# A Holistic and Systematic Scheme for Planning Reforms on Multicultural Science Education

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ABSTRACT

Reform initiatives aiming at promoting multicultural science education involves coherent efforts by policy-makers, science education researchers, and science education practitioners. Concerns and issues on multicultural science education involve a complex array of variables, perspectives, and conditions. Depending on the perspectives and rationales taken by the policy-makers, different goals and methods for promoting multicultural science education may be proposed. It is noteworthy that there are three mutually interacting key elements of multicultural science education, namely, its rationales, goals, and methods. They form a convenient conceptual framework for reviewing the consistency among the policy, research and practice aspects of multicultural science education. In addition, important elements and variables that are relevant to students' learning of science at schools are summarized in a school-based learning model. The model consists of five essential elements, namely, the driving forces, contexts, inputs, processes, and products, which are closely related to students' learning of science. A holistic and systematic scheme for planning reform efforts on multicultural science education is proposed in this article, by combining the rationales/goals/methods conceptual framework with the school-based learning model. Some examples are presented, in order to illustrate the procedures involved.

Key words: policy, planning, reform, multicultural science education

## INTRODUCTION

Multicultural education deals with ideas, reforms and programs aiming at providing equitable learning opportunities for students of diverse socio-cultural backgrounds in a socially just society (Banks & Banks 2004; Cochran-Smith, 2004). Concerns and issues for quality science education to all in a multicultural world are also receiving increasing attention (Atwter & Riley, 1993; Hodson, 1993). The National Science

Education Standards in the US (National Research Council, 1996) provide clear requirement that science is for all students-regardless of age, gender, cultural or ethnic background, ability, aspirations, or interest and motivation in science. Other countries such as Australia, Canada, and New Zealand have also made similar efforts in recent years. Problems and difficulties in the teaching and learning of science may be understood and tackled from various perspectives, including psychological, social, and cultural factors (Duit & Treagust, 1998; Aikenhead, 1996). From a cultural perspective, tasks for providing a meaningful and quality science education to mainstream and relatively homogenous group of students are often difficult and demanding, they are much more difficult when it comes to the teaching and learning of culturally diverse students.

The increasingly wider acceptance of the importance of multicultural science education internationally can be illustrated by the following development. First, Aikenhead, Allen, and Jegede (1999) organized a Pre-Conference Workshop on “Culture Studies in Science Education: Students' Indigenous Cultures Versus the Culture of Science” for the 1999 NARST annual meeting in Boston, MA. A set of papers from well established scholars in the field of Culture Studies in Science Education are available from their website. Second, a special volume of Science Education that appeared in January 2001 is devoted to issues related to multicultural science and science education in a multicultural world. Third, it is stated in the preamble of NSTA position statement on multicultural science education (NSTA, 2004):

> “Science educators value the contributions and uniqueness of children from all backgrounds. Members of the National Science Teachers Association (NSTA) are aware that a country's welfare is ultimately dependent upon the productivity of all of its people. Many institutions and organizations in our global, multicultural society play major roles in establishing environments in which unity in diversity flourishes.”

As an affiliated organization of the National Science Teachers Association, the mission of the Association for Multicultural Science Education (AMSE, n. d.) is:

> “…to stimulate and promote science teaching to students of culturally diverse backgrounds and to motivate such students to consider science-related careers; to explore and promote the improvement of science curriculum, educational systems and teaching methods in school to assist such stimulations; to recruit and involve teachers of all minorities in science education; and to initiate and engage in activities and programs in furtherance of improving the science education of culturally diverse

students."

DIFFERENT PERSPECTIVES ON MULTICULTURAL SCIENCE EDUCATION

Hambrick & Svedkauskaite (n.d.) pointed out that from a social-economical point of view, beliefs for the importance of multicultural science education might come from the following three perspectives:

- Functionalist perspective. Proponents of this perspective hold that the most important function of school is the transmission of mainstream culture and the preparation of citizens in order for them to meet the technical demands of modern society. The purpose of schooling serves as an opportunity for upward social and economic mobility, especially for the lower classes.
- Conflict perspective. Those who hold this perspective believe that differential treatment in schooling, such as tracking and so on, are only there to serve the interest of the elite class. Unless there is an uprising among the lower and working class to overthrow those in power, they claim, that there will continue to be an inevitable struggle among the classes.
- Interpretative and critical perspective. Interpretative theorists use qualitative research methods studying at the micro level on the interactions among teachers, students, and peers and schooling. The main focus for critical theorists is injustice and oppression in modern society. They assume that individuals and social groups construct their own reality regardless of the oppressive elite-dominated social hierarchy in which they exist. Each individual meaningfully reflects, reacts among themselves and others, and create objective realities.

Krugly-Smolska (n. d.) discussed in some length different theoretical perspectives of multicultural science education, assumptions on what counts as effective science teaching approaches, and suggestions for identifying variables that can cause cultural incongruence and difficulties in multicultural classrooms. In view of the commonly held assumption that learning science involves an assimilation to an Eurocentric/androcentric way of knowing and learning, Krugly-Smolska advocated the other possibility that student can be successful in science without assimilating; acculturating or accommodating yes, assimilating no. It was also suggested that the testing of hypotheses and strategies in multicultural classrooms and a comprehensive review of the literature should be added in our research agenda. It is my personal point of view that the teaching and learning of science to indigenous students may involve processes which are partly "cultural transmission", partly "assimilation", and partly "accommodation". This is a holistic and eclectic approach that I would like to add as hypothesis for further testing in the future.

Another related debate took place among participants of a forum on diversity and equity issues—that research and programs should distinguish among groups more specifically than has been common practice to date; one view which emphasized finding the general strategies wherein “rising tides lift all boats”, while the other stressed that there are “diversity within diversity” (Britton, Raizen, Kaser, & Porter, 2000). It appears that there are scopes and limitations within which each approach may be valid and useful. On the other hand, they may not be applicable under different conditions. It would be worthwhile to find out conditions for the validity of each approach.

No attempt will be made here to give a comprehensive review of the existing literature. It suffices to say that there is a wide variation among science teachers, science educators, science education researchers, and policy makers as to their conceptualizations, descriptions and concerns of multicultural science education regarding the following questions:

1. What is the nature of multicultural science education? What kind of roles does it play? For instance, multicultural science education is considered by different authors as an idea; a philosophical concept built on the ideals of freedom, justice, and equity; a field of study and an emerging discipline; an educational reform movement; a process of comprehensive school reform; a basic education for all students.
2. What are the major goals of multicultural science education? For instance, a major goal of multicultural science education is to change the structure of educational institutions so that male and female students, exceptional students, and students who are members of diverse racial, ethnic, language, and cultural groups will have an equal chance to achieve academically in school.
3. What kinds of processes, strategies and methods are needed in order to achieve the above goals? As an example, the National Association for Multicultural Education advocates the belief that students and their life histories and experiences should be placed at the center of the teaching and learning process and that pedagogy should occur in a context that is familiar to students and that addresses multiple ways of thinking.

The promotion of multicultural science education involves concerted, continuous and consolidated efforts in policy, research and practices which are influenced by a complex array of variables and perspectives. Depending on the rationales and perspectives taken, different approaches, programs and initiatives are developed. Therefore in the planning of reform initiatives, it is imperative to take a more holistic and systematic approach in making efforts towards the promotion of multicultural science education. The purpose of this article is to introduce some basic ideas and procedures involved in using such an approach.

## RATIONALES/GOALS/METHODS AS A CONCEPTUAL FRAMEWORK

Following Laudan's triadic network model (Duschl & Gitomer, 1991) and what was discussed above, a conceptual framework for promoting multicultural science education is proposed in this study. The conceptual framework consists of the following three interrelating elements: First, rationales: What are our basic assumptions, hypotheses, beliefs, knowledge, interests, attitudes, and motivation about multicultural science education? Second, goals: What are the aims, purposes, and objectives of multicultural science education? Third, methods: What kinds of educational processes, instructional strategies, programs, activities, contents, research methods, and assessments can be used and/or are needed in order to achieve the intended goals?

In the spirit of Laudan's triadic network model, there are close interrelationships among these three elements, which are essential to coherent efforts in promoting multicultural science education. The desired goals and the chosen methods must go hand in hand, and both of them are in agreement with and influenced by the rationales. On the other hand, the rationales whether explicitly stated or not are to a great extent reflected from the desired goals and adopted methods. The practicality of the methods and the realization of the goals also provide feedbacks to review the soundness or appropriateness of the rationales.

A more holistic and system approach in planning reform efforts can be done by combing the conceptual framework introduced above with a model of school-based learning shown in Figure 1 (Guo, in press). It is shown in Figure 1 that school science learning takes place in a wide context involving family, school, community, and society. It also takes place under the influence of various backgrounds, including educational policy, historical and socio-cultural development, scientific and technological development, and international conditions. Input variables important to learning processes and outcomes include the science curriculum, instructional facilities and resources, teacher characteristics, and student characteristics. The importance of processes such as student learning approaches, engagement, metacognition, perception of the context, and interaction with teachers and other students has been well documented. As for student learning outcomes, a meaningful understanding of scientific facts, concepts, principles, and theories is of course essential. Other learning outcomes, such as a better understanding of the nature of science, improved inquiry skills, international awareness and experiences, are also important for a scientifically and technologically literate person in the 21st century.

Insert Figure 1 here

The arrows in Figure 1 indicate possible influences of the variables in one category on those in the others. Figure 1 suggests the direct influence of Driving Forces on the Contexts, Inputs, and Processes of learning. Driving Forces influence Products indirectly through these variables. Likewise, student learning products or outcomes are indirectly influenced by the Contexts and the Inputs of learning. Arrows pointing toward the left in the model indicate that student learning outcomes might, to certain extent, influence the contexts, inputs, and processes of learning. The model of school-based learning shown in Figure 1 emphasizes both internal and external factors that might affect student learning outcomes. It is meant to provide broad conceptual categories while indicating possible relationships. Of course, there are limitations to the school-learning model, and there are rooms for further improvement; the main purpose here is to show how it can be used to help tease out important issues on multicultural science education.

In terms of the conceptual framework and the school-learning model introduced above, it is suggested that a holistic and systematic approach for promoting multicultural science education, as shown in Figure 2, take the following considerations into account:

1. Reform efforts in promoting multicultural science education involve a close interplay of policy, research, and practice.
2. Attentions must be paid to the rationales/goals/methods aspects and their mutual congruency when dealing with the policy/research/practice dimensions of multicultural education, both individually and collectively.
3. The school-learning model can be used as a guide to consider simultaneously all the major elements, variables, and their relationship involved in science teaching in classroom settings.

Insert Figure 2 here

It is beyond the scope of this article to discuss the essence and importance of the interplay of policy, research, and practice. However, as an example of the approach introduced above, we shall show in the following section as how it can be used in making relevant policies.

## A HOLISTIC AND SYSTEMATIC APPROACH FOR POLICY-MAKERS

With making policy plans for improving multicultural science education as an example, this section suggests some of the basic questions that need to be examined.

### *Rationales of multicultural science education*

What are our basic assumptions, hypotheses, beliefs, knowledge, interests, attitudes, and motivation about multicultural science education in regards to the variables and their interrelationships as indicated in Figure 1? A few examples are given below:

1. Driving forces: constructivism

   In spite of some debates and criticisms, Mathews (2000) stated that constructivism is undoubtedly a major theoretical influence in contemporary science and mathematics education, and few would dispute Fensham’s claim that “The most conspicuous psychological influence on curriculum thinking in science since 1980 has been the constructivist view of learning”. Various types of constructivism have been developed, including personal, radical, social, physical, evolutionary, postmodern constructivism, and so on (Murphy, 1997). Kauchak & Eggen (1998) put it concisely that constructivism is a "view of learning in which learners use their own experiences to construct understandings that make sense to them, rather than having understanding delivered to them in already organized form….Learning activities based on constructivism put learners in the context of what they already know, and apply their understanding to authentic situations".

   There are also rich sources of empirical studies on constructivism and the teaching and learning of science (Bennett, 2003; Fensham, Gunstone & White, 1994; Mintzes, Wandersee & Novak, 1998; Osborne & Freyberg, 1985; Tobin, 1993; White, 1988). In view of the important impacts of constructivism on education, and on multicultural science education as well, we need to pay attention to questions like the following:

   A. What are the basic ideas of constructivism and their implications in science teaching and learning for students of diverse socio-cultural backgrounds?

B. Are constructivist teaching approaches suitable and effective for all students under all circumstances?

2. Context: science and technology capacity

Speaking of Latin-American countries, Caillods, Gottelmann-Duret, & Lewin (1997) pointed out that in general, governments overestimated their capacities, and that of their institutions, to plan and implement a policy leading to growth based on investment in science and technology.

A. What are the relative importance of and investment for science education versus technical skill training, considering students of diverse socio-cultural backgrounds?

B. What are the areas in science and technology in which local resources are of comparative advantage?

3. Input: teachers' characteristics

Teachers play important roles in bringing about better science education for the students. Teachers' content/pedagogical knowledge and instructional skills about science teaching are important factors influencing teachers' teaching behaviors and students' learning outcomes. Teachers' awareness and understanding of the particular needs of culturally different students, their views/attitudes /beliefs about the nature of science and the goals of multicultural science education are of particular importance to the teaching of science to indigenous students (Anderson & Helms, 2002). Pertinent questions in this respect are:

A. What are the desirable teacher characteristics in these cognitive, affective, and skill domains?

B. How can they be assessed and improved?

4. Process: classroom interactions

Classroom interaction patterns are closely related to students learning outcomes. A few related questions are as follows:

A. What are desirable classroom interaction patterns in culturally diverse classrooms?

B. How can teacher-students and student-student interactions be studied and improved?

5. Product: scientific literacy

What is meant by scientific literacy? What are its goals and objectives? The answers vary from time to time and country to country. Regarding scientific literacy in the post-modern era, Jegede & Kyle (1996) raised a number of issues which are worthy of considering by policy-makers. They are as follows:

A. Do school science curricula or programs meet the need for all to study and understand science?

*B.* What are the influences of the emerging world political agenda on science education?

*Goals of multicultural science education*

In view of the above rationales, the corresponding examples for the goals of multicultural science education are given below:

1. Driving forces: constructivism
    A. To develop effective instructional strategies in the teaching and learning of science for culturally diverse students based on constructivist ideas.
    B. To develop constructivist teaching approaches for students of different cultural-social backgrounds, bearing in mind that there are facilitating factors and limitations.

2. Context: science and technology capacity
    A. To invest appropriate amount of resources for science education versus technical skill training to students of diverse socio-cultural backgrounds.
    B. To pay attention to the areas in science and technology in which local resources are of comparative advantage.

3. Input: teachers' characteristics
    A. To recruit and reward teachers with characteristics and behaviors which are positively related to the various learning outcomes of students from diverse cultural backgrounds.
    B. To set up professional development programs to help teachers develop culturally responsive instructional skills and at the same time to bring about desired changes in their views, attitudes, and beliefs about multicultural science education.

4. Process: classroom interactions
    A. To keep teachers informed of the desirable classroom interaction patterns in culturally diverse classrooms.
    B. To support research studies aiming at observing and improving teacher-students and student-student interactions.

5. Product: scientific literacy
    A. To provide all citizens with relevant information, skills and the right attitudes to make the necessary decisions for quality living.
    B. To provide all students quality science education which emphasize both the utility economic utility of science education and the notion of developing the whole person (Jegede & Kyle 1996).

*Methods for promoting multicultural science education*

Each of the goals listed above may involve concerted efforts in research and practice, and is likely to call for a number of approaches, strategies, and methods for its fulfillment. There are a number of key factors which would influence the choice of the strategies for cost-effective science education provision and the conditions under which they can be implemented (Caillods, Gottelmann-Duret, & Lewin, 1997). These factors include:

- Student participation: the proportion of students currently enrolled at different educational levels, and the proportions of those who are enrolled who specialize in science;
- Investment: the degree of financial constraint on investment;
- Supply and demand of manpower in science related careers;
- Gender :the existing level of disparity in male and female enrollments in science;
- Science achievement;
- Patterns of provision: existing policy and practice on streaming and selection, curriculum, resource allocation for science;
- National development policy.

Broad suggestion, considering the consistency between the goals and the strategies listed above is shown in Table 1, where each of the codes on the first column refers to the goals listed in the above section.

Insert Table 1 here

CONCLUDING REMARKS

The scheme introduced in this paper is holistic because it emphasizes the whole and the interdependence of its parts; it is systematic because it can be carried on a step-by-step procedure. The limited number of examples offered in this article is meant for demonstrative purpose. A more detailed and comprehensive scheme covering all the major issues can be worked out. The real power of the approach is not to generate a bunch of useless and meaningless concerns and issues for the policy-makers. Rather, with prudent judgment, it can serve as a useful tool to facilitate discussions and to guide the selection of important issues and problems. The elements shown in Figure 2 represent the most essential ones obtained from a review of relevant literature. The approach suggested in this work may be used by policy-makers, researchers, and science teachers in their efforts to promote multicultural science education, and other fields of study or reform efforts. A careful choice of the elements, variables, and their interrelationships as shown in Figures 1 & 2 should be made, or added if necessary, in order to suit the interests and purposes of the decision-makers and to fit in the educational contexts and other political-social-cultural conditions in a particular country, region, or school.

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Table 1. Suggested strategies for the listed goals

| Goal | Partici-pation | Invest-ment | Supply/demand | Gender | Achieve-ment | Povision | Develop ment |
|---|---|---|---|---|---|---|---|
| 1A | | | | ˇ | | ˇ | |
| 1B | | | | ˇ | | ˇ | |
| 2A | ˇ | ˇ | | | | | |
| 2B | | ˇ | | | | | ˇ |
| 3A | | ˇ | ˇ | | | | |
| 3B | | | | | | ˇ | |
| 4A | | | | ˇ | | ˇ | |
| 4B | | ˇ | | ˇ | | | |
| 5A | | | | | ˇ | ˇ | |
| 5B | | | | | ˇ | ˇ | |

Figure Captions

*Figure 1.* A school-based model of science learning.

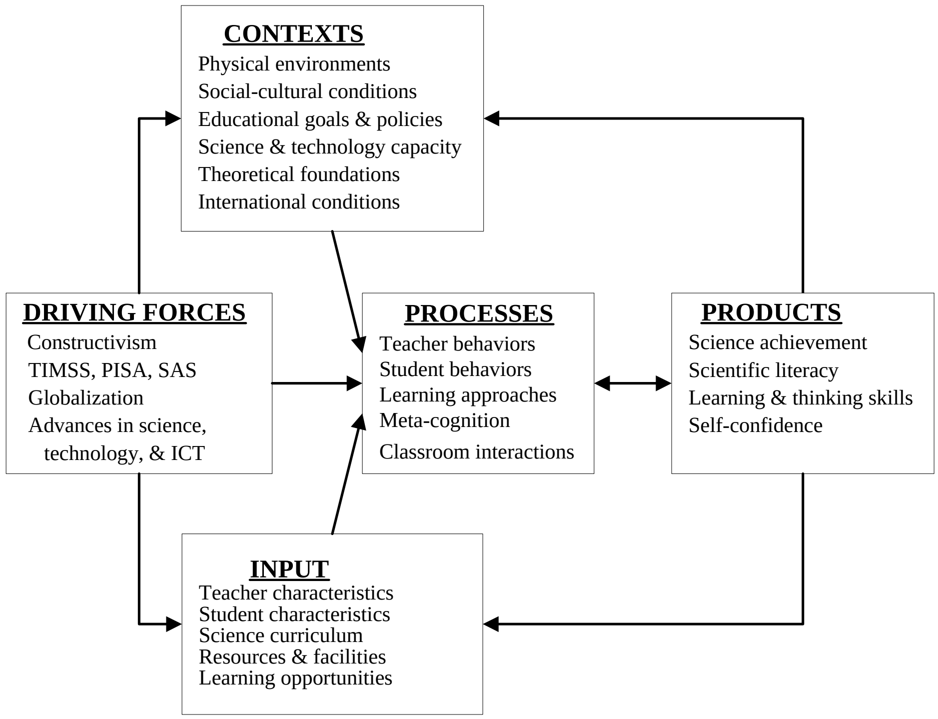
CONTEXTS
Physical environments
Social-cultural conditions
Educational goals & policies
Science & technology capacity
Theoretical foundations
International conditions
DRIVING FORCES
Constructivism
TIMSS, PISA, SAS
Globalization
Advances in science, technology, & ICT
PROCESSES
Teacher behaviors
Student behaviors
Learning approaches
Meta-cognition
Classroom interactions
PRODUCTS
Science achievement
Scientific literacy
Learning & thinking skills
Self-confidence
INPUT
Teacher characteristics
Student characteristics
Science curriculum
Resources & facilities
Learning opportunities

*Figure2.* A systematic scheme for promoting multicultural science education