Culture-Based STEM Education: Why, What, and How.

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Abstract

Culture-Based STEM Education addresses local and national goals for creating STEM literate citizens who can use STEM ideas and skills in their professional, public, and personal lives. The approach includes a set of defining characteristics that require the learning of STEM subjects, interactions with local cultures, the use of national standards in conjunction with local wisdom and knowledge, and the integration of STEM subjects. Students will be engaged in critical topics such as economic, health, food, and environmental security at local, regional, and national levels. The expectation is that local communities and ultimately nations will benefit from students learning from local community members. The benefits are expected to be enhanced community and student engagement in learning STEM subjects; community applications of STEM knowledge and skills; and, most importantly, the encouragement of students to learn STEM subjects in their present and future educational endeavors and careers. Culture-Based STEM Education is expected to be practical for teachers as they apply the given characteristics and questions that guide the development of teaching units. The questions are grounded in teachers' experiences. A systematic and robust research and evaluation program on Culture-Based STEM Education will be essential to our learning about the efficacy of the approach and to provide useful modifications.

Keywords: culture-based, STEM education, STEM education research, STEM curriculum, STEM instruction, STEM characteristics.

Culture-Based STEM Education: A Point of View

The ideas presented in this paper are developing, ongoing, and evolving with the hope that others will contribute. The ideas are provided from a Western, predominately U. S., perspective but are strongly influenced by studies and many years of experiences in Thailand. The idea of Culture-Based STEM Education has been especially influenced by the work of many teachers, most notably the lead STEM teacher from Banlatwittaya School in Banlat Petchaburi (Kullatat et al., 2015); a 2019 Fulbright funded project done with the University of Phayao; and published studies (Bybee, 2010; Bybee, 2013; Montri, 2013; Supot, 2013; Thawat, 2012; Marginson et al., 2013; Cogan & Dericott, 1998); the Thai Institute for the Promotion of Science and Technology, 2015); and Thai-U.S. Roundtables (Thawat, 2012; Office of Education Council & King Monkut's University of Technology, 2016). The ideas also have been influenced by the definition of STEM education and stated goals of the new South East Asian Ministers of Education Organization (SEAMEO) STEM Education Center.

The SEAMEO STEM Education Centre's definition:
"STEM education is a teaching and learning approach, which emphasizes the connections among – or the integration of – knowledge and skills in science, technology, engineering, and mathematics to address problems facing our communities as well as larger global issues that require a skilled workforce and knowledgeable citizens who can apply these skills and knowledge to develop solutions." (South East Asian Ministers of Education Organization, 2020) Among the SEAMEO goals are:

- "Advocating evidence-based policy research in STEM education and providing policy recommendations;
- Developing the capacity of educational personnel and policymakers;
- Enriching regional STEM learning units by leveraging existing resources." (South East Asian Ministers of Education Organization, 2020)

The ideas presented below support each of these goals. However, decisions about the utility of the ideas reside in the national and local cultures of the SEAMEO countries as do decisions about necessary modifications.

What is Culture-Based STEM Education?

The set of characteristics provided below has been gleaned from various national and international sources, was initially developed for the Institute for the Promotion of Teaching Science and Technology (IPST) (Finley, 2012), revised for a chapter in *Education in Thailand: An Old Elephant in Search of a New Mahout* (Promboon et al., 2018), and revised again before and after a Fulbright funded project with the University of Phayao. No claim is made that this is the only possible set of characteristics, but the claim is made that they offer a valuable starting point. These characteristics can be critiqued and improved by evidence-based research and cross-cultural experiences. The proposed characteristics of Culture-Based STEM Education are that it:

- uses at least two STEM subjects simultaneously,*
- requires applications of the domain specific, core and cross cutting concepts, and practices of the subjects,*
- relates directly to real-life activities from businesses, industries, governments, and NGOs in local, regional, national, or international communities,*
- includes substantial interactions with people from 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, and mathematics (Organisation for Economic Co-operation and Development (OECD), 2006) and food resources,*

- promotes students learning with joy and benefits their present and future personal, civic, and professional lives,
- 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, government agencies, businesses, teachers from the local or other schools, administrators, and students from other classrooms,
- requires and holds students accountable for being able to apply the subject matters rigorously in the planning, description, explanation, and justification of the products that result from their instruction,
- requires students to provide justified descriptions, explanations, predictions, designs, and communications related to select phenomena and societal events through the lenses of multiple relevant disciplines,
- provides opportunities for teaching about the nature of science, technology, engineering and mathematics and the interactions among those fields and society,
- provides student-centered instruction,
- requires students working and studying in cooperative groups (Johnson, D. & Johnson, R., 1999),
- uses information technologies, communications technologies, computer - based instrumentation and modeling often, and
- provides opportunities to explore many levels and types of possible STEM careers.

* (See note in the following paragraph).

A final note about the set of above characteristics is important. Using all of these characteristics in any one situation is not likely. What is more likely is that subsets of the characteristics would be used with varying degrees of emphasis depending on national and local cultures and circumstances. The creation of multiple forms of STEM units is desirable and likely (Briener et al., 2012). That said, the characteristics noted with an asterisk (*) are, at this point, considered essential to defining Culture-Based STEM Education.

Why Culture-Based?

STEM education is important because understanding STEM subjects is essential to students' present and future civic, professional, and personal lives. STEM education also is essential to national economic, health, food, and environmental securities. Unfortunately, the citizens of many communities have little direct experience with the relevance and value of understanding STEM subjects. Furthermore, their experience with STEM subjects have been highly academic, inaccessible, and unrelated to the real world (Finley, 2016). The result is a lack of cultural support for students learning STEM subjects. Too little cultural support limits students' interest and motivation in STEM education to what is required by the necessity of passing tests.

The thesis of Culture-Based STEM Education is that students need to learn STEM subjects in the context of what happens in the culture of their communities where they, along with the adults in their lives, can experience relevant and accessible applications of STEM knowledge and skills. Such experiences are likely to have lasting effects on students' interest in STEM subjects. In short, Culture-Based STEM Education is needed so that STEM knowledge and skills become a relevant, valued, accepted and a commonplace part of students' lives.

Culture-Based STEM education is supported by other reasons as well. Each of these reasons could be elaborated substantially but doing so is limited by what can be done in a single paper. For now, the following brief statements indicate additional supporting reasons:

- We need STEM experts, STEM literate politicians, media people, government officials, and administrators who support and are supported by STEM literate populations.
- Beliefs about STEM knowledge and skills – their accessibility, personal and social value, and trustworthiness - are embedded in national and local cultures and need to be considered in teaching.
- A proper understanding of STEM subjects requires that the students experience STEM subjects within their cultural contexts because science, technology engineering and mathematics are embedded in cultures.
- Always teaching STEM subjects as if they are independent of society misrepresents the nature and value of the subjects.
- Local wisdom and knowledge can be sources of new STEM knowledge.
- STEM knowledge can confirm, extend, and challenge local knowledge and wisdom.

The use of Culture-Based STEM education is not some kind of "this will fix it all tomorrow" innovation. Cultural changes require the use of well-grounded ideas in many places over many years to have large scale effects. However, enhanced STEM literacy can and must begin at local levels, with today's students within their communities. Substantial benefits can accrue to local communities and individuals as the broader cultural changes occur. Immediate enhancements of local knowledge and wisdom can be prompted by Culture-Based STEM Education. Local accomplishments can be immediate and unquestionably valuable in their own right. In fact, local accomplishments can be considered as a powerful and worthwhile goal.

How can Culture-Based STEM Education be Implemented?

Culture-Based STEM Education is a warranted and potentially impactful approach to STEM education. However, it is not the only way to approach STEM education. Problem-based learning, community-based learning, context-based learning, and place-based learning are close cousins of the approach presented here. Case studies, simulations, extended research-like investigations, and other methods also provide in-depth opportunities for students to learn. In addition, traditional methods have value, and the support of extensive instructional materials and resources. Reading text material, laboratory activities, field trips, demonstrations, problem solving, lectures, and internet search projects are teaching tools that are worthwhile and practical. In fact, it is difficult to imagine using Culture-Based STEM Education without using these tools.

Culture-Based STEM Education is a practical approach for teaching STEM subjects. It is practical because using the approach a few (2-4) times a year is recommended as is having each unit based on selected national standards. These two recommendations account for teachers reporting limited time to prepare; time needed to work with community members; and the necessity of attending to a longstanding, deeply engrained history of teaching subjects one by one; extensive national standards and national assessment requirements; government agency regulations; school schedules; and the expectations of politicians and citizens. If teachers developed one unit a year, revised that unit the next year, created one more that second year, and repeated the cycle, then, over time they would have a set of polished units to use and to share with others. What is expected from the approach is students meeting selected national standards, experiencing STEM subjects within their communities and daily lives, seeing STEM as accessible, engagement in learning, and supporting local cultures. Culture-Based STEM Education allows for in-depth relevant learning that carries into the future. The expectation is that over a few years of schooling, students will have experienced a substantial enough number of engaging and in-depth STEM units to prompt interests that are sustained for a lifetime in careers, and in their public and private lives.

Questions to Guide the Development of Culture-Based STEM Education Teaching Units.

The following is a set of questions that need to be answered to develop Culture-Based STEM teaching units. It is not an outline of what is needed in weekly or daily lesson plans. Those plans are necessary and require greater levels of detail.

The questions were derived initially from a case study of a rural school in Chachoengsao, Thailand. The situation was that the school principal, teachers, a local businessman, other community members, and students designed and developed a fish raising pond that became part of the school grounds and teaching program. The fishpond development was intended to provide a context for applying and teaching the former King Bhumibol Adulyadej's ideas of sufficiency thinking, effective business practices, career opportunities, and providing a protein source for students and community members. As the case was investigated, the teaching of STEM subjects, other subjects, and local wisdom and knowledge were evident. What was asked during the case study was, "What questions did the developers implicitly ask as they developed the project?" The case study grounded the development of the following questions in teachers' and others' actual practices. Modifications to the questions were made based on the feedback from other teachers during subsequent workshops.

Preliminaries

Project Title An example would be Designing a School and Community Fishpond.

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

Unit Design Questions

- **Q1. What culturally based project or product will the students develop?** This is a 1 - 3 sentence description of the students' project or product. Having a significant student product is essential to sustaining their engagement and learning.

- **Q2. What STEM characteristics will be used?** Select the STEM characteristics that will guide the unit development.
- **Q3. What learning outcomes from National Standards (e.g., Sciences, Computer Science and Technology, Mathematics, Social Studies, Religion and Culture, National Language, Arts, English, Health, Technology and Engineering, and Physical Education) will be used?** Teachers have indicated that they could use a Culture-Based STEM Education approach only if the national standards and testing expectations were considered explicitly.
- **Q4. What community connections will be used?** List the community organizations, contact information and other community members who will participate. State what the others will do at least initially. Community members must be involved in the development of the project from the very beginning.
- **Q5. What other schoolteachers, administrators, and staff will be involved?** List the people and offices from the school and what they will do. These people can provide expertise and resources if they are part of the planning from the beginning.
- **Q6. How will the instruction be done?** Describe the key student activities of the project and the sequence of the activities as best as possible early in the planning. Changes and detailed plans will be made during the unit development process.
- **Q7. To whom will the students present their work?** This segment is essential. Teachers have reported that students stay engaged and are more concerned about the quality of their work when they know they will present to others, preferably adults.
- **Q8. What formative and summative assessments will be used?** Assessments can include information from teachers' observations, group or student activities, artistic productions, interim reports, physical models, homework assignments, semi-structured journals, project presentations, quizzes, and tests.
- **Q9. What agencies from outside the community might be needed?** The agencies listed can provide information, resources, and opportunities from regional--and perhaps national--government agencies, businesses, and institutions of higher education.
- **Q10. What budget will be needed?** List estimates of the costs for essential elements of the unit. School administrators, community members, and other participants will ask for some idea of costs and resources that will be needed as part of considering what they might be able to provide.
- **Q11. What will be the schedule of events (timeline) for the project?** State what steps will be taken with the school and community to complete the project and when they will be taken. The answer to this question provides concrete markers about what needs to be done and by when.

Questions similar to the above were used in a Fulbright funded project with the University of Phayao and area STEM teachers in September 2019. Teachers' responses resulted in modifications in the questions and several well-prepared units. The unit topics were increasing duck egg farm production and markets; improving fishing in the Maelao River; using rice straw as fuel in a locally designed cooking stove; preventing landslides; and improving corn production. The teachers reported they would find the units usable and exhibited excitement about doing so.

Comments on SEAMEO Goals

The first SEAMEO goal is “Advocating evidence-based policy research in STEM education and providing policy recommendations.” (South East Asian Ministers of Education Organization, 2020). Research and evaluation are essential to making progress in the development of STEM education. While the above ideas are grounded in theoretical and empirical research from learning and cognition, social learning theory, the history and philosophy of science, the sociology of science, educational research and best practices, that does not mean we know the ways in which the idea of Culture-Based STEM Education will work in practice in different cultures and settings within those cultures. Evidence is needed to answer innumerable questions related to changes in students’ learning and attitudes related to STEM, community attitudes toward STEM, teachers’ knowledge and attitudes toward STEM, and the challenges and opportunities that teachers, administrators, educational planners and policy makers encounter when this idea is implemented. We, the STEM education community, need to employ a design-based strategy for the development and implementation of all STEM innovations. Design, research and evaluation, and redesign cycles are needed. Both qualitative and quantitative research and evaluation are needed within these cycles. The methods will range from practical (sometimes called action research) to rich descriptions gained from case studies to large scale quantitative assessments of innovations and eventually to experimental studies. We cannot make informed decisions with respect to Culture-Based STEM education or any other form of STEM education without in-depth and sustained studies. We cannot afford to waste time, money, and talent without learning from the efforts we make.

The second SEAMEO goal given is “Developing the capacity of educational personnel and policymakers.” (South East Asian Ministers of Education Organization, 2020). Developing and studying Culture-Based Education provides a well-grounded opportunity for meeting this goal. We can develop capabilities related how to design, teach and evaluate STEM teaching units; use local knowledge and wisdom; include all children in learning STEM subjects; have STEM be experienced as accessible and valuable; improve children’s career opportunities; and improve economic, health, food and environmental conditions at community and national levels.

The third SEAMEO goal is “Enriching regional STEM learning units by leveraging existing resources.” (South East Asian Ministers of Education Organization, 2020). Culture-Based STEM units are at the crux of the third goal. If numerous teachers plan according to the design questions given above, then the units can be entered into an open source repository for others to use, modify, and amplify as their local and national circumstances dictate. Such an open source database would be especially valuable to teachers, administrators, curriculum developers, other educators, and policy makers if accompanying research and evaluations also were posted. The posted research reports could be teachers’ own assessments of the effectiveness, usability, challenges, and suggested modifications; information gleaned from students' in-class work and reports; more formal qualitative investigations such as case studies; and quantitative studies.

Conclusion

Culture-Based STEM Education is intended to address SEAMEO and national goals; be practical by accounting for traditional expectations and demands on teachers' time; allow teachers to be innovative; and, most of all, engage students in meaningful and inspiring STEM education. In the long run, substantial and sustained use of the idea is likely to result in meeting national goals such as improving economic, health, food, and environmental security. As the long-term goal is being met, local communities can be expected to benefit from what is learned and from enjoyable interactions with children and the local schools. Sustained research and evaluation are critical to making progress toward the goals.

Fred Finley completed a bachelor's degree in geology from Michigan State University, a master's degree in elementary school science education from the State University of New York at Cortland, a Ph.D. in curriculum and instruction, science education from Michigan State University, and an honorary Ph.D. from Rajabhat Rajanagarindra University in education: locality development. He was a faculty member in curriculum and instruction at the University of Wisconsin-Madison, the University of Maryland, and the University of Minnesota–Twin Cities. Dr. Finley retired from the University of Minnesota in 2018. His research interests have been related to Earth System Science, learning and cognition, the implications of the history and philosophy of science for science education, and curriculum design. His work and interest in STEM education in South East Asia, primarily Thailand, began in 1991 and most recently was supported by the United States Fulbright Foundation at the University of Phayao, Thailand in September 2019. The publication most relevant to this paper is Promboon, S., Finley, F., and Kaweekijmanee, K. (2018) listed in the references.

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