Science Education International
Vol. 18, No. 2, June 2007, pp. 85-91

International Council of Associations in Science Education

The Six "C" Pyramid for Realizing Success with STS Instruction

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ABSTRACT *In education, STS too often is viewed as a new kind of course – new material for use in teaching. However, this view of STS is fraught with the same kind of problems as traditional teaching of natural science and technology. This major problem is that information is merely transmitted to students by lecture, discussion, verification laboratories, or textbooks, and other written materials. Nevertheless, good STS instruction captures more broadly the aspects of both science and technology.*

KEY WORDS: *Collaboration, constructivism, content, context, creativity, curiosity.*

Introduction

Science education has been in turmoil and in the public eye since 1957 with the Soviet exploits in Space. That technological success brought significant funding for science education as a response to the perceived supremacy of the Soviets. Their success was linked to the quality of K-12 and undergraduate college science in the Soviet Union, compared to the situation in the U.S. This was the period prior to Science-Technology-Society (STS) emerging as a reform effort in the 70s (in Europe) and the 80s (in the U.S.). Although STS became a popular reform effort three decades ago, it also became very controversial with many scientists and educators both declaring that STS was really an acronym for Stop-Teaching-Science. For many STS enthusiasts, this was not too negative – since STS demands that science (and technology!) be taught in a vastly different manner. We merely added: Let's Stop Teaching Science in the same old "failing" ways! Many new moves for reform take advantage of the cognitive science (psychological) research of the last several decades, where the focus is on learning rather than merely teaching a set curriculum.

Too few scientists are really interested or concerned with what science is from philosophical, historical, sociological, and/or psychological views. They do their science, because they are curious about the objects and events encountered in the natural universe, and want to satisfy their curiosities. They know that much is known about the natural world with the accumulation of much information over 3,000 years of human endeavors. But, few analyze the fundamental activities which define science. They remain immersed in what they know and what they do not know in rather narrow areas (disciplines). The important activities, which do define the scientific enterprise, include:

1) Asking questions about the objects and events in nature;

2) Offering explanations for them;

3) Seeking evidence to determine the validity of the personally offered explanations;

4) Presenting the evidence (experiments, logic, observations), which support the explanation;

5) Communicating the results and ideas to the established academy of scientists.

These activities are what science is in action, as opposed to it being portrayed as the current body of knowledge that most scientists accept as accurate. The information that accrues is not science – but instead the "products" of "sciencing."

Richard Feynman's writings and conference presentations often remind us all that the real content of science comes from the successes with the above list of activities, which illustrate science. The first of Feynman's foci for science is dealing with the things about the natural universe about which we know that we do not know. Feynman's second facet of science is dealing with the things we "know" that are not so! His third is dealing with the things in the natural universe that we do not even know that we do not know.

K-12 and undergraduate science faculty rarely take the time to emphasize the five steps of the scientific enterprise – or even consider Feynman's points of what scientists are doing. Further, little attention is typically given to technology. In addition, often, when it is considered, it is pejoratively called "the applications" of science. In schools, it is relegated to the shop. In addition, during the 50's and 60's, it was purposefully removed from the K-12 curriculum and textbooks (because it was NOT "science"!). There was an emphasis on pure science (i.e., what scientists know). Jerrold Zacharias, architect of the Physical Science Study Committee (PSSC), initiated the first national reform in the U.S. in 1956 with major NSF support (Zacharias, 1956). All the national attempts at reform centered on the major concepts characterizing the natural sciences, namely, physics, chemistry, biology, and earth science (listed in the order of importance and attention!). When asked about goals for school science, Zacharias referred to the PSSC book and indicated that the goal was to use it as the major source of information, and suggested activities that all physics teachers should use.

As the 90's emerged and the STS efforts internationally matured, there was renewed interest in technology, its role in the education of future scientists and engineers, and its ties to science. A simple definition is that technology is a focus on the human-made world – using the same sequence of activities as those listed above for science. The major difference is the fact that in technology, the end points are always known in advance. They are the tangible "products" in the case of technology, while new information and explanations are the products of science. When we talk of the human-made world, we know there is a want for faster airplanes, cooler homes in the summer, better televisions, and more efficient and powerful automobiles. In the case of science, we have to take the natural world as it is – and not worry about how the new understandings might benefit or harm humankind.

Learning from the STS reform efforts and the latest research coming from cognitive science became central to the attempt to develop and establish National Science Education Standards (NSES) in the U.S. (NRC, 1996). In fact, STS leaders influenced their development over the 1992-96 interim, during which national consensus was sought. Many in the U.S. define the completed and published NSES to be a blueprint for STS efforts in the K-12 arena. For example, the NSES list nine changes needed in instruction if real learning is to occur, as indicated in Table 1.

Table 1
Necessary Changes in Instruction for Learning to Occur (NRC, 1996, p.52)

Less Emphasis On	**More Emphasis On**
Treating all students alike and responding to the group as a whole	Understanding and responding to individual student's interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientificdiscussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

Additionally, the standards resulted in more emphasis on assessment – both in terms of establishing that real learning had occurred – but also as a way of making science education more of a science — employing the same five steps for science, but in the field of education. The changes in assessment were seen as more important than defining school programs in terms of specific content, as indicated in Table 2.

Table 2
Assessment Changes (NRC, 1996, p.100)

Less Emphasis On	**More Emphasis On**
Assessing what is easily measured	Assessing what is most highly valued
Assessing discrete knowledge	Assessing rich, well-structured knowledge
Assessing scientific knowledge (emphasizing vocabulary)	Assessing scientific understanding and reasoning
Assessing to learn what student do not know	Assessing to learn what student do understand
Assessing only achievement	Assessing achievement and opportunity to learn
End of term assessments by teachers	Students engaged in ongoing assessment of their work and that of others
Development of external assessments by measurement experts alone	Teachers involved in the development of external assessments

Wiggins and McTighe (1998) helped immensely in developing a new focus on assessment, when they assembled research to note that good instruction lies not in the presentation of content (i.e., traditional teaching), but in assessing student learning and coaching students toward better performance. Their recent work was entitled Understanding by Design. It means establishing goals first – then immediately discussing and identifying ways those goals could be assessed to know if learning had occurred. Wiggins commented recently (ASCD, 2005) that we (educators) are paid to coach learners, not to teach content!

In addition to the changes in teaching and assessment that STS demands, the NSES also provide a new vision of what defines science content. The NSES Standards define content in eight categories. These include: 1) Unifying Concepts and Processes; 2) Science as Inquiry; 3) Physical Science; 4) Life Science; 5) Earth and Space Science; 6) Science and Technology; 7) Science in Personal and Social Perspectives; 8) History and Nature of Science. STS leaders would de-emphasize the three classical facets of content (i.e., physical, life, and earth/space), and instead limit content to a single category perhaps called "science conceptual understanding." Paul Hurd (1998) has proclaimed that the only place where the traditional disciplines still exist is in high schools and undergraduate colleges. He maintains that most science research cuts across several disciplines and that the separation of science from technology no longer makes any sense. Science is completely dependent on technology for its tools. It is senseless to define technology solely as the "applications of science!" All this said, most teachers and most government officers revert to defining major concepts from the traditional disciplines for "presentation" to "would be" learners.

Figure 1 is an attempt to illustrate what the NSES and what STS educators view as the "domains" for science education. Traditionally, only the major concepts are considered and, to a lesser extent, the processes scientists have used to define the content in schools. A focus on the skills scientists use in their work has been advanced as an important consideration in U.S. science education for nearly 100 years. However, they became a focus in the 60's when the American Association for

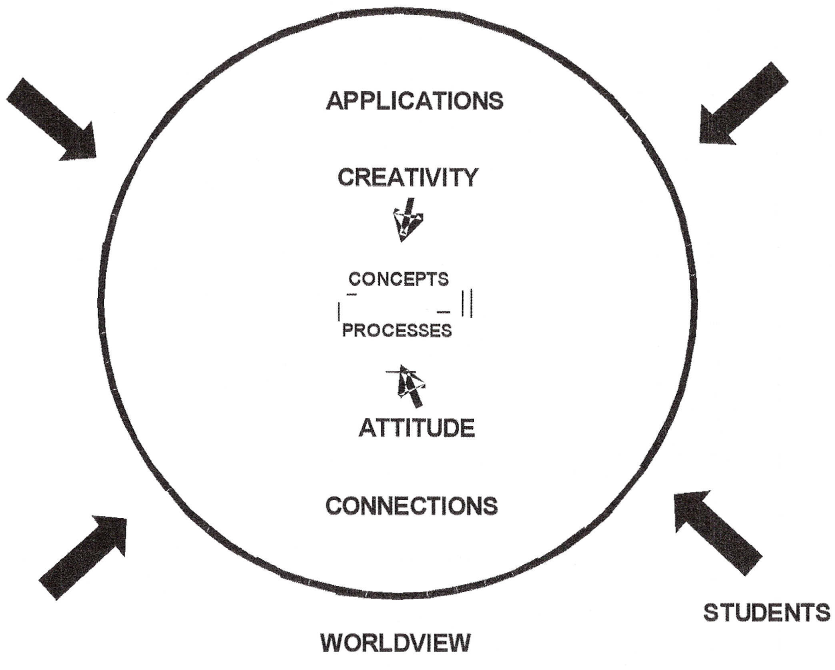

Figure 1. Domains for Teaching and Assessing Science Learning the Whole of Society

the Advancement of Science (AAAS) developed a whole elementary science program around process skills. NSF supported the development of Science-A Process Approach (SAPA) (1995) by the identification of 14 such skills as the organizers for school science.

Today over 90% of the emphasis is on the "bulls eye" (i.e., concepts over processes), as indicated in Figure 1. However, the "membrane" around the bull's eye is where primary activity should be concentrated – the enabling domains. These are attitude (affective) and creativity (questioning and hypothesizing). But, the even larger domain where most people live, work, and learn is the application and connections domain; the even larger one is the worldview that can be defined as the societal, historical, and philosophical dimensions of the scientific (and technological) enterprises. Such academics study the fields of science and technology from the outside.

It is interesting that current efforts in science education in 2007 – more than ten years after the publication of the NSES- permit a hierarchy of foci – all important if optimal learning and experience with science and technology in our modern society is to be achieved. Figure 2 is an attempt to link the six "C" words to what is happening and what needs to happen to realize the STS approach and procedures in terms of promoting real learning and developing citizens, who can be termed scientific and technological literate people. The Six "C" Pyramid displayed in Figure 2 is like the nutritional pyramid, and all that it means in terms of proper nutrition; illustrating where we are, where we need to start, and what our final objectives are, as we advance our science education reform agenda.

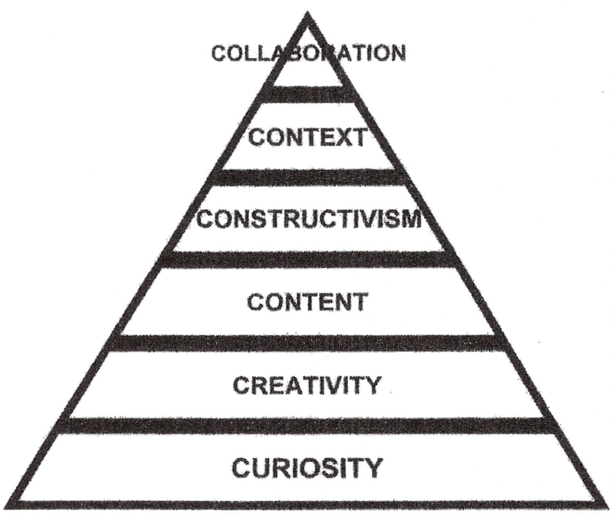

Figure 2. The Science Education Pyramid.

Just as in science and technology themselves, science education needs to start with curiosity, i.e., questions and interest. Rarely does typical instruction or standard curricula so begin. Instead, they start with content (big ideas) that someone (many times state curriculum guides) agree are the important ideas to "present to" students.

Creativity is related to curiosity. Most curious people are creative. They question; they try to answer their own questions; they identify information they need to provide evidence for the validity of their answers. Basically, the more creative a person is, the more he/she questions and relates – often in ways that people see no real connections. But, such situations require more debate and dialogue among people.

The third "C" is content – but hopefully information that is needed for actions, understanding, problem resolution – not just organized information for its own sake. It should develop from activities and situations – not as a pre-determined given.

The fourth "C" is constructivism – the major understanding of how humans learn. Some call it a Theory of Learning (Brooks & Brooks, 1993) – which can be used to define what real learning is. Basically, it is the idea that all learning takes place in individual learners; it is not something someone else tries to give to "would be" learners. Learning occurs individually because of thought and mind engagement—not from words from textbooks and teachers with success determined by remembering and repeating what was read or told.

The fifth "C" level is context. This is the situation – perhaps identified by a teacher, or an event, often in a local setting. Context is the situation that is defined as the ingredient that allows and encourages mind engagement and real learning in individuals. Without a context created or identified by learners, learning will not occur. With a focus on context – a new vision of assessment is identified. Can learners who learn in one context use it in other contexts? This is a perfect way of separating creative persons and ones who have really learned, instead of those merely pretending that they have mastered what is in the curriculum.

The sixth and final level on the Six "C" Pyramid is collaboration. Can people work together in the classroom, in the community, in the nation, in a global sense to solve the problems which surround all of us? Collaboration is needed between teachers and students, among leaders, among students, among as many as possible who can be interested in the problems of today. This includes one of Feynman's sources of science – i.e., dealing with things we know that are not so. This puts science and technology into a dynamic relationship which requires collaboration, debates, data collection, evidence sharing as real problems are resolved, which will affect the future.

Collaboration should be a top goal in education – a final test when we evaluate whether or not we have met the major goals for science education. The most important goal for education should be the production of scientifically and technologicaly literate graduates, and future citizens who are able to work toward an optimal and sustainable global society.

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