STEM and STEM Education: Collaboratively Addressing Global Challenges of the 21st Century

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Abstract

The acronym STEM, and its related phrase STEM Education, both imply some form of relationship between multiple disciplines and the education in those disciplines. One prominent aspect of that relationship is "collaboration" between people working in these disciplines as they address questions that require a nexus of knowledge and expertise from multiple disciplines. This nexus and collaboration are particularly important to address the global challenges we face at the present time. Using some examples from the USA, this article discusses the important role of collaboration in STEM education and is adapted from the keynote address the author delivered on the same theme at the 2021 international conference of the East Asian Association for Science Education (EASE).

Key Words: STEM, STEM education, collaboration, global challenges.

Collaboration, Sustainable Development, and STEM Education in the Asian Context

Being an international consortium of science and STEM education professionals from countries in the east Asian region, the East Asian Association for Science Education (EASE) is a collaborative organization by definition. Many of the educational, environmental, and economical issues faced by the countries represented in EASE are common between these countries. Hence, it is natural for EASE as an organization to consider a collaborative approach for addressing these issues, which involve two, sometimes opposing, elements: Development and Sustainability. Often, development seems to come at a cost of sacrificing sustainability (of the environment, economy, etc.) or maintaining sustainability implies an inability to pursue development. Considering the potential of science/STEM education in addressing this apparent contradiction between development and sustainability, the EASE 2021 international conference focused on building a collaborative vision for "new" science/STEM education, using the context of the Sustainable Development Goals (SDGs) developed by the United Nations Department of Economic and Social Affairs and adopted in 2015 (Gaffney, 2014).

Of the 17 SDGs, goal #4 focuses on "quality education and lifelong learning opportunities for all." Given the science/STEM education focus of EASE as an organization and of the *Southeast Asian Journal of STEM Education*, it is important to consider the implications of SDG #4 for science/STEM education and how collaborations can help address the issues and challenges we face.

STEM and STEM Education imply combining the knowledge of science, technology, engineering, and mathematics to address real world issues, especially the global issues of the 21st century. It turns out that the most pressing current issues we face at a global level, such as global climate change, COVID-19 pandemic, etc., require a nexus of knowledge from various STEM disciplines and strong education in STEM, for us to be able to effectively address and deal with these issues. Thus, a collaborative approach is imperative. To develop these abilities in our students, a focus on high quality STEM education needs to be a significant component of the "quality education" called for in SDG #4 for all students and, in order to provide this quality education, we need highly qualified teachers (SDG #4—Target 4.C).

Collaboration in STEM

The advent of the acronym STEM, and subsequently STEM Education during the final decades of the 20th century, implied a recognition of the growing trend of scholarly activities in these fields shifting from isolated works of one or more individuals in specific disciplines to collaborative interdisciplinary teams working to solve problems and address questions that transcended the traditional boundaries of different disciplines. There has been a shift, in a manner of speaking, from "lone science" to "collaborative STEM". Interdisciplinary research teams began to be formed, drawing scholars from a variety of STEM fields whose collaborative contributions would accomplish what no single field or discipline could accomplish within its own knowledge boundaries. At the same time, a great surge in interdisciplinary, hybrid fields of study—such as Bioinformatics, Chemecology, Environmental Toxicology, etc.—had been emerging (Hurd, 1997). Collaboration between disciplines and people working within those disciplines has become increasingly important and indeed necessary to deal with the issues our global society currently faces. Examples of some currently prominent and very serious issues that demand urgent and continuing attention are global climate change and the COVID-19 pandemic. They also represent problems that cannot be solved by knowledge from any one discipline of STEM.

The recognition of the need for and value of collaborative activity in STEM to solve contemporary problems is evident in the fact that the entire *Nature* issue of 17 June 2021 (Volume 594, #7863) focused on the topic of collaboration and teamwork. The articles in this issue of the journal describe collaborative activity that addressed a number of different issues, some global such as the COVID-19 pandemic, and some local such as the recent drinking water crisis in Flint, Michigan, USA. The stories in this issue of *Nature* illustrate that collaborations are happening:

- across national borders, cultures, and disciplines;
- between science and society; and
- between science and industry.

The editorial in the mentioned issue of *Nature*, titled "Research Collaborations Bring Big Rewards: The World Needs More" ends with the following statement (*Nature* Editor, 2021, pp. 301 – 302):

> The metaphor 'standing on the shoulders of giants' has been much overused by scientists past and present. Today, such 'giants' are not only the investigators named on papers and project grants, but also every other participant in the research process. **The future lies in standing on the shoulders of crowds.** (Emphasis mine)

The following two "cases" further illustrate the extent to which collaboration is helping address issues or answer questions that are too big to be tackled within the silos of traditional disciplinary boundaries.

The Human Genome Project

A project to identify and map the location of every single gene in the human genome, launched in 1990 and declared completed in 2003, may appear to be a "biology project" at first glance. However, a more careful look reveals that this project was highly collaborative, interdisciplinary, and international in nature. The following details indicate the collaborative, interdisciplinary, and international nature of the human genome project.

- *Disciplinary overlap and collaboration:* The project logo includes names of the disciplines from which knowledge and expertise was drawn to complete this project: biology, physics, chemistry, engineering, informatics, and ethics.
- *Institutional collaboration:* The work was done at 20 universities and research centers.
- *Trans-continental and trans-national collaboration:* Seven countries across three continents were involved in the work—USA, UK, Japan, France, Germany, Canada, and China.

Considered the world's largest scientific research project, it was a highly interdisciplinary and collaborative endeavor to address an extremely significant, yet most fundamental question regarding humanity.

The COVID Moonshot Project

An international collaboration to develop an anti-viral drug (von Delft, et al., 2021) had the following characteristics of a highly collaborative STEM endeavor:

- The work involved 150 participants.
- The participants represented a wide range of expertise from different fields including bioinformatics, phylogenetics, epidemiology, chemistry, computer modeling, and even military.
- The participants represented academia and several industries such as pharmaceutical and biotechnology.
- The participants represented several countries from different continents.

- A wide range of technologies were used.

This is a project addressing a current, extremely pressing global issue of the ongoing COVID-19 pandemic. Such issues cannot be addressed without the kind of collaboration seen in the COVID Moonshot project.

In an essay reflecting on her work just prior to retiring, Dr. Anne Schuchat, then Principal Deputy Director of the Centers for Disease Control and Prevention (CDC) in the US, made the following comment that reflects her recognition of the role and value of the collaborative work now so common in STEM (Schuchat, 2021):

> The teams carrying out data analysis and field investigations and launching communication drives or laboratory studies have experienced the joy of knowing their collective efforts can achieve something none of them could do on their own (p. 23).

Collaboration in STEM Education

The recognition of these collaborative trends seen more often than not in STEM is reflected in the *Framework for K-12 science education* released by the National Research Council (NRC) in the US (National Research Council, 2012). This framework identifies three dimensions of science critical for school science education. The first of the three dimensions is *Scientific and Engineering Practices*. This *Practices* dimension identifies 8 activities that characterize the work of scientists and engineers. More importantly, the identification and naming of these practices collectively as "scientific and engineering" practices clearly emphasize the close collaborative relationship between science and engineering (the S and E of STEM). They also explicitly convey the message that school science education should include and emphasize this relationship between science and engineering.

Also in 2012, an edited volume, titled *Integrating Science, Technology, Engineering, and Mathematics* (Rennie et al, 2012), was published as part of the *Teaching and Learning in Science* series by Routledge. The editors of this volume claim that it derives from 15 years of research conducted by them in two countries (Australia and Canada). This publication thus indicates that the efforts to integrate STEM disciplines in school curricula were underway well before the release of the *Framework* in the US. The editors of *Integrating Science, Technology, Engineering, and Mathematics* provide the following as the purpose of their research and the focus of this publication (Rennie et al., 2012, p. vii):

> Our focus is particularly on the school subjects of science, technology, engineering, and mathematics, the so-called STEM subjects, because we believe that these are the subjects needed for clever and creative solutions to the issues facing our rapidly changing, global world. In the real world, problems cannot be solved by experts in just one discipline, such as mathematics or chemistry; they require interdisciplinary teams to work toward solutions. …In school, we believe that integrating at least some parts of the curriculum offers teachers and students opportunities to address real-world problems. Further, it enables the school to connect with its community, and thus reflect the fact that we live in a connected, global world.

Two years after the release of the *Framework*, the NRC released another report titled *STEM Integration in K-12 Education* (National Research Council, 2014). The NRC Committee on Integrated STEM Education spent two years "to develop a research agenda for determining the approaches and conditions most likely to lead to positive outcomes of integrated STEM education at the K-12 level in the United States," culminating in the release of this report (National Research Council, 2014, p. vii).

A literature search of publications during 2000 – 2021, using keywords "Collaboration in STEM" and "STEM Education," revealed 227 peer-reviewed articles reporting on collaborative instructional activities in both K-12 and college level classes. The advent of the *International Journal of STEM Education* during the last decade of the 20th century is a testament to the rise of scholarly activity in the integrated field of STEM education, as being distinct from science education, mathematics education, technology education, or engineering education. Therefore, it is evident that similar to the rise in collaboration between professionals in the STEM disciplines since the latter part of the 20th century, integration of STEM disciplines in school curricula, collaboration between teachers of these disciplines, and scholarship in the field of STEM education has also been on the rise. The following is an example of a project specifically designed to integrate science and mathematics instruction in grades 6 – 8, around real-life local issues, followed by the description of an instructional model effective at promoting collaboration between students in the classroom.

Science and Mathematics Integration for Literacy Enhancement (Project SMILE): Collaboration Among Teachers

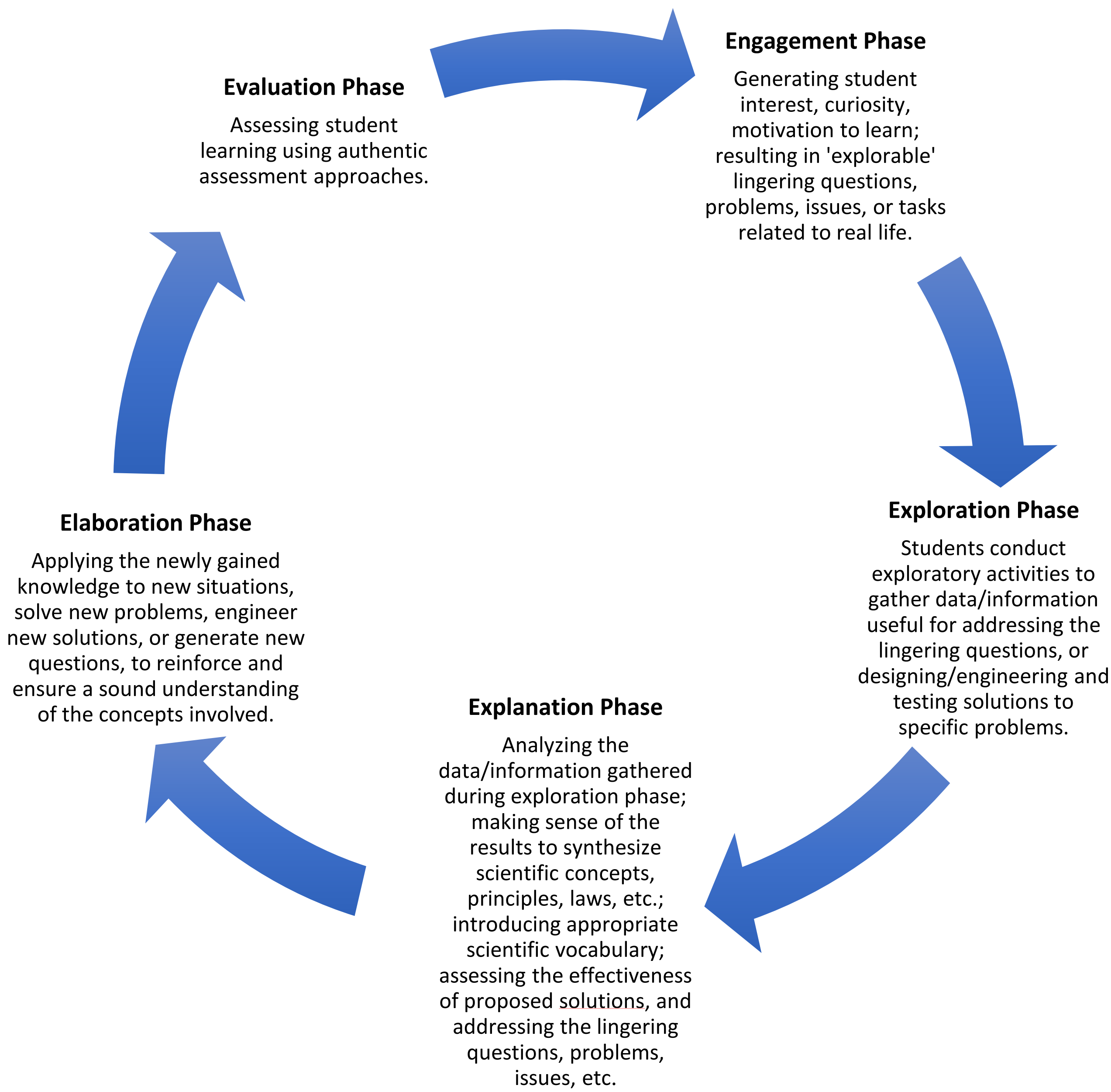
Funded by the National Science Foundation (Award #0918505), this project brought together grades 6 – 8 mathematics and science teachers in the state of North Carolina, USA. The teachers were engaged as teams over a period of three years to learn strategies for integrating science and mathematics instruction at their grade levels, focused around real-life, locally relevant issues and problems, and using *InspireData* as the specific technology tool to collect, organize, visualize, and query data relevant to student investigations. Thus, the S, T, and M of the STEM disciplines were involved in the integration process. Teachers of science and mathematics developed thematic instructional units for their grade level together as a team, and further collaborations with technology resource personnel in their schools enabled efficient and effective use of the *InspireData* software. The units were all designed around specific local issues or problems of relevance to the students' lives. All this resulted in students experiencing how real-life issues, problems, or questions can be addressed by combining knowledge from science and mathematics and employing appropriate technology tools. More details and results of this project can be found in Dass and Spagnolo (2016) and Dass and Moore (2015).

The Learning Cycle: 5E Model for Promoting Collaboration Among Students

For projects and efforts, such as Project SMILE described above, to be successful in the classroom, appropriate instructional models and strategies ought to be used by teachers for effectively engaging students in interactions and collaborations among themselves. Otherwise, students will not experience or learn what collaboration and integration really means and looks like in real life. The 5E model of the Learning Cycle maps extremely well with the *Scientific and Engineering Practices* dimension presented in the NRC *Framework*, thus proving to be an effective instructional tool in achieving the vision of the *Framework*. Complete details of the 5E model and the mapping of its phases with individual *Practices* can be found in Dass (2015). Figure 1 below provides a visual representation of the 5 phases of this instructional model.

Figure 1

The 5E Model of the Learning Cycle



While each phase of the 5E model provides opportunities for students to interact and collaborate, the EXPLORATION phase of this instructional model provides most opportunities for students to collaborate as they conduct their group investigations. An example in Southeast Asia was a collaborative project in Thailand in which high school students developed a plan to reduce air pollution caused by burning leaf litter and built composting bins, which turned the organic material into soil and created an income for the school (Intha & Phusavat, 2021).

Conclusion

As we strive to provide "quality education" to all our students, envisioned in SDG #4, we must remember that a very important component of this quality education is the opportunities we ought to give to our students to learn STEM in the context of real-world issues, whether they be local or global. This needs to be done using instructional approaches, which engage students in collaborative activities that reflect and simulate, to the extent possible in the classroom, what is done by STEM professionals in real life, as illustrated in the examples mentioned in this article. Such educational experiences in school will equip our students to handle real-world problems and make them effective as global citizens capable of dealing with global challenges they face. Of course, in order to provide this kind of quality education to our students, we need highly qualified and competent teachers, as envisioned in Target 4.C of SDG #4. Two examples of efforts to produce such teachers within the US are worth mentioning here.

100K in10 Network

This is a nationwide collaboration involving a variety of institutions, organizations, businesses, and professional associations, working together as partners to produce, provide professional development for, and retain highly qualified STEM teachers (https://100kin10.org). The network was initiated in 2011 in response to the then US President Obama's call to produce 100,000 STEM Teachers over the next 10 years. The year 2021 marks the end of that 10-year period and the network has exceeded its goal of producing 100,000 teachers by about 9,000 teachers. The network currently includes over 300 partner organizations, including the author's home institution and department, and they are pursuing many avenues of work to enhance STEM teachers and STEM teaching across the US.

The UTeach Network

Developed at the University of Texas at Austin, Texas, the UTeach model of integrated, undergraduate secondary science and mathematics teacher preparation started in 1997. The implementation of the model saw significant growth in the number of students enrolling in this teacher education program at Austin. Based on that success, the model began to be replicated at other universities across the US. At the present time there are 46 universities (including the university where the author works) in 23 states and Washington, DC, where the UTeach model is being used to prepare secondary science and mathematics teachers. Since the beginning of the

UTeach program, all of the 46 UTeach programs across the nation have collectively produced 6,870 new highly qualified teachers (https://institute.uteach.utexas.edu/).

These examples are shared with the intent that they might spark some new ideas regarding how to increase the number of highly qualified and competent STEM teachers to meet Target 4.C of SDG #4 and to make the vision of SDG #4 a reality in the classrooms across the countries represented in the membership of EASE and the readership of the *Southeast Asian Journal of STEM Education.*

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