Culture-Based STEM Education: A Path to Sustainable Inclusive Development, "STEM Education for All"

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The claim that STEM Education is important to national social, cultural, and economic development is widely accepted. The central idea presented is that STEM Education needs to be based on local, regional, and national cultures if it is to serve all who are needed in national development efforts. Consideration of three questions will guide what is presented. Who needs to be served?

STEM Education must first serve and develop a STEM literate population as the foundation for all aspects of development. Second, STEM literate politicians and administrators are essential. Third, scientists, technologists, engineers, and mathematicians are required. As will be discussed, the roles that each cadre must assume are highly interrelated and essential to national development.

What is STEM Education?
Many attempts to define STEM Education have been put forward. No single definition has been widely accepted. However, numerous papers provide characteristics of STEM Education that can be used to formulate a diverse set of culturally relevant perspectives. We present the essential characteristics that can be considered. Formulating and applying different but well-grounded, culturally relevant perspectives on STEM education increases the chances that effective STEM education will be developed and implemented.
How do we develop Culture-Based STEM Education?

We propose that developing Culture-based STEM Education is to base curricula and instruction on local, regional, and national traditions, events, objects, and innovations. STEM subjects can be taught in association with these foci. Questions that can guide developing Culture-Based STEM Education teaching units and examples will be provided.

Key Words: STEM education, national development, scientific literacy

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Introduction: The primary goal of STEM education

The claim that STEM Education is important to national social, cultural, and economic development is widely accepted. The usual argument is that innumerable businesses and industries require high-level STEM talent, and that the development of robust national economies depends on such talent. The necessity of having such a talent is undeniable. However, this viewpoint has too often resulted in government and private education programs that make the education of high-level talent the primary, if not one and only, goal. The emphasis on developing high-level talent has another source as well. In the United States and most other countries, educational STEM subjects and programs have been discipline-based and "top-down". The disciplines have been physics, chemistry, biology, mathematics, and, occasionally, Earth science. Within STEM subjects (and probably others as well), colleges and universities are designed to prepare students for graduate school, research, and development careers; high schools aim at preparing students for college and universities, middle/junior high schools are to educate students for high schools, elementary schools are to prepare students for middle/junior high schools, and preschools are to prepare students for elementary schools.* The discipline-based, top-down structure can be seen in interlocking admissions procedures, curricula, instruction, and assessments. Admissions procedures often are based on highly competitive examinations that are designed to meet the curricular demands of the "next level" and for admission to elite STEM schools. Curricula usually represented by national standards are derived from what is taught at the next highest level. Instructional methods often mimic the ways subjects are taught at higher levels as do in-school and external testing programs. Our language around schools is replete with phrases stating we must get children ready for the "next level", special tutorial schools, elite special interest schools, and the next exit or entrance examination". Our language around schools also is replete with reference to many levels of school and government accountability. In many countries, examinations are used to assign students vocational and academic educational tracks. Within academic educational tracks, assessments are used to select students for STEM subjects as we seek to place the best and brightest in STEM subjects.

The above is at the core of planning our STEM education programs. However, there have been challenges and attempts to modify, even replace, this dominant paradigm. Efforts to develop and implement curricula, instruction, and assessments with the goals of functional have been put forward, often vigorously. None have been fully developed or sustained in the face of varying demands for social, political, and economic security. At the present time, concerns about national and global economies competitiveness are most influential and have generated intense demands for educating people for careers in key STEM fields.

Three insidious side effects have resulted from the sustained use of the discipline-based, top-down paradigm. First, the discipline-based aspect of the primary paradigm is that the subjects are taught in terms of the content and methods used within the discipline. The human nature of STEM subjects as an enterprise and the ways in which STEM subjects are related to history, culture, current society, and each other are largely ignored. These omissions limit students' sense of STEM relevance to everyday life and non-academic careers.

Second, the educational process is progressively excluding many students along the way. Assessments are often used to provide the best and brightest to the best educational opportunities in STEM fields. Given that opportunities are limited, this practice is appropriate in that it helps meet one of the goals of STEM Education, identifying those who may go on to the highest-level STEM careers, However, the serious side effect is that the great social value placed rigorous assessment and placement systems and being selected for "special" programs, tells those who are not selected that STEM subjects are only for the elite. Many are discouraged from pursuing STEM subjects and the later development of STEM related interests is diminished. The effect is to decrease the pool of potential STEM interested students who can serve research, business, industry, and other social needs.

Third, the discipline-based curricula have been presented as being too difficult for all but the most talented. This may be the case because STEM subjects have been extraordinarily successful in enhancing our lives. But perhaps we have overstated its worth in society and attached a bit of arrogance to the positions of STEM subjects. The portrayal if STEM subjects as difficult limits students' sense that they are accessible and for them.

Who needs to be served to enhance national development?

The question "What should be the goals of STEM education?" can be addressed by deciding who needs to be served. The premise of what follows is that STEM Education must develop a STEM literate population as the foundation for all aspects of development. More specifically, development requires a STEM literate population, politicians, and government officials, business and industry leaders and employees, as well as a wide and deep pool of professionals in STEM related fields.

A scientifically literate population is essential so that it decides who to elect; what public programs and research agendas should be supported; the ways in which STEM-based research and innovations should be used; limitations on our use of our innovations; and even whether or not our innovations should be used.

Perhaps most importantly, a STEM literate population is essential to peoples' decisions in their daily lives and work. Should I work my land in a way that is sustainable? What crops should I plant? How can I protect water resources? Should I be vaccinated? Are my home and workplace safe? Should I reuse and recycle? Should I support one politician or political party or another? How do my actions and activities impact climate change? Should I support a building proposal that would improve the local economy? Should I become educated and work in a STEM related field? Should I become politically active or a politician? What should I do in the face of weather and climate changes? What foods and products are safe? What should I eat or not eat? What media reports and advertising should I believe? Answers to all of these questions and many more should be influenced by knowledge of STEM subjects and hopefully improve peoples' lives. The above is not to say that the knowledge of STEM subjects should be the only or even primary consideration in making these decisions. Many other considerations are essential (especially local knowledge and wisdom), but STEM knowledge should often be at least part of the decision making.

We must recognize that the general population is the well-spring for all others in society. It is the place from which all other STEM literate people will be drawn. We cannot

afford to have STEM subjects as being seen as irrelevant, inaccessible, and only for the elite. We cannot afford to leave any potential talent on the sidelines. STEM subjects must be seen as relevant and accessible throughout all students' educational careers.

STEM literate politicians, policy makers and administrators are also essential. Politicians decide what research and development will be funded and what policies will govern that research and development. STEM professionals conduct the research and development that is called for in government programs, influence what businesses and industries develop, produce, market, and inform the media and population.

Many legislative bills and government policies should consider STEM knowledge and methods when they are written, debated, and voted upon. Many government appointments require (or at least should require) STEM knowledge and skill. Policy makers at least need to be aware of when STEM knowledge should be considered in their deliberations and actions. They need to be able to identify issues that are STEM related then develop policies, programs and regulations that address the issues. Finally, they need to be knowledgeable enough to understand and evaluate what their advisors, consultants, and constituents say.

STEM literate business and industry leaders and employes are needed. Almost all business and industries are dependent upon STEM subjects. All use computers and computer-based programs for communication, materials development, product development, manufacturing processes, ways of distributing goods, agricultural planning, and practices just to name a few. The needs of businesses and industries go well beyond the need for high-level professionals and specialists. The work of employees at all levels requires STEM related knowledge and skill. For example, people working on manufacturing paints, operating power plants, running refineries, manufacturing foods, and operating robotics need to be able to recognize problems in the processes they operate, be able to diagnose and solve problems. The problems may be small, but important and need immediate solutions. The effectiveness, efficiency, and profitability of business and industries can be enhanced by all levels of employees who are STEM literate.

Finally, and obviously, the overall population supplies the essential researchers and developers in STEM related fields. Their knowledge, skills, and creativity drive innovation. Innovation drives our economies, protects our environment, enhances our abilities to communicate, changes our social structures, provides national security, provides food security, and enhances our well-being and ways of life. Many of these highly educated individuals are needed in our colleges and universities, government agencies, research institutions, businesses, and industries. The effective identification and education of researchers and developers must be supported by all of the rest of us politically and by our supplying the research and development resources they require, or else development will be limited.

In summary, a STEM literate population is the source of policy makers, business and industry leaders, employees, and STEM professionals; decides who will hold government offices at all levels; decides what issues in their lives need to be addressed by the governments, researchers, and developers; decides what business and industries need to provide; and makes a myriad of personal and work life decisions. Each of the above cadres are interrelated and essential to national development. All are needed for development to occur and be sustained.

What is STEM education?

Before deciding how to approach STEM education, we need an understanding of what is STEM education. Many attempts to define STEM education have been put forward. No single definition has been widely accepted. However, numerous papers provide characteristics of STEM education that can be used to formulate a diverse set of culturally relevant perspectives.

The following is an initial set of characteristics of STEM that has been gleaned from various national and international sources. The set of characteristics was initially developed for Institute for the Promotion of Science Teaching in Thailand (Finley, 2012) and subsequently revised (Sumonta, Finley, and Kittisak, ???). The overall goal is to develop STEM programs that are relevant, accessible, and interesting to students. A major tenet of our approach is to have STEM education be culturally relevant. To emphasis that tenet, we have shown those characteristics that emphasize cultural relevance in *italics*.

We do not claim that this is the only possible set of characteristics but only that they offer a valuable starting point that can be critiqued and improved by experience. We cannot even yet specify some subset or number of characteristics that have to be met to claim a program qualified as being a valid STEM program. We simply propose that the STEM programs can be described in terms of the following characteristics and then validated by professional judgments. STEM education would be valid if it has a substantial number of the following characteristics:

- *Promotes students learning with joy and benefits for their future and present personal, civic, and professional lives.*
- *Provides opportunities to explore many levels and types of possible STEM careers.*
- *Relates directly to real life activities from business and industry, government, NGOs, cultural or community activities in local, regional, national, or international communities.*
- *Engages students in studying critical topics such as health, energy resources, natural resources, environmental quality, natural hazard mitigation, the frontiers of science, technology, engineering, mathematics (PISA 2006), and food resources.*
- Uses at least two of the STEM subjects simultaneously. A preferred option is using three or all four of the subject areas simultaneously, but we have too little experience with STEM to recommend this course at this time.
- Requires knowledge and applications of the domain specific, core and cross cutting and practices of the subjects.
- Provides student-centered instruction.
- *Includes substantial interactions with the local, regional, national, or international communities as part of the instruction. The interactions can be the participation of local people in the schools, students studying in their communities, case studies, community-based projects, service projects, and research projects.*
- *Requires students to do what they will have to do as employees and citizens, that is, produce artifacts that have a counterpart in the real world.*
- *Requires students to communicate the products of their instruction to people from their community, teachers other than their own, or students other than their classmates.*

- Requires and holds students accountable for being able to apply the subject matter rigorously in the planning, description, explanation, and justification of the products that result from their instruction.
- Requires students to provide justified descriptions, explanations, and predictions related to select phenomena though the lenses of multiple relevant disciplines. For example, carbon cycling can be examined in terms of each of the four STEM disciplines plus the environmental sciences, social sciences, and humanities such as the history and economics of our use of fossil fuels.
- Providing opportunities for teaching about the nature of science, technology, engineering and mathematics, and the interactions among those fields and society.
- Instruction that has students working and studying in teams.
- Often using information technologies, communications technologies, and computer - based instrumentation.
- *Providing opportunities to explore many levels and types of possible STEM careers.*

The idea of designing and teaching a variety of different but well-grounded, culturally relevant STEM units of instruction increases the chances that effective STEM education will be developed and implemented. The units often should and will involve ideas from other subjects such as Social Studies, Religion and Culture; Language and Language Arts; Arts; English; Health; and Physical Education. We cannot teach STEM subjects effectively if they are isolated from other areas of culture and society. STEM subjects were developed in the context of and influenced by the cultures within which they were imbedded.

One additional and absolutely essential characteristic is that STEM teaching must meet national curriculum standards and assessment demands. Teachers should not, cannot, and will not teach in ways that do not enhance the likelihood students will do well on national examinations. Furthermore, their schools and national school assessments expect and usually demand that the national standards be employed by teachers.

How do we develop Culture-Based STEM Education?

Consistent with the above characteristics of STEM education, we propose one way of developing Culture-based STEM Education is to base curricula and instruction on local, regional, and national traditions, events, objects, and innovations. STEM subjects can be taught in association with these characteristics. This means that the STEM disciplines are taught to describe and explain the culture-based phenomena that are part of the students' lives. One approach to designing STEM instruction is having teachers answer a series of characteristic based questions that guide their planning. These questions are based on principles of curriculum design and learning theory.

<u>Context Description</u>

A description of the local community, school, and students.

<u>Guiding Questions for Instructional Design.</u>

Q1. What local, regional, and national traditions, events, objects, or innovations will be the focus of the Culture-based STEM Unit.
Q2. What cultural-based project will the students develop or what problem will they solve?
Q3. What STEM Education characteristics will be used?
Q4. What learning outcomes from National Standards will be used? (Science; Computer Science and Technology; Mathematics, Social Studies, Religion and Culture; Thai Language; Arts; English; Health and Physical Education).
Q5. What community connections will be used?
Q6. What schoolteachers and administrators will be involved?
Q7. How will the instruction be done?
Q8. To whom will the students present their work?
Q9. What assessments will be used?
Q10. What local arrangements will be needed?
Q11. What will be the schedule of events for the project?

These questions may be used in any order. One will need to work back and forth among the questions. Some questions might be omitted if they are not applicable. Some might be added. Teachers or preferably teams of teachers must use their professional judgements in these matters.

Practical limitations do not allow the presentation of full Culture-based STEM education units here as we had hoped. Hopefully, what follows at least provides some examples of what has been done previously. These examples are all from Thailand.

- The biology and geology (soil science) of corn planting and the design of objects that can be made from corn stalks and leaves.
- The chemistry of purifying marl (white clay) to make a traditional safe white cosmetic.
- The chemistry of amalgams, specifically brass, and the processes of making brass into locally produced artifacts and souvenirs.
- The geology, risks, and ways preventing landslides on steep hillsides used for growing corn thus limiting the use of slash and burn agriculture, limiting stream degradations from erosion, and preserving land for future farming.
- The hydrology, biology and chemistry of a local stream that is threatened by farm runoff, erosion, and waste pollution along with the creation of a plan to improve the stream quality and sustainable fishing for the future.
- The chemistry, physics, engineering, and mathematics of developing a rice husk furnace that can be used for cooking.
- The biology of commercial duck farming, engineering a way to preserve duck eggs such as salting them along with the chemistry of salt and solutions, and economics of selling the process and eggs in new more distant markets.

Summary

The central idea presented is that STEM education needs to be based on local, regional, and national cultures if it is to serve all who are needed in national development efforts. STEM Education must primarily serve and develop a STEM literate population as the foundation

for all aspects of development. STEM literate politicians and administrators, business and industrial leaders, employees, scientists, technologists, engineers, and mathematicians are required as well. All of these people will emerge from the general population if STEM education must become viewed as interesting, accessible, and relevant.

*Elementary schools have been somewhat less influenced by the top-down, discipline-based paradigm due to its origins in learning social-cultural norms and the basic skills of literacy such as reading, writing and mathematics that are essential to life and studies in other fields.

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