Chapter 51
An International Perspective on Science Curriculum Development and Implementation

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Science curriculum development and implementation internationally have been enacted in an enormous variety of educational contexts. According to Richard Coll and Neil Taylor (2008a), curriculum development in so-called developing countries, the principal focus of this chapter, often involves external 'experts' in imposing Western curricula in educational contexts that are very different in economic, political and cultural terms – a sentiment alluded to earlier by Brian Gray (1999). Such curricula are often delivered in English, which is a second or third language for many students and teachers in non-Western settings as reported by Chanyah Dahsah and Richard Coll (2008). Considering what we now know about the importance of context in the learning process as noted by Albert Pilot and Astrid Bulte (2006), and the influence of culture as reported by Lilia Reyes-Herrera (2007) and Ken Tobin and Wolf-Michael Roth (2006), it is perhaps not surprising in retrospect that curriculum development and implementation have been less successful than hoped (Van Eijck and Roth 2007). A number of authors have pointed to the disconnection between cultural, religious and social issues in developing countries as they grapple with the implementation of imported Western science curricula. For example, Olugbemiro Jegede and Peter Okebukola (1991), along with Gerad Thijs and Ed Van Der Berg (1995), point to a mismatch between ideas about knowledge and scientific knowledge (see also Mbajiorgu and Iloputaife 2001). Konai Helu-Thaman (1991), a Pacific Island education scholar, rather depressingly commented that the Pacific is littered

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with the 'wreckage' of aid-funded curricular initiatives of this nature, and argues that it is important to get to grips with the reasons for such failure.

In this chapter, we present an analysis of science curriculum development internationally. We consider the history of curriculum development and implementation in science, seek to ascertain what we can learn from the problems and issues encountered, and make recommendations to inform future curriculum revisions in developing nations.

International Curriculum Development and Implementation

Developing countries have invested heavily in school science education since the 1960s, mostly in order to foster economic development and improve the quality of life. However, by the beginning of the last decade, Keith Lewin (1993) reported concerns about instructional quality and student achievement were becoming acute which, according to Henry Brown-Acquaye (2001), pointed to problems with the appropriateness or implementation of science curricula. A variety of developmental approaches have been tried out, with the outright adoption of curricula from Western countries – typically the colonial power – being the most common approach.

Clive McGee (1997) says curriculum development and implementation in most countries, including developing nations, have involved the centre-periphery model. Typically, this is dominated by central government or officials charged with implementation. In a critique of curriculum development and implementation in 25 developing nations, Richard Coll and Neil Taylor (2008b) identified several key themes: the *pace of curriculum development*; the *political dimension*; the almost universal *adoption of a learner-centred curriculum*; issues to do with *the assessment regime*; and a relative paucity of *contextualised evaluation*. These themes form the framework for the following analysis of curriculum development and approaches to implementation.

The pace of curriculum development and implementation is exemplified by two contrasting examples. In the first, Turkey, Muammer Çalik and Ayas Alipaşa (2008) observe that, over a relatively short period of time, four major revisions and 11 different versions of the science curriculum were promulgated from 1924 to 2005, with six since 1968. Indeed, they note that Turkish teachers have never actually managed to implement a particular curriculum fully before it was replaced with a new version. The sheer pace of educational development in terms of growth in student numbers is exemplified by the case of Bhutan, for which Tom Maxwell (2007) reports that school enrolments rose from virtually zero, to 130,000 in a few decades. It seems likely that this level of growth would cause problems, but Tenzin and Maxwell (2008) rather surprisingly suggest otherwise, saying that the curriculum development was measured, contextualised and well managed.

The political dimension is seen in the value of education, and science education in particular, being linked to the economic and technological modernisation of developing nations (Koh et al. 2008). This notion was particularly prevalent in the

1980s and 1990s says Aaron Benavot (1992), and such thinking continues to this day (World Bank 2008). At the societal level, Keith Lewin (1993) feels that education, especially basic or elementary science education, has the potential to improve living conditions through addressing basic local issues such as the provision of clean water, sound nutrition and personal health. It was such considerations as these, associated with basic human needs, which prompted the Science for All paradigm arising from the UNESCO Minedap V conference (UNESCO 1986, p. 137). It seems that the principal driving force behind science curriculum development and reforms is the so-called *economic imperative*, with many developing nations seeking to improve standards of living by enhancing economic development.

Many developing nations had very traditional science curricula up until about the 1980s. But the 1980s and 1990s witnessed 'explosive' curriculum reforms worldwide, including in developing countries, and arguably the single most commonly shared attribute of these curricula was their constructivist origins described by Beverley Bell et al. (1995). Learner-centred education, with its origins in constructivism (and variants of constructivism) and focus on outcomes (Rogan and Grayson 2003), became something of a mantra according to Joan Solomon (1987). Richard Coll and Neil Taylor (2008a) believe that this was largely driven by a perception that, because developed or Western nations had developed constructivist-based curricula, developing nations feared being left further behind economically and strove to adopt a learner-centred curriculum as rapidly as possible in order to overcome reliance on subsistence agriculture or production of primary produce – something claimed to be the prime source of tenacious poverty in many developing nations (World Bank 2008). According to Martha Montero-Sieburth (1992), even if not directly based on constructivism, other curriculum development efforts also were learner-centred in nature.

Graham Vulliamy (1988) comments that, before the educational reforms of the 1980s and 1990s, assessment in developing countries was dominated by a series of high-stakes, external, summative examinations (see also Postlethwaite 1991). Furthermore, these examinations largely focused on lower-level cognitive skills such as recall. Whilst developing nations have since attempted to develop and implement learner-centred curricula as noted by Hsin-Kai Wu and Ya-Ling Huang (2007), Richard Coll and Neil Taylor (2008b) argue that they seldom have made commensurate adjustments to their assessment regimes. Consequently, examinations still dominate the education system in developing nations. Plainly such examinations are inconsistent with learner-centred education, because the examinations consist of tests of memory recall, which encourage rote memorisation of scientific 'facts'. This is by no means unique to developing countries. Anne Hume and Richard Coll (2007), commenting in the context of New Zealand, reported that the development of a matched assessment regime trailed curriculum reforms by nearly 10 years. But, the situation in many developing countries is often much more severe and is compounded by limited secondary school places and highly competitive examination systems such as in India as observed by Mridula Ranade (2008). However, there are signs of hope, with Neil Taylor et al. (2003) reporting that Fiji, once dominated by a series of five gate-keeping external summative examinations, is now embarking on a rather radical shift towards competency-based assessment. This change will be

part of a major reform of education, beginning with primary science, involving the development of a new student-centred curriculum and accompanying resources. The crucial difference from previous curriculum development projects is that the assessment system will also be reformed with a move away from external summative examinations and the introduction of elements of continuous assessment as described by Neil Taylor et al. (2008). Without this move away from external summative examinations, there would be little prospect of a change in pedagogy, as teachers would continue to employ the transmissive teaching strategies that have always proved successful under the examination regime.

The best educational reforms and the most sophisticated curricula – even if well matched to an assessment regime – are likely to prove fruitless unless reforms and implementation of new curricula are accompanied by adequate teacher professional development. Teacher professional development, according to Shirley Grundy (1995), has typically been of the 'pit stop' or 'one shot' variety that consists of a series of one-off teacher professional development workshops run by ministry officials soon after the official launch of new curricula. Josef De Beer (2008) comments that, even nowadays, the normal response to such an approach is 'business as usual'. In other words, teachers look to see how they can continue with existing teaching practices in the 'new' curriculum, albeit with a little tinkering so that it appears that things have changed in the way intended. Chanyah Dahsah notes this is exactly what happened in Thailand. A learner-centred curriculum was developed in the 1990s and duly 'implemented' (Dahsah and Coll 2008). But her research suggests that many Thai teachers had little appreciation of what learner-centred education actually means (despite being readily able to recite definitions) in terms of teaching practice. The development of learner-centred curricula has been accompanied by recent local research into how actually to deliver such curricula, mostly with a focus on constructivist-based pedagogies such as the use of analogies reported by Muammer Çalik et al. (2007, 2009). However, despite the introduction of a new learner-centred curriculum, teaching remains didactic in nature in most Thai schools.

It seems that, despite enormous amounts of money being spent on curriculum development and reform (some local monies, much foreign aid from international organisations or NGOs), relatively little evaluation research has been conducted. Certainly a number of developing nations have participated in international monitoring projects such as TIMSS reported by Heiner Rindermann (2007) and PISA reported by Vassilia Hatzinikita et al. (2008), but contextualised, local evaluation or research efforts, with a few exceptions, remain modest. Chao-Ti Hsiung (2007) reports that Taiwan has embarked on substantive efforts to conduct local research, and much of this is evaluative in nature. In Thailand, the situation is similar, and this is driven by a research institution charged with improving science education by means of research – the Institution for Promoting Science and Technology (IPST) his institution which funds a substantial PhD program in science education, with many Thais being sent overseas for doctoral studies and then encouraged to continue in research when subsequently appointed to teacher training institutions upon their return, as described by Chockchai Yuenyong et al. (2008). However, Muammer Çalik and Ayas Alipaşa (2008) caution that often even high-quality local research

might not make much difference in the classroom, partly because it is not seen as relevant to or accessible by teachers. Difficulties identified are the habitual ones associated with many constructivist-based teaching strategies, such as those noted by Ken Tobin and Debora Tippins (1993) – taking more time to cover the curriculum, something highly unpopular when teachers are faced with a crowded curriculum as reported for the Solomon Islands by David Sade and Richard Coll (2003), or a lack of resources for delivering practical work as noted by Michael Kahn (1990). The other main cause is that alluded to above, namely, inconsistencies between the assessment regime and a learner-centred approach to teaching. Teachers are evaluated in terms of performance based on pass rates in summative examinations. Indeed, in many countries, school examination pass rates are published in local newspapers and league tables. It would be a brave teacher indeed who engaged in learner-centred education, if she or he feased it adversely affected school pass rates.

Lessons Learned and Recommendations for Curriculum Development and Implementation in Developing Nations

So what can we learn from our experiences of curriculum development and implementation in developing countries? Looking at the 'wreckage', to use Konai Helu-Thaman's (1991) term, one might think that we have not learned very much at all. But we suggest here that a critical analysis of local experiences provides a sound platform for further development and implementation. The recommendations made here are derived from the above discussion.

Our first recommendation is that *curriculum development should be needs-based*. Although this might seem rather self-evident, curriculum development has seldom been based on a needs analysis of the specific educational context. Economic development, we suggest, is not necessarily the 'be all and end all' of curriculum reforms. Consider some contextualised examples. Africa is ravaged by HIV/AIDS, which is not unrelated to economic development. If a large proportion of a nation's young people suffer from potentially fatal illnesses such as HIV/AIDS, Jonathan Clark and Cedric Linder (2006) rightly note that this will exert a serious impact on economic development. But surely, as its first priority, science education in developing nations should be about health-related matters, such as HIV/AIDS prevention in Africa and sub-Saharan African nations, which Joseph Matsoga (2008) says is the major social issue; the water-borne diseases that are crucial in India, according to Mirdula Ranade (2008) and in Pakistan, according to Nelofa Halai (2008). Likewise, the notion that producing more science graduates will result in economic growth is, to us, too simplistic. Vanwyck Chkasanda and Ida Mbendera (2008) talk about the pointlessness of Malawi continuing to produce far more technical college graduates than the local manufacturing industry can ever employ.

Second, the literature suggests that the curricula enacted in developing nations are still dominated by external, foreign ideas (such as constructivism or learner-centred education). We are sympathetic to the notion of learning from others; it would be

imprudent to ignore high-quality international educational research about teaching approaches that genuinely seem to improve teaching and learning. We also recognise the temptation of developing nations to adopt what appears to have been successful in developed nations. However, we suggest that *curriculum development and reform need to be built upon careful evaluation of past* local *experience*. This is not to say that we should ignore international ideas and trends, but we *must* tailor them to the peculiarities of the local context (Hsiung 2007). It is not unreasonable to decide after careful evaluation that we do not need to substantially reform our curriculum. As the case of Turkey exemplifies, repeated change is highly destabilising and likely to result in teachers ignoring any reforms and carrying on teaching in much the same way. It would be nonsensical effectively to ignore the enormously valuable, in-depth, local research about science education in Thailand conducted under the auspices of IPST, or the massive body of research conducted about science education in Taiwan.

Third, there needs to be *coherence between curriculum aims and assessment of learning outcomes*. Again, one might think that this is self-evident, but again we argue that it seldom actually occurs, especially in developing nations. If we want teachers to use learner-centred teaching approaches, we cannot expose them to ridicule or bad employment evaluations by retaining assessment regimes that are wholly inconsistent with such teaching approaches. This is what John Biggs (1992) refers to as 'constructive alignment': curriculum objectives and learning outcomes are duly aligned with methods of teaching and learning, which in turn are aligned with modes of assessment. The literature suggests that we need to employ multiple modes of assessment to be consistent with a learner-centred curriculum (Tobin and Tippins 1993; Wheatley 1991). Richard Coll and Neil Taylor (2008b) note that assessment regimes in developing nations are the principal drivers of teacher behaviour, and that no amount of professional development will bring about pedagogical change if summative assessment regimes are retained. There are promising indications that this connection is finally being made and that there are signs of constructive alignment in some nations. In Fiji, as mentioned above, major efforts are being made to link the assessment regime with intended learning outcomes (Taylor et al. 2008). Likewise, Princy Selvaruby et al. (2008) report a shift towards school-based assessment in Sri Lanka, which is something that they argue enables teachers to combine formative and summative assessment systems. Such change to assessment practices is often contentious, but Anne Hume (2003) argues this is often just because it takes time for all stakeholders to adjust to new assessment regimes, especially if they are radically different from those experienced in the past. Patience could be required to win over the sceptical!

Fourth, whilst we have argued above that teacher professional development will not, of itself, bring change to pedagogy or intended learning outcomes, *curriculum reform and subsequent implementation need to be accompanied by substantial and* ongoing *teacher professional development*. The logic here is deceptively simple; we can hardly expect teachers to change from a highly didactic teaching approach towards a more learner-centred education system if we fail to develop a shared understanding between teachers and curriculum developers of what learner-centred education actually means (Sade 2008; Varela 2007). We have good evidence of

what does not work according to Chen-Yung Lin et al. (2005). Anthony Koosimile and Bob Prophet (2008) report that the cascade model, in which selected teachers receive training and then convey the message to their peers, has failed spectacularly in Botswana despite enormous resources being provided for implementation. Teacher professional development should be collaborative in nature, especially if new curricula involve new, imported or foreign ideas or theories. Bill Atweh et al. (2008) report a fascinating collaborative model for teacher professional development in the Philippines framed as 'capacity building'. The idea is not dissimilar to Koosimile and Prophet's (2008) cascade model, but differs in important ways. Key differences lie in 'minimizing the uncritical transfer of knowledge and value' (Atweh et al. 2008, p. 4), along with careful attention to the status attributed to the foreign expert and local curriculum developers or teachers. Atweh and colleagues remind us that the teacher is the principal mediator of curriculum implementation and that, unless we want implementation to 'fall at the last hurdle' (i.e. the classroom), we need to view teacher professional development as an integral part of the investment in curriculum development or reform, and not some additional cost towards the end of the process that Choshi Kasanda (2008) says occurs all too often. The alternative, noted by Ann Ryan (2008), is that science education is strongly influenced by neo-colonial influences that significantly contribute to the 'silencing' of the local voices. Implicit in this silencing is the notion of respect, something that Kathryn Scantlebury argues is all too often lacking in foreign experts' treatment of locals during curriculum development (Scantlebury 2008).

Fifth, and again one might think it obvious, *curriculum development and particularly effective implementation take time* and typically a lot longer than allowed. It is difficult to divorce the time element from the political dimension as the Turkey situation indicates. John Rogan and Diane Grayson (2003) report that curriculum implementation that was based on good ideas in South Africa failed because the newly elected government did not allow sufficient time for implementation of a curriculum. 'In Southern Africa in general, there appears to be a tendency to ignore existing diversity and to mandate complex and comprehensive changes in systems that may or may not be ready to cope with them' (Rogan and Grayson 2003, p. 1175). It is imprudent to expect effective implementation of a new or reformed curriculum in a few years, but our contention here is that this implementation should be a measured *incremental* process that is informed by evidence-based research and evaluation studies that are contextualised to the particular educational setting (Weinstsein 2008). John Rogan (2007) talks of the *zone of feasible innovation* and relates curriculum change to Vygotsky's zone of proximal development. We need to move into a 'curriculum space' that represents genuine advancement, but only at a pace that stakeholders can cope with. Research in China by Bangping Ding (2008) suggests that the central government was very measured in its approach to curriculum development. It first engaged in the development of a sound rationale for curriculum reform and subsequently it identified four distinct phases for curriculum implementation: alignment with modernisation; a study of future employment needs; raising quality in education; and considering the role of science in society and addressing environmental problems (Bing and Thomas 2006).

Conclusions

It is all too easy to become despondent if one reflects upon Konai Helu-Thaman's exasperation and feels that not much has changed. But we suggest that there are genuine signs that we have learned from the mistakes of the past. There are indications that the governments of many developing nations appreciate the importance of a concerted, consistent and holistic approach to curriculum development and implementation. Good-quality international research provides helpful ideas for implementation in the very different educational contexts that exist in developing countries. Our recommendations and Rogan's model provide a sound basis for a much more thoughtful and measured approach to curriculum development and implementation in developing countries. Naturally we would expect failure if we tried to teach students something very far from their zone of proximal development; unless we do likewise with curriculum development and implementation, we are doomed to repeat the mistakes of the past.

We make two concluding comments. First, a critical reader might feel that our recommendations are all very well in theory but impractical because of a lack of resources. We disagree. We suggest huge amounts of money have always been spent, often unwisely, on science curriculum development in developing nations by local governments and local and international NGOs and aid organisations. We would argue that the money needs to be better targeted (as suggested above), and its spending should take cognisance of local realities. Second, in some cases, development of a common core science curriculum might make sense. This might seem to conflict with our first conclusion, but the key emphasis here is on the common *core* curriculum. This could be supplemented with modules that cover specific local needs. As an illustration, in a study of primary science curriculum projects amongst Pacific Island countries, Neil Taylor et al. (2003) discovered considerable duplication of effort for island states with small populations and very limited economic resources. Based on this finding, Taylor et al. argued for a common core curriculum with optional modules to cater for local difference in, say, biodiversity or particular local issues such as phosphate mining in Nauru. Probably this would be much more cost-effective than the current individual approach that often results in rather sub-standard curriculum resources being produced.

A key feature of our analysis here is that it is largely based on literature and research reports produced by local people in developing nations. Our contention is that these reports provide valuable insights from people intimately involved in science curriculum development and implementation in developing nations. It would be both imprudent and arrogant to ignore their voices. Failure to do so risks repetition of past mistakes, resulting in highly predictable failure in the development and implementation of science curricula.

References

Atweh, W., Bernardo, A. B. I., & Balagtas, M. (2008). Capacity building as a collaborative model in international development projects: Lessons for the Philippines. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 3–15). Rotterdam: Sense Publishers.

Bell, B., Jones, A., & Carr, M. (1995). The development of the recent national New Zealand science curriculum. *Studies in Science Education*, *26*, 73–105.

Benavot, A. (1992). Curricular content, educational expansion, and economic growth. *Comparative Education Review*, *36*, 150–174.

Biggs, J. (1992). Enhancing teaching through constructive alignment. *Higher Education*, *32*, 347–364.

Bing, W., & Thomas, G. P. (2006). An examination of the change of the Junior Secondary School Chemistry Curriculum in the PR China: In the view of scientific literacy. *Research in Science Education*, *36*, 403–416.

Brown-Acquaye, H. A. (2001). Each is necessary and none is redundant: The need for science education in developing countries. *Science Education*, *85*, 68–70.

Çalik, M., & Alipaşa A. (2008). A critical review of the development of the Turkish science curriculum. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 161–174). Rotterdam: Sense Publishers.

Çalik, M., Alipaşa A., & Coll, R. K. (2007). Investigating the effectiveness of a constructivist-based teaching model on student understanding of the dissolution of gases in liquids. *Journal of Science Education and Technology*, *16*, 257–270.

Çalik, M., Alipaşa A., & Coll, R. K. (2009). Investigating the effectiveness of an analogy activity in improving students' conceptual change for solution chemistry concepts. *International Journal of Science and Mathematics Education, 7*, 651–676.

Chkasanda, V. K. M., & Mbendera, I. K. (2008). Technical education reforms in Malawi. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 223–234). Rotterdam: Sense Publishers.

Clark, J., & Linder, C. (2006). *Changing teaching, changing times: Lessons from a South African township science classroom*. Rotterdam, The Netherlands: Sense Publishers.

Coll, R. K., & Taylor, N. (2008a). Science education in context: An overview and some observations. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. xi–xiv). Rotterdam: Sense Publishers.

Coll, R. K., & Taylor, N. (2008b). The influence of context on science curricula. Observations, conclusions and some recommendations for curriculum development and implementation. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 355–362). Rotterdam: Sense Publishers.

Dahsah, C., & Coll, R. K. (2008). Thai grade 10 and 11 students' understanding of stoichiometry and related concepts. *International Journal of Science and Mathematics Education*, *6*, 573–600.

De Beer, J. (2008). Inclusive science education for the rainbow nation: Reflections on science teaching and the development and implementation of the national curriculum statement in South Africa. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 261–270). Rotterdam: Sense Publishers.

Ding, B. (2008). Learning from other countries: A critical examination of the current primary science curriculum reforms in mainland China. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 343–352). Rotterdam: Sense Publishers.

Gray, B. V. (1999) Science education in the developing world: Issues and considerations. *Journal of Research in Science Teaching*, *36*, 261–268.

Grundy, S. (1995). *Action research as professional development* (Occasional Paper #1, Innovative Links Project). Canberra: Australian Government Publishing Service.

Halai, N. (2008). Curriculum reform in science education in Pakistan. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 115–129). Rotterdam: Sense Publishers.

Hatzinikita, V., Dimopoulos, K., & Christidou, V. (2008). PISA test items and school textbooks related to science: A textual comparison. *Science Education*, *92*(4), 664–687.

Helu-Thaman, K. (1991). A letter from a curriculum officer. In C. Benson (Ed.), *Report of the Pacific Curriculum Conference* (pp. 98–105). Suva, Fiji: Institute of Education, University of the South Pacific.

Hsiung, C.-T. (2007). A Taiwanese journey into science and science education. In K. Tobin & W.-M. Roth (Eds.), *The culture of science education: Its history in person* (pp. 165–174). Rotterdam: Sense Publishers.

Hume, A. (2003). The National Certificate of Educational Achievement and formative-summative tensions: Are they resolvable? In R. K. Coll (Ed.), *STERpapers* (pp. 68–92). Hamilton, New Zealand: University of Waikato.

Hume, A., & Coll, R. K. (2007, April). *The influence of a standards-based qualification on student inquiry in science*. Paper presented at the annual meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Jegede, O., & Okebukola, P. A. (1991). The relationship between African traditional cosmology and students' acquisition of a science process skill. *International Journal of Science Education*, *13*, 37–47.

Kahn, M. (1990). Paradigm lost: The importance of practical work in school science from a developing country perspective. *Studies in Science Education*, *18*, 127–136.

Kasanda, C. D. (2008). Improving science and mathematics teachers' subject knowledge in Namibia. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 199–209). Rotterdam: Sense Publishers.

Koh, T. S., Tan, K. C. D., & Cheah, H. M. (2008). Science education in Singapore: Meeting the challenges ahead. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 283–290). Rotterdam: Sense Publishers.

Koosimile, A. T., & Prophet, R. B. (2008). Science teaching in context in Botswana. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 187–198). Rotterdam: Sense Publishers.

Lewin. K. (1993). Planning policy on science education in developing countries. *International Journal of Science Education*, *15*, 1–15.

Lin, C.-Y., Hu, R., & Changlai, M.-L. (2005). Science curriculum components favored by Taiwanese biology teachers. *Research in Science Education*, *35*, 269–280.

Matsoga, J. T. (2008). Handling school science curriculum in Botswana: Local context realities and experiences. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 177–186). Rotterdam: Sense Publishers.

Maxwell, T. W. (2007). The important issues facing children in the Kingdom of Bhutan. In I. Epstein & J. Pattnaik (Eds.), *The Greenwood encyclopedia of children's issues worldwide: Asia and Oceania* (pp. 53–77). New York: Greenwood.

Mbajiorgu, N. M., & Iloputaife, E. C. (2001) Combating stereotypes of the scientist among preservice science teachers in Nigeria. *Research in Science and Technology Education*, *19*, 55–68.

McGee, C. (1997). *Teachers and curriculum-decision-making*. Palmerston North, New Zealand: Dunmore.

Montero-Sieburth, M. (1992). Models and practice of curriculum change in developing countries. *Comparative Education Review*, *36*, 175–193.

Pilot, A., & Bulte, M. W. (2006). What do you need to know? Context-based education. *International Journal of Science Education*, *28*, 953–956.

Postlethwaite, T. N. (1991) Achievement in science education in 1984 in 23 countries. In T. Husen & J. P. Keeves (Eds.), *Issues in science education: Science competence in a social and ecological context* (pp. 35–64). New York: Pergamon.

Ranade, M. (2008). Science education in India. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 99–114). Rotterdam: Sense Publishers.

Reyes-Herrera, L. (2007). Science education in Columbia: Possibilities and challenges. In K. Tobin & W.-M. Roth (Eds.), *The culture of science education: Its history in person* (pp. 197–205). Rotterdam: Sense Publishers.

Rindermann, H. (2007). The g-factor of international cognitive ability comparisons: The homogeneity of results in PISA, TIMSS, PIRLS and IQ-tests across nations. *European Journal of Personality*, *21*, 667–706.

Rogan, J. M. (2007). How much curriculum change is appropriate? Defining a zone of feasible innovation. *Science Education*, *91*, 439–460.

Rogan, J. M., & Grayson, D. J. (2003). Towards a theory of curriculum implementation with particular reference to science education in developing countries. *International Journal of Science Education*, *25*, 1171–1204.

Ryan, A. (2008). Indigenous knowledge in the science curriculum: Avoiding neo-colonialism. *Cultural Studies of Science Education*, *3*, 663–702.

Sade, D. (2008). Technology education development in the Solomon Islands. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 45–53). Rotterdam: Sense Publishers.

Sade, D., & Coll, R. K. (2003). Solomon Island stakeholders' views of technology and technology education. *International Journal of Science and Mathematics Education*, *1*, 87–114.

Scantlebury, K. (2008). Whose knowledge? Whose curriculum? *Cultural Studies of Science Education*, *3*, 694–696.

Selvaruby, P., O'Sullivan, B., & Watts, M. (2008). School-based assessment in Sri Lanka: Ensuring valid processes for assessment-for-learning in physics. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 131–141). Rotterdam: Sense Publishers.

Solomon, J. (1987). Social influences on the construction of pupils' understanding of science. *Studies in Science Education*, *14*, 63–82.

Taylor, N., Maiwaikatakata, T., Biukoto, E., Suluma, W., & Coll, R. (2008). Improving elementary science education in a developing country: A case study from Fiji. *International Journal of Educational Reform*, *17*, 133–152.

Taylor, N., Vlaardingerbroek, B., & Coll, R. K. (2003). Exploiting curriculum commonality in small island states: Some strategies for primary science curriculum development in the South Pacific. *International Journal of Science and Mathematics Education*, *1*, 157–174.

Tenzin, W., & Maxwell, T. (2008). Primary science curriculum in Bhutan: Development and challenges. In R. K. Coll & N. Taylor (Eds.), *Science education in context: An international examination of the influence of context on science curricula development and implementation* (pp. 313–332). Rotterdam: Sense Publishers.

Thijs, G. D., & Van Den Berg, E. (1995). Cultural factors in the origin and remediation of alternative conceptions in physics. *Science and Education*, *4*, 317–347.

Tobin, K., & Roth, W.-M. (2006). *The culture of science education: Its history in person*. Rotterdam: Sense Publishers.

Tobin, K., & Tippins, D. (1993). Constructivism: A paradigm for the practice of science education. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 3–21). Hillsdale, NJ: Lawrence Erlbaum.

UNESCO (1986). *Education in Asia and the Pacific: Retrospect*, *prospects*. UNESCO: Bangkok.
Van Eijck, M., & Roth. W.-M. (2007). Keeping the local local: Recalibrating the status of science and traditional ecological knowledge (TEK) in education. *Science Education*, *91*, 926–947.
Varela, G. A. (2007). Rising to the top. In K. Tobin & W.-M. Roth. (Eds.), *The culture of science education: Its history in person* (pp. 175–183). Rotterdam: Sense Publishers.
Vulliamy, G. (1988). Third world schools. In S. Briceno & D. C. Pit (Eds.), *New ideas in environmental education* (pp. 143–157). London: Croom Helm.
Weinstsein, M. (2008). Finding science in the school body: Reflections on transgressing the boundaries of science education and the social studies of science. *Science Education*, *92*, 389–403.
Wheatley, G. H. (1991). Constructivist perspectives on science and mathematics learning. *Science Education*, *75*, 9–21.
World Bank (2008). *World development report: Agriculture for development*. Retrieved September 1, 2008 from http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/0,,menuPK:476823~pagePK:64165236~piPK:64165141~theSitePK:469372,00.html
Wu, H.-K., & Huang, Y.-A. (2007). Ninth-grade student engagement in teacher-centered and student-centered technology-enhanced learning environments. *Science Education*, *91*, 727–749.
Yuenyong, C., Jones, A., & Yutakom, N. (2008). A comparison of Thailand and New Zealand students' ideas about energy related to technological and societal issues. *International Journal of Science and Mathematics Education*, *6*, 293–311.