students in more meaningful way, as they, with their teacher, explored how science plays a part in broad, familiar and interesting contexts like *Transport and Sport* (PLON Physics, The Netherlands) or *Clothing and Drinks* (Salter's Science, England) or *Cooking and Keeping Warm* (Physics, Australia). The relational nature of science concepts, and their power in being applicable in different aspects of these familiar contexts, would thus be more easily learned and appreciated by students. In turn, the conceptual learning would deepen the students' understanding of the real world contexts. Similar intentions underlay the integrated thematic approach to primary science. I remember visiting a teacher who had achieved enthusiastic and deep learning in his class in a small rural town with the theme, *Moving Heavy Objects*, that they had been exploring in class and on excursions into the local community for several weeks. Another example of a fruitful theme

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was *Soil*, which in the early 1990s was chosen by several primary teachers in different schools who agreed to share their developmental and implementation experiences with each other. Some of questions that were investigated were :

- Do seeds grow the same in different soils?
- Can we change sandy soil into better soil?
- How long does it take for water to pass through soil?
- Do different animals live in different soils and why?
- How do bugs eat, breathe and move under soil?
- Does soil come into some food chains?

There was no problem in spending ten weeks on these mutually-suggested set of investigations. In the process the teachers were able to cover many concepts in the prescribed curriculum list.

The conception of Science that underpinned these integrating themes was still the conceptual one of the curriculum document as a whole. Real world themes that integrate a number of science concepts are also, of course, ones that can provide links with other curriculum areas. Some of those I have just exemplified can be addressed in ways that fit well into the fields of social studies. That is, they have historical, geographical, social and economic significance that may also be relatable to the content demands in these social areas of the primary curriculum. For teachers who went that far there seems again to have been a significant difference between a theme that is initially chosen for science study, and then extended to social study, and a theme that is chosen initially for social study, and later is to be extended for science study. In the former case the maintenance of the science is easier than in the case of the latter.

MID 1990s – on

More demands on the curriculum

This new estate for primary science had hardly begun to be recognized by schools when another twist of the external pressures on primary education occurred. Although language and number learning have always been the central features of primary school education, there was suddenly a new international concern for "Literacy" and "Numeracy". There were calls for national literacy targets and regular national testing in these two areas of learning. Deficiencies in them were highlighted, although the research evidence did not always show that deterioration over time was occurring. The demand was for even more attention to be given to these two areas.

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At this time also, the impact of computers on education, which had been rather haphazard for at least a decade, crystallized in the form of Information Technology (IT), a whole new area of knowledge and expertise to be introduced in the primary years for mastering during schooling.

With these three pressing demands on primary schooling, it was inevitable that there would be a downplaying of the newly established Science as well as of several other areas of knowledge, like social, physical and aesthetic education that primary schools try to include in their curriculum. The systems have not, however, as yet cut back their intentions for Science in the primary years proportionately. With less time and so much content to cover, the already, not very confident teaching of Science becomes even more transmissive and superficial. A recent study in Australia found that language regularly commanded nine hours per week, number 5-6 hours, and science 1-2 hours. In such a situation, the thematic approach above, that integrates within the science curriculum becomes much less tenable, since its extended investigations need regular connected time, and the thread of the theme and its conceptual learning is constantly broken when it is not being extended on a daily basis.

New opportunities for integration

The current reinforcement of language and number literacies as the priorities in the primary years of schooling suggest that, if science is to be other than marginal in the primary learners' experience, it should seek alliance with these two dominant areas of the curriculum. Teaching science in integrated ways that emphasize its roles in both language literacy and number literacy are strategies that seems much more likely to be much more fruitful than maintaining its earlier alliances with social studies and technology.

- Can an educational case be made for these two integrations, with language and number?

To answer this question we will find that it is necessary to face again two questions:

- ***What does learning Science mean?, and***
- ***More particularly, what are the goals of Scientific Literacy in primary schooling.***

Fortunately for the purpose of exploring integration as an approach to teaching primary science, we do not have to pioneer the opening of these two questions, because they are currently being debated in many national and international fora.

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INTEGRATION WITH LANGUAGE

Science as narrative story

Since the mid-1990s there has been an awakening to the fact Science is a narrative human story. Every piece of scientific knowledge, and the way it has been modified and developed over the years, has associated with it a human story in which there are actors, events and all sorts of interactions between them as the plot to elucidate this aspect of nature is pursued. We enjoyed and were reminded of the truth of this description of Science, when we read the exciting story about how Watson and Crick unraveled the structure of DNA - one of the truly great achievements of science in our time. Great scientific story tellers like Stephen J Gould and Primo Levi have been producing popular best sellers that are these human stories of science. **Five Equations that Changed the World**, a more recent book by Michael Guillan, tells the stories of how these equations became part of the store of science, and how that process changed the lives of the people involved, and in due course all our lives.

It is thus strange, indeed, to realise that story telling has not been among the many pedagogical approaches that have been canvassed, promoted and explored in the thirty years since the great curriculum reforms occurred, that underpin school science and first identified primary science. Primary teachers, among all teachers at the various levels of educational systems, are the ones to whom story telling comes most naturally to use with confidence in classrooms. Perhaps because scientists and secondary science teachers have been so much in control of all the curricular reforms-even those for primary science - that we missed such an obvious pedagogy for so long.

In **Beyond 2000**, the report of a futuristic projection in Britain to ***define Science Education for the Future*** recommends '*that scientific knowledge can best be presented in the curriculum as a number of key explanatory stories*' (Millar and Osborne, 1998). Before this legitimation of science education as story telling, several new curricula had appeared that are based on Science as story. One of these is the **Salters A level Chemistry** course in England and Wales. Its student text is entitled ***Storylines*** and each of its advanced topics is presented in story form. Because of this form, the conceptual chemistry involved is directly and explicitly in a context that gives it depth of meaning and provides students with the coherence for longer retention, that they have found so difficult, when the the same concepts are presented in the abstracted independence that has been the hallmark of the 1960s reforms.

For the other end of schooling, the Curriculum Corporation in Australia in the mid 1990s produced two sets of materials for primary Science: ***They***

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Don't Tell the Truth about the Wind (for grades 1-3), and ***There's an Emu in the Sky*** (for grades 4-7). In both these volumes of curriculum materials, the authors have specifically recognised both the motivating effect good stories have on primary age learners, and the basic literacy skills that are rehearsed by them when their learning of science comes in story form, or is to be put by them into story forms that may be journalistic, creative or dialogic in style.

Science as discourse

Another answer to the questions stems from the burgeoning interest over the last decade in interpreting learning in terms of discourse. ***To learn a discipline is to be able to participate in its discourses.*** From this dictum as the frame, there has been no shortage of interest among linguistic scholars in Science as a source of a particularly rich set of discourses. Among the scientific discourses that are being considered are *explicating a scientific question, issue or phenomenon, asking scientifically investigable questions, explaining observations with the use of different level of ideas, and argumentation involving assumptions, claims and evidence.*

This is rather a new view of school science and it extends very considerably the earlier appreciation in the 1970s and 1980s when *Words in Science* or the role individual words play in science was an important subject for research by science educators. The new concern is not just with the fact that many words are used with precise meanings in science, that are different from the looser meanings they have in other contexts. Nor is it limited to how well students appreciate logical connective words such as in English: *because, thus, therefore, and so*. The new interest is concerned with how the scientific status of the ideas, claims and evidence that lie on either sides of these connective words is presented in language.

Studies of each of the above scientific discourses among school age children (including those in the primary years) are now quite regularly being reported by science education researchers. They are not finding it difficult to collaborate with interested teachers in establishing lively oral discussions among the students in a classroom. Furthermore, they are showing that skilful scaffolding by the teacher, can assist students to become aware of the epistemological features that makes these discourses scientific, as distinct from the discourses that they may use in other subjects and genres of language. In like manner, there has been parallel interests among linguists and science educators in the discursive ways in which science is reported in text and how students can be helped to acquire the skills involved in writing their experiences in science.

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It must be noted, however, that these discursive aspects of Science, and their mirroring in school, science are quite different from the so-called content-free "science processes" that I have described earlier as the unsatisfactory answer the 1960s reforms gave to *What is Science in primary schooling?* In the case of these discourses the science content is integral and essential. There is no generalized "explaining" or "argumentation" in Science. An explanation of plant growth intimately involves the specific features of this growth, and the particular conditions under which this growth does and does not occur. A scientific argument about the association of the widespread use of CFCs in refrigeration and aerosols with increased ultra violet radiation, involves empirical investigation of the properties of these substances, this particular form of energy, and how interaction between them may be occurring.

The implication of the content embededness in these scientific discourses is that that not only the science knowledge of a topic needs to be known, but also how that knowledge was arrived at, and how the knowledge can be related in different contexts to other pieces of knowledge. A study of the science knowledge of primary teachers a few years ago made the interesting suggestion, that the latter two aspects of the science knowledge of a topic may be the clue to the confidence aspect of these teachers with respect to Science and its teaching (Osborne and Simon, 1996). In other words, the end product knowledge of a science topic that a textbook gives is necessary, but insufficient as knowledge in itself, to enable primary teachers to engage with their students in the open discussions and text compositions that Science as discourse requires.

Both Science as narrative and Science as discourse require the content of the primary science curriculum to be specified in terms of a deeper study of a small number of topics, that are both socially and scientifically important, rather than in terms of the many smaller topics that can only at best be treated in a superficial way as far as teaching/learning is concerned. This assumes we can be very clear about what the aim of primary school science is - that is, we have to answer the two questions above - and then we will have to use this aim as a ruthless criterion to select just which topics, from among the many possibilities, and those already in the current lists, will best achieve this aim.

Integration with Number

I mentioned earlier that *Measurement*, an integral notion in many aspects of Science, is a topic that primary teachers very readily also see as a mathematical topic within their responsibility. I have a suspicion that in primary mathematics, *Measurement* is seen essentially as skills to be learnt

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that involve the standard units and measures of length, mass, and time, and number operations on the number values associated with these measures. In Science, *Measurement* certainly has similar skill aspects, but it also has a strong conceptual aspect since any natural phenomenon must be observed and quite specifically addressed in order to decide what may be an appropriate way to measure it. For example, counting, not usually regarded, I think, as a means of measuring in primary mathematics, is commonly used as the appropriate means that science uses to measure its phenomena when the something to be counted is sufficiently well defined.

I hope someone with more knowledge of primary mathematics, and of the current thinking of its curriculum developers, will be able to point out that my suspicions are ill-founded. If the conceptual aspect of measurement in primary science is also part of primary mathematics, the prospects for effective integrated teaching and mutual learning are much enhanced.

Whatever is the case, Science in primary schooling can, at the skill level, provide motivatingly real and intellectually concrete contexts for young students to measure, and hence to practice counting, standard measuring, and number operating. At the conceptual level (if this too is shared) Science in combination with Mathematics facilitate classroom discussions of interesting contexts to be measured, that can lay strong foundations of the meaning and limitations of measurement in the minds of these young learners. Such critical appraisal of the meaning and worth of measures, will stand them in good stead when they encounter the quantitative measurements, so often of dubious validity, that advertisers, lobby groups and politicians so regularly use to persuade citizens of their worth.

Integration : in whose interest?

I have over the last decade been involved in two very large international projects to assess student learning in the literacy areas of science and, mathematics in the first and science, mathematics and language in the second. In both cases, it was always the Science group who made the overtures for cooperation, or for dual use of items, that could assess both the interests of science and the interests of the other field. When I look at curriculum statements about language literacy and number literacy, I do not so readily find the references to integrative advantage (with science or with mathematics), that I can easily find in the science curriculum debate. I know also teachers, albeit not too many, who are implementing integrated teaching of science in their classroom practices because they have experienced its value. I hope, once again, that my knowledge of these other fields is not a good assessment of their proponents' recognition of the

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integrative advantage for their concerns in the teaching/learning in the primary years.

REFERENCES

AAAS (1993). *Benchmarks of Scientific Literacy*. Washington, DC: American Association for the Advancement of Science.

Andersen, A.M. and Sørensen, H. (1995). Nature/Technology: Science education at primary level in Denmark. In A.M. Andersen, K. Schnack, and H. Sørensen (Eds.) *Science-Natur/Teknik, Assessment and Learning*, 5-26. Copenhangen: Royal Danish School of Educational Studies.

Millar, R. and Osborne, J. (Eds.) (1998). *Beyond 2000: Science education for the future*. London: School of Education, King's College.

NCC (1991). Science - Statutory Guidelines. London: National Curriculum Council.

Osborne, J. and Simon, S. (1996). Primary Science: Past and future directions. *Studies in Science Education*, **27**, 99-147.

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