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Science Curriculum Design: a model based on *who we are*

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In this paper I present a model for understanding and implementing science curriculum design. Numerous factors influence what we wish to teach and how we teach. A number of these factors are in conflict, some are contested across interest groups, and some of our goals are constrained by resources. We may struggle to find a vision that is inspiring, acceptable and feasible within our contexts and constraints. I suggest in this paper, which draws on science curriculum research, values in education, and worldview, a way of reflecting on the complexity of issues that need to be considered in science curriculum design. Traditionally we have been concerned with improving students' ability to learn, to produce results, and to demonstrate knowledge and skill. Have we paid enough attention to the human context and the consideration of science for purposes of harmony and openness? Is there an opportunity now to focus on the values inherent in science education? Could this be a central starting point worthy of both contested debate and deep caring for the significance of our learning?

Key Words: Science curriculum design; values

مویرا کین

در این مقاله نویسنده سعی در ارائه‌ی مدلی برای درک و اجرای طرح برنامه‌درسی علوم دارد. عوامل متعددی بر محتوا و شیوه‌ی تدریس اثر می‌گذارند. برخی از این عوامل با یکدیگر در تعارض می‌باشند، و برخی دیگر به طور مشترک مورد تأیید گروه‌های مختلف هستند، و به این صورت برخی از اهداف ما توسط منابع محدود می‌گردند. ما در پی یافتن منظری می‌باشیم که در حوزه‌ی محدودیت‌ها و بسترهای ما الهام‌بخش، قابل پذیرش، و امکان‌پذیر باشد. در این مقاله، که به پژوهش‌های برنامه‌درسی علوم، ارزش‌ها در آموزش و جهان‌بینی می‌پردازد، شیوه‌ای برای تأمل پیرامون پیچیدگی‌های مسائلی که در طراحی برنامه‌درسی علوم باید مورد بررسی قرار گیرند پیشنهاد خواهد شد. پیش از این آموزش عمدتاً بر بهبود توانایی‌های فراگیران جهت یادگیری، ارائه‌ی نتایج، و نشان دادن دانش و مهارت خویش تمرکز داشت. اما آیا ما توجه کافی به بسترهای انسانی و کاربرد علوم به هدف یکپارچگی و کشودگی داشته‌ایم؟ آیا اکنون فرصتی برای تمرکز بر ارزش‌های موجود در آموزش علوم وجود دارد؟ آیا این می‌تواند نقطه‌ی آغازینی برای مباحث رقابتی و توجه عمیق و دقیق به اهمیت یادگیری به شمار آید؟

کلید واژه‌ها: طراحی برنامه درسی علوم، ارزش‌ها

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Introduction

> *"...knowledge is not an end in itself but just a means to a greater end, namely that of human happiness."* (Ernest, 2008:14)

Curriculum design is not a trivial activity. It requires an in-depth understanding of the context of, and pressures on the education system as well as a multidisciplinary understanding of science, children, learning, planning, creativity, and science education research. This list is not exhaustive. It also requires a vision that is shared, that will allow for positive change and growth but that will build on our knowledge and cultural heritage. In the models presented here I approach curriculum design from an educator's perspective, where there may be scope for innovation and for broadening thinking around science teaching and learning.

The purpose of this paper is to expand the possibilities in conceptualising science learning through drawing on eclectic sources that provide guidance on curriculum design, insights into worldviews and approaches to values. I first present factors that influence the curriculum; reflect on the concept of curriculum; and consider some of the purposes that shape content and design; then introduce the role of values and worldview in science; and finally suggest elements of design and a model that is centred on human well-being.

Factors that influence curriculum design

If we look through science texts books, or syllabus outlines, or curriculum statements, or science education research topic areas, we are likely to find science education linked to the following key factors. There is: language, student interests, local relevance, culture, values, political goals, needs of the economy, the environment, global pressures, the nature of science itself, key content concepts, as well as theories of teaching and learning. It is probably necessary to include most, if not all, of these factors in our thinking about science curricula. These act as contexts, constraints, drivers and influencing factors on the

learning of science. We also need to consider what we mean by a curriculum.

Concept of curriculum

It is well established that *science curriculum* appears in many guises and disguises. The curriculum that is designed is probably different from the one implemented, which, in turn, is different from the one learnt. The intended curriculum is underpinned by the hidden curriculum – which in turn is modified by place and participants.

"The learned curriculum is the one that counts: it is also much richer and more subtle than the intended curriculum." (Malcolm, 2004).

While this is often true, the learned curriculum may include negative aspects or at least an outmoded ethos. We know the actual learned curriculum may be more limited than the intended curriculum and may produce unintended consequences; of course, the learned curriculum may, on the other hand, be richer. If students do not achieve the course outcomes they attain other outcomes – both positive and negative. Much has been written about the 'hidden curriculum'. The hidden curriculum is usually embodied in the power play of institutions, their communication modes, values and even the architecture of schools and arrangements of classrooms (Stefan, 2010). If we decide to consciously explore the "richer and more subtle" *learned curriculum* we may aim for including in science education the influences and transformations that have made us who we are and who we aspire to be. This leads to the question of our educational purposes.

Purposes

Science Curricula around the world have statements about the purposes of the subject in schools. South Africa provides a typical example where science learning should include:

- knowledge, skills and values worth learning
- values necessary for self-fulfilment, and meaningful participation in society as citizens of a free country
- provision for access to higher education
- providing employers with competent employees.

The curriculum in general has a further lofty and key purpose of transforming society:

> *"... ensuring that the educational imbalances of the past are redressed, and that equal educational opportunities are provided for all sections of our population..."*

Science educators sometimes considers themselves exempt from such purposes and expect such aims to be address in humanities and courses such as civics. The question remains open: do science teachers have a role to play in promoting broader educational goals? The examples of such expectations from South Africa's National policy continues:

- Human rights, inclusivity, environmental and social justice; environmental justice and human rights as defined in the Constitution of the Republic of South Africa.
- The National Curriculum Statement Grades 10 – 12 is sensitive to issues of diversity such as poverty, inequality, race, gender, languageinfusing the principles and practices of social and
- , age, disability and other factors;
- Valuing indigenous knowledge systems; acknowledging the rich history and heritage of this country
- Credibility, quality and efficiency; comparable to those of other countries.

Policy further comments on the type of learning expected. This should be:

- "Active and critical learning; ...rather than rote and uncritical learning of given truths;
- High knowledge and high skills

The National Curriculum Statement Grades R - 12 aims to produce students who are able to:

- identify and solve problems and make decisions using critical and creative thinking;
- work effectively as individuals and with others;
- organise and manage themselves responsibly and effectively;
- collect, analyse, organise and critically evaluate information;

- communicate effectively;
- use science and technology effectively and critically showing responsibility towards the environment and the health of others; and
- demonstrate an understanding of the world as a set of related systems.

While policy clearly intends that education be holistic I have seldom seen real attempts to include a significant number of these purposes in any level of science education. Rather like the dilemmas we face in our own professional lives, it is all too easy to be caught in what is urgent rather than in what is important. For schools, improving pass-rates is urgent; comparisons on international tests put pressure on teachers to deliver content, as do national league tables. IN all of this do we have time to reflect on what is really important? If what we want is happiness for ourselves and out children – are we creating conditions for this?

In every country the science curriculum is embedded within political, environmental, cultural and socio-economic tensions. Thus, as different groups exert influence, we have great shifts in focus that may move from science for economic development; to multicultural science, science-for-all, and humanistic science; and then back to emphasising science content and skills. In our own thinking and lesson designs, an aspect that may be helpful in reconciling contesting agendas is to draw on interdisciplinary learning and multidisciplinary research.

At least at the level of policy, attempts are made to include significant values and a wide range of purposes in the curriculum. In South Africa these include access, transformation, redress, gender, culture, indigenous knowledge and diversity.

Role of Values

> *"It is necessary to create an atmosphere in which moral values and humanity can flourish naturally" (UNESCO, 1993.)*

As researchers we are encouraged to address a *problem,* so we often focus on *barriers* to learning rather than on the ways existing knowledge *contributes* to learning. Does looking at existing values,

strengths and cultural resources provide a stronger base from which to design our aspired knowledge legacy? The role of values is acknowledged in the following examples:

> "Values lie at the heart of the school's vision of itself as a community.' (UK National Curriculum Council, 1992).
>
> "Values permeate all educational activity.' (Scottish Curriculum Council, 1991, quoted in Edwards, 1996:172)

These references to values at the level of a mission statement or policy level tend to refer to values in the sense of moral principles that guide behaviour. I broaden the conceptualisation of values later. In this fist sense values are assumed to correlate with right conduct and good intention; to align with ethical behaviour as explained by Adams St. Pierre (2006: 260):

> *"...ethics... is what happens when the simplistic rules and moral codes our culture provides become inadequate in the face of the difference of the Other. I suggest that science is what happens when we give up the simplistic definitions and procedures our culture provides in the face of inquiry... Thus I will always be unprepared to be ethical, and I will never know what science is."*

The appeal of this position is in the avoidance of moralising. Following rules is one thing; deciding how to think and act in complex and new situations requires wisdom and freedom from assumptions. This stance is not necessarily a comfortable or popular one. Solomons and Fataar (2011:225), while pointing out that the literature does not provide a consistent understanding of the meaning of values in education, claim that: "This lack of clarity leaves room for speculation and misinterpretation." Is it better to have a community of young people who can be relied upon to make wise and ethical judgements in a changing world, or should we aim to produce a cohort of citizens who have been trained to follow set behavioural rules? Should some values be expected? Should others be deepened through discussion? Can values have individual nuances? Are values the same as virtues?

Values are often considered as individual qualities, ways of being that resonate with a person while virtues are developed habits of goodness. Values provide meaning and guidance for being in the world. Some may be grand social concepts such as equity, justice, democracy, or they may be personal ways of learning and acting such as achievement, helping people, establishing order, sharing or integrity.

Should education promote civil or social values described as desirable by the state, or should it foster and encourage the expression of personal values?

In South Africa 'values education' has drawn on constitutional principles. "Ideals from the constitution should be consciously embedded in curricula and be visible within the institutional ethos." (Department of Education, [DOE], 2002:3) Embedded values within the school culture form part of the hidden curriculum. These values include: equity, tolerance, multilingualism, openness, accountability, and honour (DOE, 2000). It is clear that these values have a special and specific significance in South Africa which is still healing from the atrocities of apartheid. Should science educators ignore values? Is this too contentious an issue or is it irrelevant to learning science content and method? I argue that we are what we do and also *what we do not do*. By ignoring values educators are still taking a position. Education is never value-free; science is not value-free. Ivorgba, (2011) argues that

> *"...genuine education must not only instil information and skills and prepare individuals for jobs; it must also empower us to use our minds creatively, ...create a deeper understanding of how and why our long-term wellbeing depends on the wellbeing of others. Using education to simply transmit information and skills is not good enough. We must also attend to emotional, behavioral and spiritual values."*

Strangely enough, although as science educators we are preoccupied with the science achievement of pupils, most educators would agree that personal integrity and the way we use knowledge is as important as

the knowledge itself. In spite of the logic of this we see in many societies, as Ramphele complains, a culture of: "... personal entitlement, personal enrichment, corruption, ..." and an " 'I, me and myself' pathology that should be a matter of concern for all." Ramphele, (2008:10, quoted in Solomons & Fataar, 2011: 228).

In a similar but larger scale, by over-emphasising the needs of the economy as drivers for knowledge production, policy-makers and educators become cut off from reflection, critique, affection, and diversity of purposes in themselves and in their students. Yet, as has been argued with respect to the hidden curriculum, being cut-off is something of an illusion. We are culpable for both what we do and what we do not do; what we teach and how we teach, and what we chose not to teach. By leaving out say, different ways of knowing, or affective domains, they are not simply absent but the message sent out is that they are not important.

How we frame the central values that are either needed to correct past imbalances, or that contribute to wordview perspectives, depends on where we are and our vision of where we want to be. The 'Values the Education Programme' in South Africa advocates goals that aim for redress and the promotion of human rights (DOE, 2002:4).

Democracy & an Open Society	A culture of Human Rights & Non-racism
- Learners are open to new ideas - Learners respect the opinions of others - Learners are able to articulate their needs and rights - Learners are able to resolve conflicts	All Learners have access to teaching and learning; and are catered for in the school All Learners feel valued and welcomed in the classroom, irrespective of racial, class, religious and language backgrounds

These values are expressed as inner resources of students as well as rights; outward-looking behaviours that will lead to harmony and belonging.

In the UK the focus is more about developing intrinsic character traits:

"Pupils should be helped to develop a personal moral code... concern for others, industry and effort, self-respect and self-discipline, and well as moral qualities such as honesty and truthfulness, should be promoted..." (National Curriculum Council, 1990:4, quoted in Taylor, 1996:123)

In holding common values, a culture is nurtured as promoted in these Constitutional Values in South Africa of:

- Democracy
- Social Justice & Equity (tolerance)
- Equality
- Non-racism & non-sexism (tolerance)
- An Open Society
- *Ubuntu* (Human Dignity) compassion & respect.
- Reconciliation (tolerance)
- Accountability (Responsibility)
- The Rule of Law
- Respect

Respect is an underlying or central value. Ramphele advises: "Moral regeneration will be realised only when citizens are treated with respect and the wounds of humiliation inflicted upon them over the years are healed." That is to say, showing respect has the ability not only to heal woundedness but to regenerate society. In various research projects into relevant science in schools, participants indentified 'respect' as one of the key aspects to be included in the science curriculum. (DOE, 2001; Keane, 2005; Khupe, 2011.)

The first six values (in the above list) were shamefully absent prior to the country's change to democracy in 1994. The last four values are clearly needed to rebuild a fractured society. How do values move from policy documents into society? This problem may seem beyond the scope for teaching science. Yet, only if we grant science special exemption from the broader vision and assume that there needs be no accountability in investigation, no respect for other points of view, no

room to publish contentious findings, no equity in learning opportunities for different groups, and so on.

Here we have been considering the role of values in education and in the development of a healthy society and whether values have a role in the science classroom. Another way of looking at values in science is just that: values *in* science itself. Surely this is something that cannot be contested for relevance in science curricula. Consider values implicit in science: tentativeness, uncertainly (tolerance), openness – these are often absent at lower levels of schooling where syllabi focus heavily on content. Whereas valuing inquiry; logical argument; problem solving; expressing detachment; honesty in reporting are more commonly evident – especially at higher levels of schooling. We may contrast the values expressed in working scientifically to the values *of* science: predicting; relating cause and effect; finding applications; explaining phenomena. Then again, we may consider the values of science *education:* lucrative employability; states industrial strength; commercial advantage; product development; solving global problems; developing mental agility and abstract and precise thinking. Value and values are everywhere.

In the lists of values in the previous statements in policies I have loosely linked 'tolerance' to similar values. This is one example of how humanitarian values may link closely with science concepts. It is interesting to note that the value of 'tolerance' is expressed in physics and also relates back to the earlier quote from Adams St.Pierre. In pointing out that all knowledge is uncertain, Bronowski, too, acknowledges: "We may be wrong" and that there is consequently an element of tolerance in all knowledge claims. He suggests that Heisenberg's 'uncertainty principle' should be renamed 'the principle of tolerance'. "...science is the language of tolerance." (Bronowski, 1973, quoted in Malcolm, 2002:127). In understanding the fallibility of even such powerful knowledge as science, students are experiencing the value of tolerance.

If we accept that knowledge and values are a means to human happiness and societal well–being, we may also accept from the above narrative, that values and knowledge are best held tentatively or at least held with reference to context. To highlight this I extend the reflection on values into the concept of worldview.

The role of Worldview

"...the word 'education' should not be coupled with predicates such as 'Western' or 'African' because to become educated is to achieve some measure of autonomy from any culture or heritage." (Morrow, 1989:72)

And yet, values arise from how we see ourselves in the world. As educated humans, and especially as educators, we need awareness of our own knowledge boundaries and blind-spots; we need openness to the possibility of alternate assumptions about reality. To illustrate this I turn to the African concept of *ubuntu*. Simply defined as "I am what I am because of who we all are." Or: "a person is a person through (other) persons." This is a humanist perspective that emphasises interconnection above individualism. This perspective is an example of a value shaping the way we see the world and each other. In this way it has direct bearing on learning. Learning that is student-centred, constructivist, or culturally consonant will need to rest in an awareness and respect for worldview. Ogunniyi (2002) describes worldview as a thought system which determines to a large extent the habitual way in which one copes with experience. Table 1 briefly sets out examples of commonly defined differences in Asian and Western worldviews. Nisbett, (2003) points out that these worldviews exists more along a continuum than in dichotomous categories. He also found in extensive studies around the world that individuals may be atypical of their culture. (A similar argument put forward by Morrow – quoted previously.) However, an interesting trend is nevertheless evident.

Table 1: Contrasting worldview perspectives

Asian and African	Western
The world is seen as holistic and anthropomorphic (Ogunniyi, 2002).	The world is categorised into dualities: living & non-living; mind & matter
Causes of events are complex	Causes are linear & predictable
Interdependence of all things is self evident	Independence is prized
Substance is important	Form is important
Success relates to harmony	Conflict & critique lead to achievement
Abstraction not developed	Abstraction valued as a thinking tool
"To argue with logical consistency ... may not only be resented but also be regarded as immature." (Nisbett)	Logical argument considered an essential aspect of education
Hierarchy valued as a norm	Aiming for equality assumed as a universal value (or worth while endeavour)
Co-operation encouraged Success seen as a group goal	Competitiveness encouraged Success seen as individual achievement

From this it is evident that one worldview may be inimical to that of another in obtuse and unconscious ways. There is likely to be accepted and assumed 'good practice' in our teaching, intended outcomes, and processes that may be at odds with another cultures' paradigms. Consider 'abstraction'. In English adjectives can turn into nouns: Happy – happiness; white – whiteness; whereas in Chinese there .is no word for "whiteness". There is only: "white like snow"; "white like a swan". Similarly there is no word for "size" (Nisett, 2003). The implication for science learning are enormous. Yet certainly this does not imply a superiority of one way of thinking over another. This points, rather, to entrenched axioms that remain unquestioned within a cultural context. The Greeks could not manage well the concept of ambiguity. Something could not exist and not-exist simultaneously. Hence they never conceived of the notion of zero. A 'nothing' could obviously not exist in this worldview (Nisbett, 2003).

These differences also provide an insight into values: the practical may be seen as more important that the abstract. Similarly, as one example, consider the value placed on 'competitiveness' in the West as opposed to co-operation. In the school processes of assessment, league tables, competitiveness is privileged over co-operation; assertiveness over harmony; independence over interdependence.

Nisbett (2003) contrasts Asian and Western worldviews as organising the conceptual world according to 'relationships' and 'categories', 'harmony' and 'contradiction' respectively. In Africa, sharing and reciprocity are norms throughout the continent (Nsamenang, 1992). However, in the critical area of academia, and especially in science education, seeking categorisation and disputation – instances of contradiction - are usually more common than seeking relationships and harmony. As mentioned earlier, a Western worldview emphasises thinking over being while in *ubuntu* identity centres on 'I am because I participate'.

One of the advantages of designing curriculum from the 'inside out' – from 'who we are', is that we can start from a point of inspiration (Mandela, 1997; Stevens, 2010). To take one example: implementing multicultural science. Some argue that many students are working from a Western framework which is alienating (Moodie, 2003; Ordora Hoppers, 2002). As researchers we are encouraged to address a *problem,* so (as in this case of worldview) we often tend to focus on *barriers* to learning rather than on the ways existing knowledge and world-views *contribute* to learning. Through noticing our paradigms we may be able to think beyond them, design curricula with greater awareness, and also be able to teach more effectively and meaningfully to diverse groups of students. The following section suggests approaches to curriculum design and the illustrations provide an overview of factors influencing this process.

Design elements

Curriculum design becomes supported through a creative environment which allows for: involvement, freedom, debate, trust and openness (Palmer, 2002). What I propose here then is a flexible and multilayered model that illustrates the structure of a design process. This model takes into account the Factors influencing design; Purpose of the curriculum, Values and Worldview; Integrating linear and holistic structures. These factors are best arrived at through debate, and research literature, as well as sharing across cultures and communities of practice. The first three layers of the model consist of established categorisations including external influences, process of pedagogy, and aspects of curriculum as illustrated in Figures 1, 2, and 3.

Figure 1. Factors influencing curriculum design

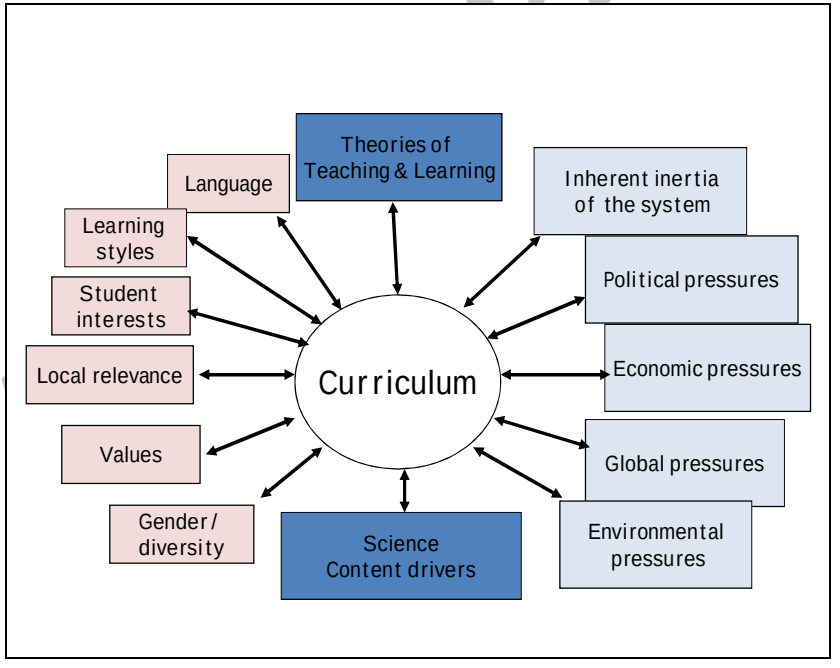
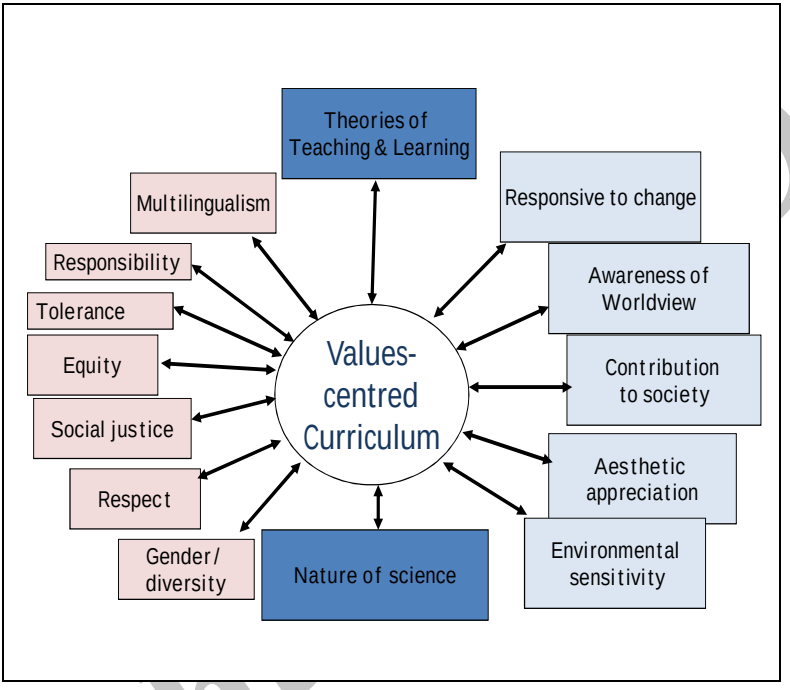


Figure 2: Changing the central focus for design to values



The various values listed on the left in Figure 2 are, of course, context-dependent and the example given is merely illustrative, hence the need for debate and contributions from diverse participants. In terms of the focus of design it is appropriate to note that: "It is easier to ask "Are students learning?" than to ask "Does what they learn matter?" (Malcolm, 2000) By placing values as a central concern, what we learn is more likely to matter. I present now a more linear layout of thinking in the third layer.

The third layer consists of a project plan approach of educational purposes (aims); processes (pedagogy); content; context; and structure (of implementation) (Keane, & Malcolm, (2003), in Figure 3.

Following this is a concentric flow design adapted from Stevens, (2010), in Figure 4.

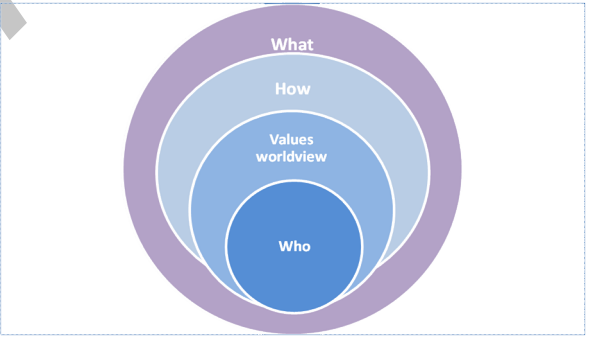
Figure 3: Project plan approach to curriculum design

Purposes: (*Who; Why)* • Learning to know • Learning to Do • Learning to Be • Learning to live together* • Humanistic science • Science for tertiary entry • Transformative	Processes: (*How)* • Experiental learning • Problem-based learning • Science in society • Science concept-based learning • Investigation-based
Content: *(what)* • Theme-based • Local relevance • Indigenous knowledge • Traditional science content	Context: *(Where)* • Time • Phase • Place • Type of school

*UNESCO Report on Education which defines four goals of learning [6].

These layered approaches to design may be synthesised or overlaid into a simplified design model that places values in the centre. The linking thread here is a value-centred approach – starting with defining who we are and what we value and care about. One of the advantages of designing curriculum 'naturally' from the 'inside out' – from 'who we are', is that we tend to then start from a point of inspiration.

Figure 4: Integrated Model starting from who we are



In this model I draw on the evidence from leaders who start from a vision, from values, from who they are. Martin Luther King started his famous speech: "I have a dream" not: "I have a plan." The head of Apple computers starts by proclaiming: "We believe in thinking differently." ('Who' they are.) Then he moves to the 'how': "We design things beautifully". He goes on to comment incidentally "We happen to also make computers": (The 'What'.) People are inspired by Values and Vision (Stevens, 2010). Perhaps in science curriculum design we can begin with our vision and move into learning processes and only consider content after we are clear about what really matters. In considering this model we would need to examine our worldviews and those of our students, and teach with the assumptions of these paradigms in mind. While science curriculum design is the *central focus* of this paper, I propose that in synthesising the complexity of the drivers mentioned we draw the elements together by understanding our values and 'who we are'. This requires intellectual creativity, and an awareness of trans-disciplinary inputs, along with reflection that is sensitive to worldview.

Despite the many competing orientations to curriculum design and the contexts that affect implementation, at the centre we hold values that inspire us and that provide for personal and community transformation. The big picture and the central focus on values provide for both depth and open-mindedness which are marks of science learning and the cultivation of the mind itself. It is up to us to decide what values matter.

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