From the Editor

Looking at my previous message for V2 No.1 in January, it seems as though I could write the same thing again for this issue. The world is still moving forward as all countries struggle to find what is by now the overworked term “new normal.” Educational programs are still trying to define what the “new educational order” will look like. We are still seeing students and teachers in virtual settings while in some locales students are heading back to face-to-face classrooms, but with a variety of safety measure in place, or in some districts and states with no safety measures in place at all. We are still a long way from “normal!”

Here at SEAMEO STEM ED, the parent organization of the *Southeast Asian Journal of STEM Education,* STEM education projects are continuing to be developed with an eye to the not-too-distant future (we hope) when they may be rolled out face-to-face on site. We have come to understand what we expected: while virtual instruction and workshops are necessary, they are not nearly as effective as learning in the classroom or with live face-to-face educational specialists modeling research-based, effective STEM teaching strategies in a sustainable multi-year process.

In this issue, we have five outstanding articles from STEM educators in three countries, all sharing projects or studies that are quite different, yet all contributing to the knowledge base for effective STEM teaching and learning.

Lindsey M. Swagerty and Michael K. Daugherty share the results of a pilot research study that aims to clarify the role that project-based STEM could play in the elementary grades, model project-based learning for selected elementary teachers, and measure elementary students' change in perceptions about the STEM disciplines. **Gregory MacKinnon** takes the position that “anchor texts” are a useful means of promoting literacy in developing countries when linked to STEM education approaches. In particular, using these texts with STEM activities have been shown to be effective in developing countries where the lack of substantive child-centred discussions and activities has seriously impacted children’s language literacy levels. **Tomohiro Takebayashi and Yoshisuke Kumano** report on a qualitative case study in which Japanese students learned about local geology through a STEM approach in their Earth and Space Science curriculum. **Amber Meyer**, **Claudia Burgess, Vincent Genareo, Nina Soto Ramirez, and Alejandro Tovar** describe the grant-supported program that recruits and supports migrant agricultural workers to obtain university degrees in the field of education with an emphasis in STEM. The authors provide two recommendations for future STEM Institutes serving college level students enrolled with similar background experiences. **Ruiqi Ying and Todd Campbell** explain how the Next Generation Science Standards (NGSS) and the Compulsory Education Middle School Science Curriculum Standards (CEMSSCS) in China align so that science and engineering practices can be integrated to offer students in China the opportunity for a more interactive and critical thinking skills-building experience.

I hope you will enjoy reading these articles. As always, we value your feedback and would love to hear from you. We would also welcome manuscripts about integrated STEM studies, position papers, or projects, so we encourage you to share your experiences in STEM education!

Finally, my sincere thanks go to the reviewers as well as colleagues who have advised me for this issue. We are fortunate to have a world-class review board who offer high quality critiques and support.

John Stiles, Editor in Chief

Affecting Children's Attitudes Toward STEM

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Abstract

Elementary teachers play a vital role in encouraging and building confidence among young learners related to science, technology, engineering, and mathematics, as well as confidence in their abilities to solve problems creatively. Thus, it is necessary to teach STEM and prepare elementary teachers to deliver engaging project-based STEM during the formative years in elementary school, prior to students forming lifelong attitudes about the role that STEM might or might not play in their future academic and professional endeavors. This pilot study research aimed to clarify the role that project-based STEM could play in the elementary grades, model project-based learning for selected elementary teachers, and measure elementary students' change in perceptions about the STEM disciplines as a result of participating in the research. A questionnaire to assess students' perceptions of STEM and its role in their lives was implemented. From this empirical study, obstacles to the awareness of STEM through elementary education are discussed. The analysis of the results of the questionnaire implies that the inclusion of project-based learning and integrated STEM lessons could positively influence student perceptions early in the formal educational timeline leading to sustained interest.

***Keywords**:* Elementary STEM, Project-based STEM, Elementary STEM attitudes, Student engagement, STEM pedagogy, Elementary STEM perceptions, Integrated STEM, STEM interventions

The acronym STEM (science, technology, engineering, and math) has become a well-worn descriptor among classroom educators for advancing science, technology, and math learning as well as an instructional strategy implemented to provide a foundation and motivation for students to pursue STEM focused careers (Becker & Park, 2011). The United States, as well as other nations, has been focused on ensuring that we have a sufficient labor supply for the projected growth and to serve the needs of our future economies. The most chronic economic shortage areas require individuals to have a strong background in STEM education and related technical skills to promote competitive economies (Caprile et al., 2015; Vilorio, 2014). Subsequently, U.S. policy makers and political leaders have placed the responsibility for preparing American citizens to accept such new jobs on the PK-12 public school system. Within the elementary grades, science, technology, and engineering have not historically held an obvious place within the curriculum. As a result, the content from these subjects has not been introduced to most American students during these important developmentally critical years (Daugherty, 2009). To address this new demand for increased student exposure to STEM, educational leaders have been tasked with the goal of vastly increasing the treatment of STEM content and 21st century skills within the PK-12 educational system (Owens et al., 2012; Thomasian, 2011).

In the endeavor to raise STEM interest, research has suggested that the best time for students to create a connection, awareness, and interest in STEM is before post-secondary and preferably during elementary school years (Russell et al., 2007). While a few elementary schools have begun to address some aspects of science in the elementary school, content from the fields of technology and engineering are rarely included in the curriculum. This results in elementary students not being exposed to concepts like design, problem solving, invention, and creative thought (Catterall, 2012). The goal of STEM programs within the elementary grades is to attract and maintain student interest in STEM subjects while increasing student performance within those subjects—especially with science and math content (Havice, 2015).

Best Practices for Elementary STEM

Numerous researchers have expressed widespread agreement on several best practices with regard to teaching integrated STEM content; these practices involve a challenge-based learning curriculum such as problem-based and project-based learning, cooperative learning, integrated disciplinary STEM content, and a design-based curriculum, i.e., materials and lessons that connect to the real world and are relevant to the student's interest and needs (Katzenmeyer & Lawrenz, 2006; Smith et al., 2009). Some research also suggests that primary students are more willing to participate in and remain engaged in learning STEM content when they have a positive connection to the content and experience some level of success in applying the STEM content (Capobianco et al., 2015). These crucial experiences are most commonly created when students are engaged in thought-provoking challenges and learning activities that they see as relevant to their current world and environment (Ainley & Ainley, 2011). While engaging students through meaningful and relevant instruction is not a new pedagogical concept it is important to remember that it is the heartbeat of STEM teaching and learning as it provides the connection to the real world (Margot & Kettler, 2019).

While it is important, increased math and science content knowledge is not the only factor that students need to be successful in STEM; they also need to know how to work and communicate effectively with others inside and outside their immediate area of influence. It is a reliance on 21st Century skills such as cooperative learning, problem solving, and critical thinking that seem to be driving some of the most effective STEM education programs (Brusic & Shearer, 2014). Macpherson (2008) defines cooperative learning within the classroom as an interaction between students in which inquiry and communication come together to increase mutual understanding. He asserts that the difference between individualized instruction and cooperative learning strategies makes a substantial difference in learning outcomes. In traditional small or individualized instructional groups, there is no structured interdependence, individual accountability, or active communication between learners. This demands that the teacher incorporate cooperative learning methodologies that require students to think critically, cultivate a deeper understanding, defend their positions, and practice social interaction skills to successfully promote proposed solutions and communicate ideas that may solve the given problem.

Children do not come by these skills naturally, and a cooperative learning classroom can create a safe environment for novice students to practice using cooperative learning strategies, build confidence in themselves and their abilities, and exercise social interaction practices, which are critical within the STEM fields (Yoruk, 2016). Furthermore, cooperative learning allows educators to put the emphasis back on the student. This may allow the student to acknowledge and identify helpful group behaviors, promote effective teamwork, and force the creation of group and individual accountability toward an end goal of team success (Sahin et al., 2014). Successful outcomes with cooperative learning may be attributed to the promotion of continuous team discussion, debate, and clarification that is critical for successful team problem solving. Ultimately, cooperative learning creates a student-centered learning environment that allows students to engage with new content while resolving conflicts by using research and acquired knowledge as the foundation to negotiate solutions (Cohen, 1994).

Integrated STEM lessons or content-rich STEM challenges that arise from the student's perspective seem to be most effective in attracting and maintaining student engagement. In a study conducted by Habashi et al. (2008), the researchers found that teachers were more effective at directing elementary students' interest toward integrated STEM content when the students' personal interests were explored through tangible objects rather than abstract thoughts or feelings. Similarly, DeFraine et al. (2014) noted that student success occurs when the teacher delivers a content-rich learning challenge that integrates STEM content through a hands-on project or challenge. Additionally, DeFraine et al. (2014) noted that the hands-on challenges should demonstrate how the applied content is not only applicable in the real world, but also how it relates to the students and their community.

Supporting this notion, Goeke and Ciotoli (2014) implied that students experienced increased levels of motivation in classroom learning when they were able to recognize a personal connection from their integrated STEM projects to the real world. These students also exhibited an increased level of engagement and became more engrossed in the exploration of the content as well as the life application of what they are learning when the content was delivered through an authentic problem with which they could relate. These methods are recognized for creating realistic learning opportunities for students that exhibit innate problem-solving inclinations, embrace creativity, view hands-on projects and challenges as fun learning experiences, while also being open to learning new content that they may have never received in a traditional classroom or individualized learning experiences previously (Allendoerfer et al., 2014).

The Role of Bias and Attitude on Learning

In order to implement best practices successfully in the primary classroom, the teacher must not only understand the student but also be aware of gender bias and student dispositions toward STEM. One critical element that must be considered to expand student engagement and interest in STEM subjects is the student's current disposition for learning. Several researchers (DeJarnette, 2012; Wigfield, 2010) implied that elementary students develop beliefs and dispositional attitudes toward science and math content by the end of the fourth grade. Further evidence suggests that almost half of students decide to avoid continued or advanced STEM subject matter learning before reaching the eighth grade. In a study conducted by Archer et al. (2012), the researchers discovered that once a student develops a negative disposition toward STEM subjects, that attitude will influence decisions throughout his/her educational experience and ultimately influence their career choices. Therefore, efforts must be taken to develop curricular programs and instructional approaches that reach these impressionable students while they are still open to the possibility of a continued acceptance of, and engagement in, STEM subject matter learning and investigation (Agranovich & Assaraf, 2013).

Another factor that may influence student engagement in STEM is perceived or real gender bias. Several research studies have suggested that young girls rely heavily on role models when developing their interests and future career aspirations (Toma & Greca, 2018; Tyler-Wood et al., 2018). Gender bias has been known to have a stronger emphasis on decisions than the student's achievements, especially in mathematics and science (Catsambis, 1995; Mattern & Schau, 2002). A student's gender can also affect how they approach learning and demonstrate an understanding about STEM subjects (Murphy & Elwood, 1998). Masculine and feminine societal expectations can play a role in how students respond to and participate in certain subjects. In a study conducted by Virtanen et al., (2015) it was found that girls were more likely to concentrate on the environment and making decorative projects, where boys were more interested in using tools. This study also noted that boys were more confident in their ability to learn new things in comparison to their female peers who required encouragement from the teacher to continue. In turn, the teacher's misconceptions and lack of awareness of gender bias, or the perception of bias, can also influence the way those students, especially girls, approach STEM subject learning. Supporting these research findings, Berekashvilli (2012) found that female students' skills and talents were often underrepresented and unpraised within the classroom. Berekashvilli (2012) noted that teacher's expectations were unknowingly lowered for female student achievement in math and science but often raised in subjects like English and reading. The author noted that this was often done without malice but rather happened without forethought. The implications of these research studies emphasize the vital need for elementary teachers to engage all students, especially females, for these students to build the confidence needed to continue their pursuit of STEM learning and achievement.

Teaching and Instructional Strategies in the Elementary Classroom

The last twenty years have marked a steep increase in the use of national and state standards or frameworks to guide instructional practices and curriculum development among public schools in the United States (Shepard, 2009). There is a consensus among educators for increased STEM content and for the application of 21st Century Learning Skills to be included as a part of the daily classroom curriculum (Lamb et al., 2015; Darling-Hammond, 2019). However, Judson (2012) suggests that most elementary teachers focus their curriculum primarily on literacy and the content identified on the yearly benchmark tests that include scant science, technology, or engineering content or learning experiences. Archer et al. (2012) found that in elementary classrooms the introduction of science as a content subject area does not often occur until after the fourth grade. Unfortunately, this occurs after many students have already begun to form decisions about their interests and future in STEM. Our public schools have responded by adopting and utilizing national standards like The Standards for Technological Literacy (STL) standards, the Common Core State Standards (CCSS), and the Next Generation Science Standards (NGSS) as guideposts to validate curricular offerings. Among other things, these learning standards were all designed to promote college and career readiness by using integrated content learning during the early grades (Stage et al., 2013). For example, the NGSS standards impact student learning and the development of 21st Century skills through the inclusion of engineering practices and design-to-demonstrate core concepts, such as problem solving, multi-discipline learning, and the use of models and hands-on projects (Cardno, 2013).

These standards call on the elementary teacher to deliver the content standards by developing STEM or integrated lessons and challenge-based learning experiences that draw upon the connections between the content of these four fields of study and other disciplines (Adams et al., 2014). Ideally, students who complete such learning experiences will be able to expand on multiple subject matter knowledge areas to solve problems and design creative solutions to learning challenges in collaborative learning environments (Adams et al., 2014). Students engaged in learning driven by integrated content standards should experience a level of learning that more readily transfers to the workplace and society in the 21st century (Darling-Hammond, 2019).

In a recent study examining the teaching methods for STEM content, Capobianco and Rupp (2014) affirm that the elementary teacher's ability to develop integrated STEM lessons or real-world design challenges that draw connections between essential content from all STEM subject matter, while making connections to students' personal interests was sorely needed if we are to make an impact on the student for continued pursuit of STEM learning in the future. While most elementary educators would likely agree with that assertion, it is not uncommon for elementary teachers to feel apprehensive about teaching integrated STEM lessons in their classrooms for a host of reasons (Goodnough et al., 2014). Notably, many elementary educators express a sense of apprehension and fear of STEM because they have not had deep educational experiences or training in the STEM content areas.

Rittmayer and Beier (2008) noted that teaching integrated STEM content in the elementary school might be hampered by the teachers' lack of confidence and content knowledge as well as general discomfort with ill-structured, inquiry-based, or problem-based learning methodologies. Supporting this assertion, Boulay and Van Raalte (2013) found that teachers were lacking the ability and resources to create real-world applications of STEM content for their students. Essentially, elementary teachers need to be prepared to design and implement ill-structured theme-based design problems that cause elementary students to solve engaging problems directly related to STEM or other content standards (Margot & Kettler, 2019). Teo and Ke (2014) note that the ability to model appropriate best practices for teaching and implementing new integrated STEM programs within the elementary classroom will be essential if wholesale changes in curricular offerings are to be expected. Without modeling support and direction, elementary teachers will likely be unsuccessful in their efforts to lead integrated STEM in their classrooms--leading to frustration for the teacher and the students (Teo and Ke, 2014).

Epstein (2011) proposed that there is an urgent need to develop elementary teacher education programs and projects to prepare highly skilled STEM teachers who have the ability and confidence to provide engaging integrated lessons that deliver core content from the STEM disciplines in a realistic manner. Given the fact that most existing and future elementary grade teachers are not likely to have extensive content knowledge or practical experience in the STEM disciplines or extensive experience developing STEM lessons and activities, modeling best practices of exemplary STEM programs might be the most appropriate avenue toward comprehensive change. Pinnell et al., (2013) suggested that for elementary teachers to fully understand and implement integrated STEM lessons and projects with real-world applications, they will need to have appropriate practices modeled for them. This modeling could be carefully crafted to illustrate methods by which current curricular practices could be modified to increase the treatment of STEM in the elementary classroom. Subsequently, the following research was conducted to serve as a model illustrating how STEM best practices directly relate to the learning and engagement of elementary students.

Methodology

This pilot research study investigated how integrated STEM content, when coupled with cooperative learning involving problem-/project-based learning, can influence change, increase student interest, and improve student performance in one local elementary school in the United States Mid-South region. This project served as the first time that cooperative learning integrated with problem-/project-based teaching had occurred within this elementary school. The research was implemented to introduce second-grade students to project-based integrated STEM content lessons, while simultaneously modeling best practices in problem-/project-based teaching for grade level teachers. Throughout the school year, numerous project-based integrated STEM lessons were developed and delivered that targeted specific content from second grade STEM standards identified in CCSS, NGSS, and STL. These lessons delivered content utilizing real-world contexts while providing hands-on learning and 21st century skills, including the use of problem-solving techniques and communication systems. Using data collected from two different second grade classrooms, the study attempted to determine whether the integrated STEM lessons impacted students' engagement among the STEM disciplines and their efficacy related to the STEM fields, as well as their career aspirations within STEM fields.

This study was coordinated through the University of Arkansas's Education Renewal Zone. The Arkansas Education Renewal Zone was established in 2003 with the overarching goal to address the current needs of community schools by providing resources, strategies, and tools to improve school performance and academic achievement for all students. This Education

Renewal Zone program was designed to connect a content expert such as a professor, staff member, or doctoral student specializing in a specific area, with elementary teachers in local partner school classrooms several times throughout the school year. The Education Renewal Zone sent an email request for participation to area classroom teachers as well as to university faculty, staff, and graduate students across campus. The Education Renewal Zone matched the interested participants based on expertise and classroom teacher needs. The content experts and the elementary teachers were then introduced to each other at a banquet where they met, planned, and coordinated their schedules for the semester.

This study was conducted in a second grade classroom within one of the elementary schools participating in the Education Renewal Zones program. The classroom teacher was primarily concerned with her students' reading scores, particularly inferential reading as the majority of the students in the class had scored below benchmark expectations on a recent state standardized test. The researcher used inferential reading as a catalyst to introduce the integrated STEM content. The researcher developed curriculum materials for the research that both delivered STEM content in a real-world context while providing hands-on learning and 21st century learning skills including problem-solving experiences, reading in context, and communicating their designs using real data. In addition, the curriculum developed for the project included a sense of relevancy and excitement to ensure that the participating students were engaged in not just the project but also in the associated learning content.

Three interventions were developed for this study. They consisted of three one-hour integrated STEM lessons delivered to the participating students by the researcher. The first intervention lesson included a design problem that asked students to work in teams to modify a shelter to keep the popular Olaf character from the Disney movie *Frozen* cold enough to visit their school. This lesson targeted three main learning goals, which included the design process, understanding of water properties, and the use of measurement. The students were given a themed newsletter, which directed them to explore different heat stations and materials. The students used the newsletter to track observational data from each station. The researcher stressed the importance of documenting key details and discussed why this was important and how researchers in the real world also had to document data for use in other studies and applications. Once completed, the students were assigned to small table groups and were required to complete an engineering design journal. The journal required students to defend and explain their contributions and rationale using data from the previous activity before building their project. The students were provided with an assessment rubric and were assessed, not only on the overall design, but also on their understanding of the content, reading, and writing. During the conclusion of the lesson, students were asked to share their design and experience from the project as a method for assessing their ability to communicate and share ideas.

The second intervention lesson asked students to work as electrical engineers. The students in this lesson were required to complete a simple electrical circuit to illuminate Rudolph's nose and guide Santa's sleigh. In order to complete this project successfully, the students were required to demonstrate understanding of science through energy transfer, technology, and engineering via energy forms, troubleshooting, and mathematical fractions. The students were provided with content, which was directly applied to the project. The students were provided with an assessment rubric, and were assessed not only on the overall design, but also on their understanding of the content, reading, and writing. During the conclusion of the lesson, students were asked to share their design and experience from the project as a method for assessing their ability to communicate and share their ideas. This was used as a formative assessment for student learning and understanding of core learning concepts.

The third intervention lesson required students to work in small table groups as mechanical engineers to build a fishing pole that could hold the most weight. The narrative text *Jangles* was used in this lesson to engage students and draw them into the project. The students were required to complete an engineering journal, including rationales for their designs and explanations for any modifications to their designed fishing pole. The students demonstrated understanding of science content through their explanations and project designs to minimize the force and weight of the fishing pole, technology, and engineering via their design journals and redesign of their projects, and mathematics through their calculations of the weight held on the balance scale. The students were provided with an assessment rubric and were assessed, not only on the overall design, but also on their understanding of the content, reading, and writing. At the completion of the lesson, students were asked to share their design and experience from the project as a method for assessing their ability to communicate.

The researcher's participation in this project allowed her to model and share exemplary practices for integrated STEM in the elementary classroom. This was done through a cooperative learning environment, allowing students to navigate the learning within each lesson, and ensuring the targeted learning concepts were met for each student.

Preliminary research data were collected using a student interest survey. The student interest survey was completed by students participating in the research as well as students in another second-grade classroom within the same school (control group) that did not receive the treatment. The demographics for the two involved classrooms are listed below in Table 1. The data for this study were analyzed using an independent t-test as well as Cohen's d to measure the effect size.

Table 1

Classroom Demographics

Control Group	Treatment Group
N=18	N=20
Boys = 8 Girls = 10	Boys = 12 Girls = 8

Findings

Although the research served as a pilot-test for a larger research project, the initial findings reveal that the integrated STEM design challenges delivered through the three interventions did influence the student's current interest in STEM subjects as well as their career aspirations within STEM fields after treatment in comparison to the control group that did not participate in the research treatment. The data showed a significant difference for the students who completed the intervention as indicated below in Table 2.

Table 2

Comparison of Student's Attitudes toward STEM after Experiment

					95% CI		
Variable	*t*	*df*	*p*	*MD*	*LL*	*UL*	*d*
I am good at science.	2.25	36	.03	-.46	-.88	-.05	.72
I am good at math.	2.43	36	.02	-.54	-.99	-.09	.78
I am good at engineering.	6.41	31.6	.000	-1.08	-1.43	-.74	2.05
I like learning how things work.	3.66	36	.001	-.63	-.98	-.28	1.18
I am creative.	.27	36	.79	-.05	-.42	.32	.08
I like solving problems that I don't know the answer to.	7.56	34.14	.000	-1.28	-1.62	-.93	2.43
I like to build and make things.	4.77	36	.000	-.94	-1.34	-.54	1.55
I would like to be a scientist.	1.74	36	.09	-.37	-.81	.07	.56
I would like to be an engineer.	9.28	25.28	.000	-1.34	-1.64	-1.05	2.03
I would like a job where I could invent things.	3.55	36	.001	-.68	-1.06	-.29	1.15
I would like to design machines that help people.	3.78	36	.000	-.70	-1.08	-.32	1.23
Scientists help make people's lives better	5.75	36	.000	-1.04	-1.41	-.68	1.86
Engineers help make people's lives better.	3.10	36	.004	-.54	-.89	-.19	1
I know what scientists do for their jobs.	2.75	36	.01	-.48	-.84	-.13	.9
I know what engineers do for their jobs.	1.84	36	.07	-.32	-.68	.03	.6

As indicated in Table 2 the data analysis illustrates that students in the experimental group held significantly higher self-perceptions of “being good at science” t(36)=2.25, p=.03, d=.72; “being good at math” t(36)=2.43, p=.02, d=.78; and “being good at engineering” t(31.6)=6.41, p<.001, d=2.05 than the students in the control group.

Similarly, students in the experimental group presented significantly different results in their interest related to STEM in the following categories of “learning how things work” t(36)=3.66, p=.001, d=1.18; “solving problems that are not familiar” t(34)=7.56, p<.001, d=2.43; and “building and making things” t(36)=4.77, p<.001, d=1.55 than the students in the control group.

Students in the experimental group also presented significantly different results in their interest to pursue STEM careers in the following categories of “career aspirations in engineering” t(25.28)=9.28, p<.001, d=2.03; “career aspirations for inventing” t(36)=3.55, p=.001, d=1.15; and “career aspirations for designing machines to help people” t(36)=3.78, p=<.001, d=1.23 than the students in the control group.

Students in the experimental group also showed differences in their beliefs and understanding in these STEM areas: “belief that scientists make people’s lives better” t(36)=5.75, p<.001, d=1.86; “belief that engineers make people’s lives better” t(36)=3.10, p=.004, d=1; and “self-knowledge of what a scientist does for their job” t(36)=2.75, p=.01, d=.9 than their grade-level peers in the control group.

While this pilot study was designed to focus on the impact on the students, the impact of learning for the teacher is also worth noting. The classroom teacher was always present in the classroom during the research interventions. During the first two lessons, she mainly sat in the back of her classroom and observed. After the second lesson, she asked more questions about the curriculum development piece. Her questions focused on how ideas for the lessons were created, how to implement the priority standards for grade-level learning, and on developing assessments. During the third intervention, the teacher took a much more active role in the students’ learning, design process, and using observational data for formative assessment. Following the three interventions, the classroom teacher noted that the project helped her develop the confidence that led her to continue developing and teaching additional integrated STEM lessons throughout the school year. This teacher also commented on how anxious she would be when the researcher asked certain students to defend an idea or decide as a group which design they would choose when their ideas conflicted with each other. She said that watching her students defend their work as well as have their peers support them in that process was something she intended to encourage moving forward.

During the third intervention when it came time to test their design modifications, the students became very excited and loud, but also actively engaged. The other grade level teachers, along with their school principal, observed the students testing their final product designs. The researcher asked the principal if she could stay for a few more minutes to listen to our discussion and lesson debriefing. The students were eager when we asked which group wanted to share what they learned, why it was important, and if they would want to pursue a career that involved this type of design and knowledge. These students were able to defend their ideas using their design journals to provide the necessary evidence to support their claims. The principal was impressed with the student responses to questioning and their perceived value of their own learning. This project helped to raise her expectations for student learning and engagement at the lower grade levels.

Conclusion

This pilot-test research suggests that teachers can influence STEM interest by ensuring that all students are routinely involved in problem solving, critical thinking, collaboration, planning, and communication. This can be accomplished by providing elementary-aged students with engaging, positive, and successful experiences within the STEM disciplines, thereby creating an environment where children yearn for more information, search for solutions to human problems, regularly blend disciplinary boundaries, willingly conduct research, seek answers, and continue learning well beyond the classroom. Delivering integrated STEM lessons in the elementary classroom is another step towards creating a more involved and more intellectually curious society and an insurance policy for the future of our nation.

STEM is increasingly important to our society and elementary teachers can affect student interest by engaging students in the study and application of these disciplines at an early age. By engaging students during the early years, educators can supply them with the tools necessary to keep them engaged throughout elementary, secondary, and postsecondary education. This will require classroom teachers to not only understand the learning standards but also to understand their significance within the students’ interests and community. Teachers should also develop an enthusiasm for finding and exploiting the connections between disciplines, real-world applications, and centering their teaching on the students and their world. Educators must communicate information utilizing a variety of teaching methods that allow the students to explore, create, and learn concepts important to the world around them. Teachers must not only commit to teacher professional development but also have a willingness to develop and teach content in a manner that ensures that our students’ environment connects with their learning. This process begins by preparing elementary teachers who are capable, comfortable, and enthusiastic about implementing integrated STEM education in the elementary classroom—this can best be accomplished by modeling best practices for those teachers.

(See author bios on the following page—Ed.)

Lindsey M. Swagerty is a Ph.D. candidate in Curriculum and Instruction with a cognate in integrated elementary STEM Education at the University of Arkansas in the U.S. Ms. Swagerty's current research focuses on STEM teaching in elementary classrooms to identify best practices for student engagement, effectiveness, achievement, and continued interest. She has co-authored several peer reviewed journal articles, presented at professional development seminars as well as national and international conferences for incorporating STEM into classroom curriculum and teaching as well as community outreach for STEM programs and expanded learning. Lindsey currently serves as director of the Education Renewal Zone (ERZ) at the University of Arkansas where she is responsible for identifying and developing programs and events that strengthen local schools by providing resources through programs and partnerships with higher education, businesses, and other community resources.

Michael K. Daugherty is a Distinguished Professor of STEM Education in the College of Education and Health Professions at the University of Arkansas in the United States. He earned a BS, MS, and EdD from Oklahoma State University. Dr. Daugherty speaks nationally and internationally on STEM education, project-based learning, technological literacy, standards, and curriculum development. He is the author of 26 books and book chapters, over 70 journal articles, and numerous curriculum sets. Michael has conducted more than 100 presentations and keynote addresses at state, national, and international conferences. He has been the recipient of numerous awards including the Technology Teacher Educator of the Year Award by the *American Council on Technology and Engineering Teacher Education,* the Award of Distinction by the *International Technology & Engineering Educators Association*, and most recently, the Mary Margaret Scobey Award by the Elementary STEM Council.

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A Case for Using STEM Anchor Texts to Promote Literacy

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Abstract

The author of this paper takes the position that anchor texts are a useful means of promoting literacy in developing countries. In particular, books in the STEM category are especially advantageous because of the context they develop and furthermore, the inherent integration of subjects. Feedback from teacher interns in both North American and Chinese teaching settings has identified factors that impact effectiveness of the anchor text approach. Exemplars of STEM books in two subsets of technology are provided.

Keywords: Anchor texts, STEM Curriculum, curriculum integration.

STEM curriculum offers a unique opportunity to enhance children's motivation to learn through the establishment of rich and engaging contexts. STEM curriculum is also arguably well-positioned through these contexts, to promote language literacy gains especially in developing countries. The following discussion argues that STEM curriculum linked to the use of anchor texts has the potential to enhance vocabulary, communicative expression and even second language learning.

A STEM text may be defined as a book in the curricular area of at least several of the component fields of science, technology, engineering and mathematics. Further, the book may act as a foundation for investigating curriculum outcomes whilst developing literacy through scaffolded discussions. In this way the book acts as an anchor with multifaceted purposes of advancing not just core STEM concepts, but also more global 21st century outcomes of effective communication and critical thinking (www.P21.org).

Literacy Development: An Ongoing Concern

The worldwide community monitors student literacy and numeracy in countries through the Organisation for Economic Co-operation and Development (OECD) using the Programme for International Student Assessment (PISA) results as one measure. The distribution of success on this assessment (PISA, 2019) spans several contexts, but it is clear that developing countries with fewer resources and evolving educational systems still face challenges.

When one drills down into unique systems and contexts, there is strong evidence that the nature of classroom teaching and learning has significant impact on literacy. Take for instance a recent study of countries in the Organization of Eastern Caribbean States (OECS) reported by the World Bank (2018):

> A key component of educational achievement is the quality of teaching. The OECS still struggles to attract and retain qualified teachers, especially at a higher level of education. While 76 percent of primary school teachers are trained, the share of trained secondary school teachers in the OECS is only 57 percent, and less than 45 percent in Antigua and Barbuda, Dominica, and Grenada. A study using the Classroom Assessment Scoring System (CLASS) shows that the weakest area in every country was instructional support, which includes skills such as the use of instructional discussions, activities to promote students' higher-order thinking skills, and the use of feedback to extend and expand learning; across OECS countries these scores were around 3, the bottom of "mid-range." This suggests that pedagogical skills, which are closely linked to learning outcomes, are the area where teachers need most professional development and support. (World Bank, 2018, pp 61-62)
>
> Note: 63 Trained observers used CLASS to assess 134 teachers in Grenada, 93 in St. Lucia, 107 in St. Vincent and 95 in Dominica in 2017.

In these countries, using a standardized instrument Classroom Assessment Scoring System (CLASS https://teachstone.com/class/), it has been established that the lack of substantive child-centred discussions and activities has seriously impacted children's language literacy levels. The full report suggests that students, as passive learners, don't have opportunities to learn new vocabulary or extend their usage through conversation with the teacher or their peers. It also suggests that language development is slowed by the lack of interactive problem-based activities that typically enhance language through cooperative learning modes (Johnson & Johnson, 2002). Herein lies an opportunity for STEM curriculum to play a role in promoting literacy.

Why is STEM Well Suited to Respond?

When one considers the evolution of STEM curriculum from such initiatives as the Science-Technology-Society (STS) curriculum in the 1990s (Cutcliffe, 1990), it is clear that integrated curriculum does an excellent job of creating context for learning (Drake & Reid, 2018). The constructivist teaching and learning model of Driver and Oldham (1986) expressly points to *Setting the Stage*. In their model (paraphrased below in Figure 1) this is more than setting a mood, they mean to set the cognitive stage that Piaget followers would recommend causes disequilibrium. Introducing interesting and authentic contexts for learning necessarily invokes rich discussions, often within a problem-based setting. Posner et al. (1982) suggest that these central questions are critical to promoting accommodation of new knowledge and therefore conceptual change. It is therefore arguable that integrated an curriculum such as STEM investigations have a pivotal role in creating settings that invoke significant discourse, hence the connection to literacy and language acquisition. The Driver and Oldham (1986) model further promotes discussions by eliciting students' prior knowledge, scaffolding student investigations, consensus building about learning outcomes, and finally application of learning, the so-called transfer of knowledge to novel contexts. STEM activities coupled with constructivist approaches have shown great promise in promoting conceptual change and overall language literacy (Jorgenson et al., 2014; Portsmore & Milto, 2018; Milto et al., 2020).

Figure 1

A Constructivist Model for Teaching and Learning
(reconstituted/paraphrased from the work of Driver and Oldham, 1986)

Setting the Stage

"the cognitive stage"

generate a single question to investigate

Elicitation

"seeking *background* knowledge about the system"

*__Do not__ answer the stage setting question here!

Restructuring

"classroom activities that investigate and help students re-conceptualize such that they can respond to the *stage setting* question"

1. Activities
2. Scaffolding
3. Closure/summary of what was learned

Review

"reviewing the new-found understanding as it relates to the stage setting question"

Application

"applying the new-found knowledge or process to a new setting to judge transfer of knowledge"

Defining our Terms and Posing an Example of Integrated Curriculum

In the context of the ensuing discussion, it is worthwhile defining terms because it provides introspection into how a book in its contents may fit as a foundational STEM text. Science is *a way of knowing*; how do we find out about the natural world around us? Technology is *a way of adapting*; how do we enhance the human condition through problem solving? Engineering is seen as the *artifacts* of our systematic problem solving and Mathematics as *describing our world using numbers*. Recognizing the complex synergies within STEM resources, the educator can capitalize on opportunities for extended discussions (literacy development) in the classroom. This is not only important for first (native) language English classrooms but consider that new terminology for second language leaners is only reasonably internalised through usage. STEM topics naturally provide enhanced discussion opportunities by their inherent nature. The examples that follow should demonstrate the unique opportunity for classroom discourse that STEM offers.

An example of an integrated study (MacKinnon & Yetman, 2001) involved children in learning about the use of Acadian dike systems in North America to reclaim land from the ocean for farming. The technology of the dike "aboiteau" (Eng.: "sluice") originated in the Netherlands and found its way to Canada via ancestral connections to northern France (http://www.girouard.org/cgi-bin/page.pl?file=dikes&n=9). In this classroom activity, students learned about the science of the tides, the ingenuity, problem-solving, and work ethic of the Acadian builders and the construction/engineering of the aboiteau system. The dikes allowed the settlers to plant specialized grain and therefore sustain their livestock through the harsh winters. As such it solved a human problem. Also inherent in the study were mathematics of the tides, history of the peoples, language arts around writing about Acadian lifestyle, and the creative arts of building a mathematically scaled dike model. This example demonstrates the richness of context that comes from STEM learning.

The Anchor Text Approach Blended with Integrated Curriculum

The notion of an anchor text builds on several foundations. The text, such as a children's book, could be undertaken as a *read aloud* about a topic of interest. A *read aloud* is a standard classroom approach where children gather and listen as the teacher reads and displays a book. There are also many documented examples of self-paced reading of stories that act as an anchor (Butzow & Butzow, 2000). The storybook acts as an anchor, because much of the learning will be centred around the book. A children's book may contain a story to *set the stage,* perhaps posing an interesting question. The book will invariably contain new vocabulary, which can be accentuated through pauses in the reading to reinforce spelling and pronunciation (Buchholz et al., 2021). New words can be highlighted further by contextualization in related sentences. The book may contain new concepts that would have the teacher pause and invoke discussion between students themselves (e.g., think-pair-share; see: https://www.readingrockets.org/strategies/think-pair-share) and/or Socratic exchanges with the teacher. Teachers may choose to do a *half read* where they (a) pause to allow students to take up a challenge such as construction, writing or research activity or (b) pose a question such as, "What do you think will happen next in the story?"

An example of a popular anchor storybook in science and technology is *The Salamander Room* by Anne Mazer (See https://www.youtube.com/watch?v=78agcNVQxWQ). Typically, teachers use this as an anchor to look at ideas of food chains, habitats, ecosystems, care of pets, and the environment. Ideas of clear-cutting and overuse of technology are natural extensions of the book. Jackson et al. (2021) have recently provided examples of using books to teach engineering-based thinking. Noted pedagogical strategies include (a) choosing a biographical story about an engineer and (b) a trade book that poses a problem. They argue that such stories invoke child-centred activities and scaffolded discussion.

Technology as a Component of STEM; How is it Taken up in Elementary Grades?

Ortega and Ortega (1995) have suggested that technology studies in elementary school fall into two categories. It is useful to consider these designations as we can apply anchor texts to STEM learning quite systematically:

(a) ***Technology Learning Experiences*** are awareness activities that provide students with a knowledge and understanding of the technologies in the world around them, e.g., stories of the development and context of technological advances, observing construction of buildings and bridges (shapes, structures, materials), transportation modes, mass production facilities, energy, and power machines.

(b) ***Technology Design Problems*** are activities that allow students to explore materials, engage in systematic planning, develop hands-on process skills, and build and test prototype problem solutions, e.g., stories of design (*The 3 Pigs*), Plasticine® structures, paper towers, stick bridges, balloon powered vehicles, Lego® blocks, gears and pulley systems, and computer tools for design and construction.

An example of an anchor text for category (a) above would be the story of *Elijah McCoy* (author Wendy Towle), a little-known black inventor who made significant contributions despite the racial stereotypes that hampered his progress. (See: https://youtu.be/OGWfzs2cRYA). An example of an anchor text for category (b) above would be the story entitled *Galimoto*. (author Karen Lynn William). Here a young boy wants to design a truck (Galimoto) and must problem solve to gather parts and build his model. This story could easily serve as a precursor to studying the design loop in engineering (See: https://www.teachengineering.org/activities/view/cub_creative_activity1) and challenging children with simple prototyping exercises (See read aloud: https://www.youtube.com/watch?v=lSD4vFozwXU).

A third example invokes a study of snowflakes. The science of ice involves hexagonal formation of water molecules, which necessarily determines the appearance of snowflakes. The book entitled *Snowflakes* (Libbrecht, 2008) has pictures of snowflakes captured using digital technology. The mathematics of snowflake symmetry invokes rich discussion of why and how they are formed. The children use digital microscopes and chilled slides to capture snowflakes as they fall and create their own digital compendium with potential portfolio tools as Word® or PowerPoint®. The book includes clear connections to science, technology and mathematics but also promotes literacies through rich discussions. The segue to a STEM activity of creating their own library is an added benefit that serves the notion of constructivist child-centred learning.

The STEM books in Table 1 each indicate a read aloud site and category of technology activity for elementary grades. These, amongst others, are being promoted in national curriculum revision currently being undertaken in Guyana and St. Kitts and Nevis.

Table 1

Electronic STEM Books

Book Title	**Author**	**Description**	**YouTube Read Aloud**	**Duration**	**Technology Category**
The Most Magnificent Thing	Ashley Spires	Building useful objects	https://www.youtube.com/watch?v=UM8oN4yzJqw	6:47	Design
The Boy Who Harnessed the Wind	William Kamkwamba & Bryan Mealer	Building a windmill	https://www.youtube.com/watch?v=stjOzn1etjc	5:40	Design
The Lorax	Dr. Seuss	Impacts of technology	https://www.youtube.com/watch?v=EdWesdMfyd4	18:18	Awareness
Cao Chong Weighs an Elephant	Songju Ma Daemicke	Solving a problem	https://youtu.be/ljKfjjfh-DQ	6:37	Design
The Wump World	Bill Peet	Impacts of technology	https://www.youtube.com/watch?v=PORV4ZnKwdA	14:52	Awareness
The Doctor with an Eye for Eyes	Julia Mosca	Science & technology careers	https://www.youtube.com/watch?v=0EIjnOgQl-s	8:55	Awareness
The Girl with a Mind for Math	Julia Mosca	Science & technology careers	https://www.youtube.com/watch?v=L0tM4NbOM1k	6:58	Awareness
Iggy Peck Architect	Andrea Beaty	Building challenges	https://www.youtube.com/watch?v=lm611U0ym0Q	4:26	Design/Awareness
Rosie Revere Engineer	Andrea Beaty	Design challenges	https://www.youtube.com/watch?v=31eBdgnPsCo	6:49	Design/Awareness
What's so Bad About Gasoline?	Anne Rockwell	Impacts of technology	https://www.youtube.com/watch?v=MLdJHdll2VI	14:49	Awareness
If I Built a Car	Chris Van Dusen	Design & construction	https://www.youtube.com/watch?v=mYgqMvE3K2E	5:07	Design
Gnu and Shrew	Danny Schnitzlein & Anca Sandu	Problem solving	https://www.youtube.com/watch?v=_gji-P0Tvms	7:01	Design

Feedback on Using the Strategy in Real Classrooms

In our teacher education program, we routinely ask teacher interns to use read-aloud approaches or alternatively, to create their own digital read alouds to upload to YouTube®. Further we ask them to prepare accompanying lesson plans. The primary goal is to promote literacy by using the books as anchor texts for teaching in a highly integrated elementary school curriculum. In many cases students have used the hard copy book in their practicum classes but appreciate having the electronic copy as backup. Informal feedback over three years, from a population of 120 teacher interns suggested the following important features of the anchor text approach:

a) The chosen book needn't directly deal with any one particular curriculum outcome but instead a blended situated around a real-world question.
b) STEM books are useful because they integrate multiple subject outcomes.
c) It was helpful to make word and concept lists to accompany the book so as to add structure.
d) Sometimes a concept map was useful to clearly articulate how the book helped relate book ideas.
e) Half-read strategies were useful when integrating hands-on activities with the book. Children liked to come back to the book after they had time to investigate the ideas on their own.

Quoting one teacher on the integrated nature of STEM anchor texts, "I find it easy to create discussions out of STEM books because they cover several content areas but also introduce many new concepts; science isn't my strength, but I love books." Another teacher suggested that "STEM topics by nature already have inter-related ideas and strong context; this motivates children to participate in discussions." Many young elementary teachers are drawn to Language Arts. From our informal feedback, the use of integrated STEM books seems to make it easier for teachers to see connections with literacy particularly if they have fears about teaching science and mathematics (Bursal & Paznokas, 2006).

Teaching Settings Involving English as a Second Language (ESL)

In ESL classrooms, reading comprehension is routinely approached by using storybooks as learning anchors. The pedagogy typically involves teacher scaffolding coupled with formative assessment tools, modeling of scanning text and skimming the book, providing context clues, and summarizing with children the story development and plot (Sahlan & Cook, 2021). Choosing engaging texts is crucial and STEM-oriented stories have great potential to hold children's interest as they negotiate concept development and language learning in tandem. The increased cognitive load (Schnotz & Kürschner, 2007) inherent in this combination of learning goals, makes it even more important to choose books with context that motivate learners. This is coupled with the fact that a well-chosen STEM anchor text can integrate subjects so that a single text can offer multiple opportunities for teachers to capitalize on diverse core subject outcomes.

Each year since 2002, we have ferried upwards of 100 children's books to build a library for interns to support their practicum teaching in China. In addition, our teacher interns have often tried to take their own English children's books to China. Teaching supervision and concomitant interviews with teacher interns in China (MacKinnon, 2020) unearthed the following attitudes towards using English anchor texts:

> "Children in China are very interested in English language read-aloud approaches."
>
> "I find it easy to create classroom discourse with anchor texts because the kids are fascinated by English stories."
>
> "STEM books have built-in context for discussions; I introduce new words that we can pronounce and review on the board, alone and in new sentences."
>
> "I like the STEM books that promote careers and the ones that deal with societal issues like the environment; they are easy to get kids talking about (them) and practising new words."

This speaks to another issue of access to good texts. In countries where teachers have little access to hard copy books and/or YouTube read alouds, the anchor text approach may pose challenges. Our solution for that problem has been to prepare our international-bound teacher interns to create their own storybooks using free software such as Bloom® (see: https://bloomlibrary.org/). The Bloom library contains contributed books in several languages, which allows for the anchor text approach to be applied in countries abroad. Since 2002 we have placed over 175 teachers for a four-month practicum in urban China. They have found the anchor text approach to be very productive in (a) motivating second language (L2) learners by creating contexts for learning, (b) seeing words and phrases situated in simple story sentence structures, (c) practicing the English language using the new vocabulary in classroom discourse, (d) articulating pronunciation through multiple usage of new words in a story and practicing those new words, and (e) promoting active learning using the anchor text as a foundation.

Closing Thoughts

In many elementary school jurisdictions worldwide, there is a predominant concern regarding literacy and numeracy of children. This has applied increasing pressure to reduce time spent on science and social studies curricula. Because technology, in the broadest sense, is about humans solving problems within social contexts, this trend also will necessarily diminish technology studies. The emergence of strong integrative STEM pedagogies has the potential to maximize the impact of these core subjects given the little instructional time teachers have at their disposal. An argument can be made that STEM anchor texts show great promise for situating learning in meaningful contexts that promote *just-in-time* learning, a process by which children access specific subject-based information as it relates to the problem they are trying to respond to. (Collins & Halverson, 2018).

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A Case Study of Geological STEM Education for Elementary and Junior High School Students: The Processes of Sand Formation Using the Geological Characteristics of Niijima Island in Japan

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Abstract

In this study we explored geological STEM education among students in elementary (5th -6th) and junior high school (1st -2nd) in Japan. This is a qualitative case study in which data were collected from the students' worksheets and their actions and behaviors. The theme of the lesson was "To investigate and explain the process of sand formation by using our own observation data (The children understand part of the earth system from the rock sources to the sand.)". The samples used were focused on geological features unique to East and Southeast Asia (Pacific Rim orogenic zones and volcanic islands) and used Tokyo Niijima Volcanic Island, beta-quartz sand and mafic sand, rhyolite and basalt from the Habushiura and Wakago areas. Google Earth™ satellite images and microscopes were provided as technological tools for the children. The children thought about their observations systematically and logically, and in the end, 13 of the 14 Students were able to describe the process of sand formation in writing based on their observations. The value of this study is that it focused on Asian geology-specific mineralogy and applied it to Earth and Space STEM education.

Keywords: Earth and Space STEM education, Geology, Crosscutting Concepts, Earth System, Sand

The Earth forms a complex and diverse system of constantly interacting material and energy, and all the materials form a circulation cycle from the surface to the mantle. Earth and Space Science, Technology, Engineering, and Mathematics (STEM) education require of students an understanding of the changes and cycles of Earth's materials and energy. For example, sands are a natural product of the Earth's material cycle and has in it the information of the source rocks. Students need to understand correctly that sand is not made spontaneously, but rather by the cyclical process of Earth's materials, and it is a systematic or continuous phenomenon. The STEM Crosscutting Concepts requires students to develop skills in systematic observation and understanding, pattern discovery, and energy changes.

Southeast and East Asian countries have many islands, and Japan is one of them. Therefore, sand is a familiar material and easy to collect, and there are previous reports of sand and clastic materials as a teaching material (e.g., Shimooka et al., 2012; Sakata and Kumano 2016). However, prior research has not discussed much about 1) developing educational materials that provide a visual understanding of the relationship between source rock and the outcrops, 2) building on STEM education, and 3) focusing on mineral properties.

In this study, we conducted a case study (qualitative research) in a formal field setting, looking for methods and rock/mineral samples that allowed the children to draw their own conclusions based on their STEM education and from their observations, discussions and arguments. The samples for the STEM teaching materials were chosen to focus on geology unique to Asia and Southeast Asia (the Pacific Rim orogenic belt), and we focused on the rocks and minerals of the Niijima Island near Tokyo, Japan. Because Niijima Island has black and white contrasting sandy beaches and outcrops, it is geologically easy to understand the relationship between the sand, the outcrop, and source rocks (Takebayashi & Kumano, 2020).

STEM education has spread rapidly in East and Southeast Asia in recent years, with Japan being one of the countries implementing it. In the Japanese educational system, compulsory education is provided in elementary and junior high schools (ES and JHS), and schools and textbook companies follow the course of study from the Ministry of Education (MEXT [MEXT 2017a, b]). For Science 2019, the Japanese Government has mentioned STEM and STEAM at MEXT (Matsubara, 2019; Tamura, 2019), and It is increasingly likely that STEM education will become an established part of science education in Japan. For example, there is active research in STEM education, including comparative studies of STEM in the U.S. and Japan, STEM case studies in various fields, and STEM camp practices (Okumura and Kumano, 2016; Kumano, 2019). Hence, the value of this study is to report the results of a qualitative study (case study) of Earth and Space STEM education, specific to geology unique to Asia, and to consider the prospects for geological STEM education in Asia.

Background

STEM Education and Earth System

STEM education of the NGSS in the United States (U.S.) has three distinct and equally important dimensions (3D-Learning) to learning sciences in years K-12: (1) science and engineering practices, (2) the crosscutting concepts, and (3) disciplinary core ideas (DCIs) (National Research Council [NRC], 2012). Since 2009 in the U.S., there are Public Laws (PL) of STEM education (PL 114–329, PL 114–59.) and STEM education activities are conducted by research institutions in the U.S. (e.g., the National Science Foundation [NSF], the National Aeronautics and Space Administration [NASA], and the U.S. Geological Survey [USGS]). The interdisciplinary core ideas are divided into four areas, one of which is Earth and Space sciences (NRC, 2012). Similarly, Japanese science education has an Earth and Space science field.

The scientific and engineering practices and crosscutting concepts for use in years K-12 have been discussed in NSTA publications (Bybee, 2011; Duschl, 2012). Outlined as a common aim of scientific and engineering practice, summarized as 8 practices (Generation Science Standards [NGSS], 2013), children are required to make problem-solving predictions, collect their own data, discuss and draw conclusions based on the data in order to solve the problem. The crosscutting concepts are (1) patterns; (2) cause and effect: mechanism and explanation; (3) scale, proportion, and quantity; (4) systems and system models; (5) energy and matter: flows, cycles, and conservation; (6) structure and function; and (7) stability and change (Duschl, 2012; NGSS, 2013).

Earth and Space STEM education places importance on children's understanding of the correlation between human society and nature, and studying the Earth environments (NGSS, 2013). Further, Earth and Space STEM education includes Earth System education, which advocates the educational goal for children to recognize the Earth as a continuous system (e.g., material-cycle, water-cycle, etc.) and being curious about the nature on Earth (Earth System Science Committee, 1988; Goto, 2005; Mayer, 2014; IESO, 2016). For example, there are elements of understanding of the Earth System in the “Crosscutting Concepts” (Duschl, 2012; NGSS, 2013).

Niijima Island's Geology is Unique to Asia

Niijima Island is one of the volcanic islands on the Izu-Bonin-Mariana (IBM) Arc, located about 157 km south of Tokyo. The island is mostly made up of rhyolites, and part of the northern area (Wakago area) is made up of basalts (Isshiki, 1987). The sandy beaches of the island depend on the geology of the region and are clearly split into white and black. Most grains of the white sandy beaches of the island are composed of highly beta quartz (as "rock crystal" [The definition of rock crystal in this paper supports gemology, e.g., Dana, 1962]), which is rare in the world. Habushiura, one of the white sandy beaches is estimated to be composed of approximately 70% quartz (Kitamura et al., 2003). In addition, Niijima has a unique culture of architectural stone industry and glass art. Niijima produces a large amount of fire-resistant bricks called "Kouka-seki (Watanabe, 1914) " and is one of the biggest mines in the world. Glass art has been a world competition since 1987, and Niijima Glass and its resources have attracted attention. Therefore, its study is of interest to Japanese students.

Methods

Case study method and assessment of students' writings

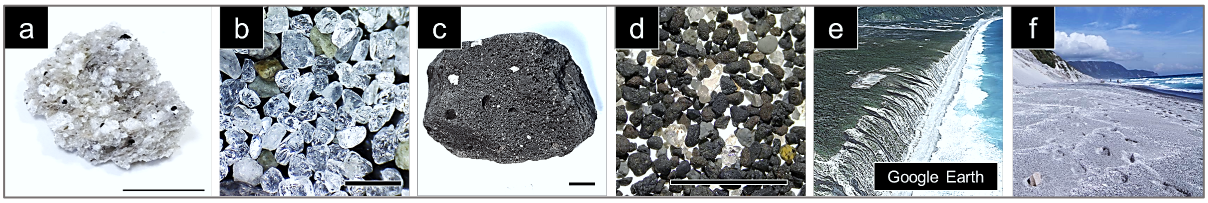
This qualitative case study was conducted in formal education environments. The theory base follows the STEM education of the NGSS. The students were asked to complete a worksheet. The class examined whether the students' writings on their worksheets were appropriate for the NGSS Crosscutting Concepts and whether their actions were compatible with science and engineering practices.

Preparation (Educational Materials)

We utilized the specimens we sampled (2014-2017) on the island to teach the class (Figure 1). The specimens in the class were rhyolite (biotite pumice) and rock crystal sand, basalt, and black sand (mafic, i.e., igneous [with iron and magnesium] sand), collected at Habshiura, Wakago, and Ishi-mi overlook points (The areas are located outside the national park areas). In addition, we also prepared Google Earth^{TM} satellite images and photos of outcroppings for students to use in class.

Figure 1

Rock and mineral specimens used in practices



Note: Scale: (a), (c), and (d) are 1 cm, (b) is 1 mm. (a) Biotite pumice (Kouka-seki) from Habushiura sandy beach, near Ishimi overlook; (b) rock crystal sand from Habushiura sandy beach; (c) basalt from Wakago coast; (d) black (mafic) sand from Wakago sandy beach; (e) Satellite image of Habushiura Beach (Google Earth™); (f) Photo of Habushiura Beach taken at the site. Photo by T. Takebayashi.

Program Framework

Our laboratory, which was accepted by the Japan Science and Technology Agency (JST) for the Next Generation of Human Resource Development projects in 2018, launched a STEM Academy in Shizuoka prefecture, led by Professor (Name hidden) (Table 1). This academy engaged ES and JHS students in STEM educational activities over an academic year. We used the STEM instructional periods (120 minutes) in February 2019 to practice the newly developed STEM activities using rocks and sands obtained from Niijima island. The goal was to have students observe the rocks and sand and explain how sand is made based on their observational data. There were 14 participants (seven boys and seven girls; n = 2 fifth grade and n = 5 sixth grade ES students; n = 2 first grade and n = 5 second grade JHS (equivalent to Grades 7 and 8, respectively, in western middle schools) students). Tables 2 and 3 show the program flow and assessment methods. To begin the class, we gave them a pre-question "Do you know the origin of sand?" Students who answered "I'm not sure" wrote their assumptions about the origin of sand, and those who answered "I know" wrote a concrete explanation.

Table 1

The Program at STEM Academy

Sequence	Student actions	Teacher actions	STE(A)M connection
Start	Observations: 1: quartz sand from various parts of the country. 2: rock crystal sand (Location: Niijima) 3: black sand (northern part of Loc. Niijima)	1. Show the samples to students 2. Indicate learning objectives	Rock crystal sand stimulates a child's curiosity. (Theory-based: A of STEAM and Earth System Science Education)
Asking the Question	Making a prediction.	Students observe diversity in the sands. Niijima has a contrasting black and white sandy beach. Question: What process makes sands?	Theory-based: S of STEM
Main Part	Observation (Sample from Niijima) 1. Sands 2. Rocks Students can use… 1. Stereoscopic Microscope 2. Laptop: Google Earth 3. Loupe Worksheet 1. Observation data 2. Discovery, understanding. 3. Thinking	1. Requirements →The teacher should not give the answer directly. 2. Experimental support 3. Worksheet: Students write their observations, findings, and thoughts (importance of research notebooks). Attention: Accident prevention: Do not look at the sun or other strong light with a loupe (fear of blindness).	STEM: Crosscutting Concepts 1. Patterns 2. Cause and effect 3. Scale 4. Systems and system models 5. Energy and matter 6. Structure and function 7. Stability and change T of STEM →satellite image
Explanations and Designing Solutions	1) Students choose the data to be collected. 2) Students write a conclusion based on their data.	In the conclusion section, students write about the process of sand formation based on their observations.	Constructing explanations and designing solutions
Conclusion	Presentation 1) Communication between students and teacher		Argumentation
Explanation		Commentary from an expert's viewpoint. Advice.	S of Science
Next step	Thinking the question.	Work with students to find a question.	Return to the beginning of the STEM 8 practice.

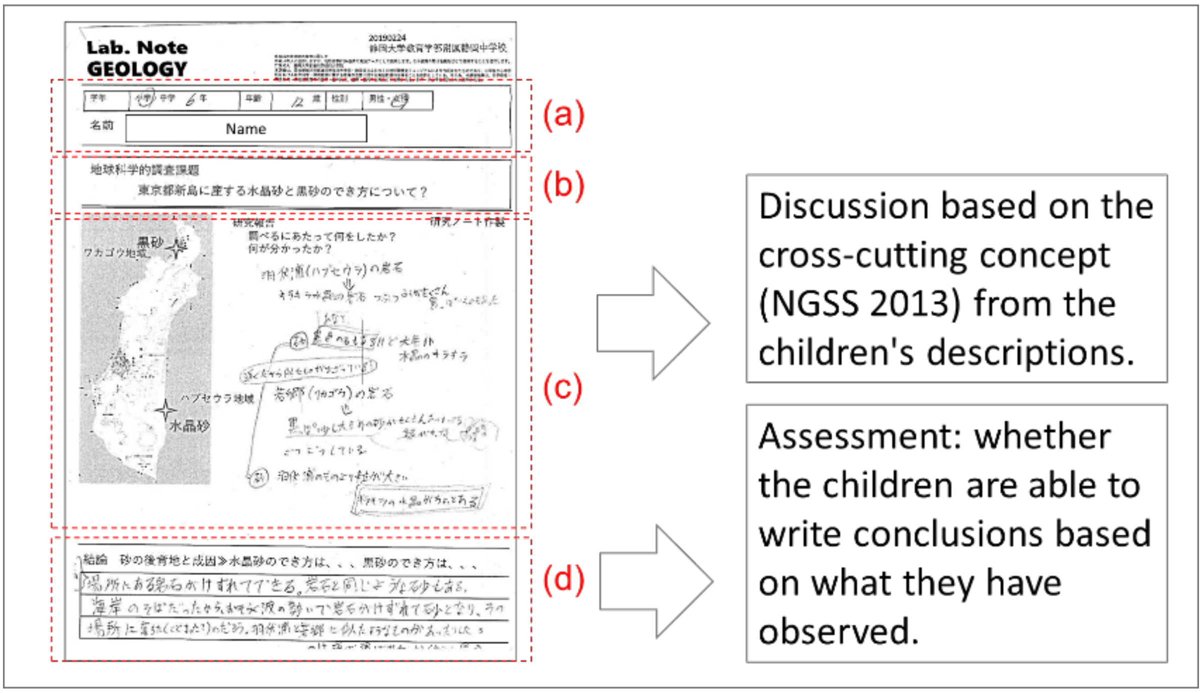
Data Collection: Students' Worksheets

The students were asked to record their observations and thoughts on their worksheets, which had a map of Niijima island printed on it (Figure 2). The conclusion section at the bottom of the paper gave the students space to write their conclusions based on their data.

The students' activities are documented in photographs and on their worksheets. In practice, the discussion was focused on whether the students could construct a conclusion based on the evidence of their observational data. A good assessment requires being able to use the evidence and explain logically, rather than relying solely on knowledge.

Figure 2

Example of a worksheet completed by a 6th-grade ES student



Note: (a) student information; (b) lesson objectives: "Find out how rock crystal sand and black sand from Niijima are formed"; (c) free writing space, where students write what they observed, discovered, and thought; (d) conclusion section, where students write their conclusions.

Results of Students' Writing and Activities in the STEM Academy

Pre-lesson Questionnaire: "Do you know how sand is made?"

Table 2 shows the results of the pre-survey and the results of the free statements. The students who answered "Yes" focused on the water. The five ES and JHS students wrote about river erosion and transportation; one student wrote about water, and two students made vague comments about content (e.g., "Sand is made up of broken rocks."). The following are examples of the students' responses:

- "While flowing on a river, a rock is broken down gradually and forms sand." (2nd grade JHS);
- "Reducing in size, sand is made by changing from rock to stone, and from stone to sand by breaking. Wind and water cause the stone to break." (6th grade ES);
- "A theory of the origin of sand is that big rocks flowing in a river are broken down by being knocked together and rapidly reducing their size." (6th grade ES);
- "Rocks are broken down and reduced in size. I remember that sand is more than 0.8 mm and mud is smaller than that." (5th grade ES).

On the other hand, the students who answered "No" expected that sands were the result of a rocks breaking. The following are examples of the students' responses:

- "Sand is broken rocks (including stones). Sand is the excrement of fish." (6th grade ES);
- "Sand is finely broken rocks or stones." (2nd grade JHS);
- "Sand is made by the repetition of big rocks breaking. Sand is the excrement of fish having eaten coral. Sand is compressed volcanic ashes." (2nd grade JHS).

Table 2

Student responses to "Do you know how sand is made?"

Y/N	Number	Summary
Yes	8	One 5th grade, four 6th grade ES students, and three 2nd grade JHS students
No	6	One 5th grade and one 6th grade ES students, and two 1st grade and two 2nd grade JHS students

Note: ES = Elementary school, JHS = Junior High School

Student Behavior

The students acted on their own without being told what to do. They used observational instruments and conducted experiments to find out the conclusion by their selves. For example, they collaborated with each other and used Google Earth™ and microscopes when observing the samples, even though they had different school affiliations and were in different grades. When using Google Earth, the students pointed their fingers at the screen and discussed their observations. The students observed the samples and wrote down on their worksheets what they noticed.

Worksheets

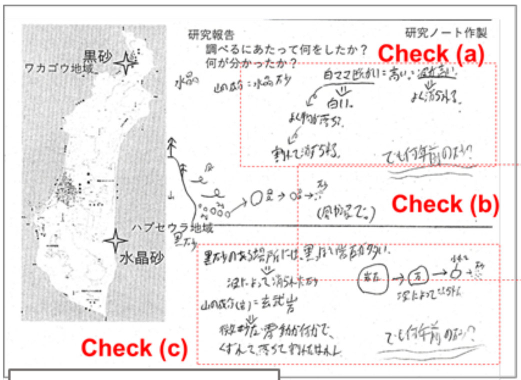
The students' worksheets presented their observations in a well-organized way. Almost all the students wrote about the characteristics of rocks and minerals (e.g., the color, shape, and feel of the surface) and the appearance of the outcrops (e.g., height, rockiness, and color) from satellite imagery, and they compared these data. Several students wrote descriptions that fulfilled the crosscutting elements of STEM, including descriptions that focused on the energy used to make sand, descriptions that focused on physics, such as the fragility of rocks, and sketches that focused on the mechanism by which sand is formed. After completing a description of their observations, the students (n = 13 of 14) used the data to write their conclusions. Five of the six students who answered that they did not know the genesis of sand before the practice were able to explain that sand is made of rock, using their observed data as evidence. Figures 3, 4, and 5 are examples of the worksheets completed by students in each grade. The student responses are in Japanese and we have tried to translate with care into English to preserve the correct terms.

(See Figure 3 on the following page. –Ed.)

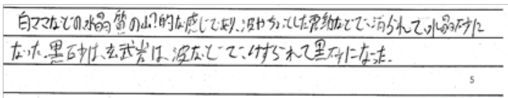
Figure 3

Student A: JHS 2nd grade student

Student A: age 13 (Junior high school student [grade: 2nd])



Student's Conclusion



Based on my observations, I think that the geographical feature around Shiro-mama cliff has quartz quality. Crystal sand was made from rocks being shaved by the waves or bite-size vibrations. Black sand was made from basalt being shaved by the waves.

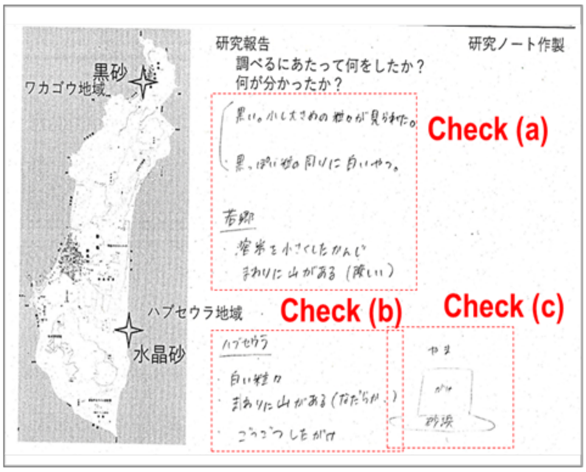
	Student' descriptions	STEM
a	The constituent object of the mountain=Rock crystal sand.	Pattern, Structure and function
a	Shiro-mama cliff=high→stones often fall in an outcrop	Scale, Energy and matter, Systems and system models
a	(Sea around Habushiura coast) high waves→strong polishing	Energy and matter, Systems and system models, Cause and effect
a	The samples characteristically breaks and is shaved.	Cause and effect
b	A Sketch	Systems and system models
c	*A place of black sand has many blackish rocks.*	Pattern
c	*The constituent object of the mountain (rock) : basalt.*	Pattern, Structure and function
c	*These are the sand shaved by waves.*	Scale, Energy and matter, Systems and system models, Cause and effect
c	*I guessed that the origin of sand is the result of rocks' having fallen and broken by the factor of small vibration or others.*	Systems and system models
c	(Memo) *The age of sand: ?*	The students discovered a new question.

(See Figure 4 on the following page. –Ed.)

Figure 4

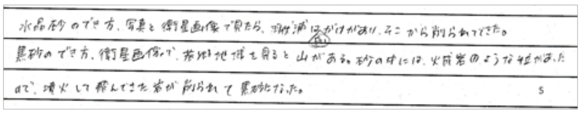
Student B: JHS 1st grade student

Student B: age 12 (Junior high school student [grade: 1st])



	Student' descriptions	STEM
a	Sand is black and contains slightly large grains.	Pattern, Structure and function
a	white minerals are around a blackish grain.	Pattern,
a	The feature of sand is small lava.	Structure and function
a	Steep mountains are around an outcrop.	Scale
b	Sand is made with white grains.	Pattern
b	Gently-sloping mountains are around an outcrop. Rocks are rough	Scale
c	*Sketch*	Systems and system models

Student's Conclusion

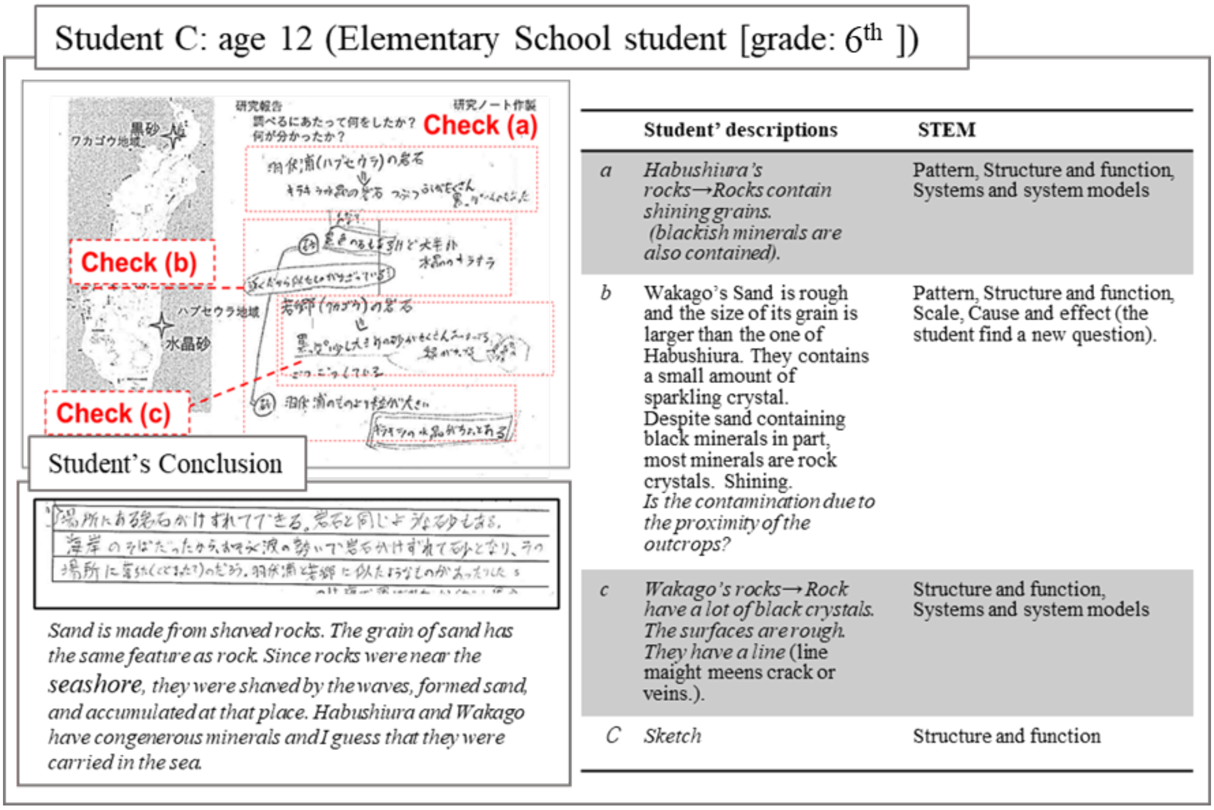


The origin of crystal sand: The observation with photograph and satellite imagery shows that a white cliff is in Habuseura and white sand is made from shavings from the cliff. The origin of black sand: A mountain is found in Wakago area in satellite imagery. Sand contains grains like igneous rock. Therefore, black sand is made from shaved volcanic rocks.

(See Figure 5 on the following page. –Ed.)

Figure 5

Student C: ES student (6th grade)



	Student' descriptions	STEM
a	*Habushiura's rocks→Rocks contain shining grains. (blackish minerals are also contained).*	Pattern, Structure and function, Systems and system models
b	Wakago's Sand is rough and the size of its grain is larger than the one of Habushiura. They contains a small amount of sparkling crystal. Despite sand containing black minerals in part, most minerals are rock crystals. Shining. *Is the contamination due to the proximity of the outcrops?*	Pattern, Structure and function, Scale, Cause and effect (the student find a new question).
c	*Wakago's rocks→Rock have a lot of black crystals. The surfaces are rough. They have a line* (line maight meens crack or veins.).	Structure and function, Systems and system models
C	*Sketch*	Structure and function

An Unexpected Response

On Japan's mainland, there are many rivers. Therefore, in formal science education in Japan, erosion by rivers is taught in textbooks in the upper grades of elementary school. On the other hand, in the case of this practice, there are no clearly identifiable rivers or streams in Niijima from outcrop photos or satellite images, and it is important to consider whether the students were able to describe the mechanism of rock destruction from observation rather than relying on memorization.

In the preliminary questionnaire, five students wrote about the river, and after the class, four students gave their reflections based on the observation data from this experiment. However, one student wrote about a river in the conclusion section, as follows: *"The basalt sand was formed by the collapse of stones from the sea and rivers."*

Discussion: Are Rocks and Minerals in Niijima Suitable for STEM Education?

Students' Perspectives

Students in Japanese elementary and junior high schools are taught to memorize the process of how a rock breaks down into sand using pictures and illustrations in textbooks. However, in STEM education it is important to gather and discuss evidence from experiments and observations. For example, rock/mineral, sand, and outcrop don't have a directory answer for the question of "sand origin". Their materials have a variety of scales, structures, and components. However, the relationships between sands and rocks/outcrops have been investigated, and the original rocks and location of sands have been proven by geological methods (cf. Takebayashi & Kumano, 2020). In STEM education, there are cross cutting concepts and eight practices, so it is important to integrate independent data into one evidence to solve the problem. Students could come to the conclusion based on their data and numerical analysis. For example, in their worksheets (cf., Fig., 3-5), we can see the student's considerations; students found common information from diverse data (rocks, minerals, and outcrops), and after they tried to find the meaning from their collected data (cf. prominent, Fig. 5). The students thought about the rocks and geological scales while making their observations, indicating that they were not just observing but that they were observing with a purpose. As a result, the students made connections between their observations to reach their conclusions.

Technology Strongly Supports STEM Educational Activities

As technology evolves, we can easily get clear satellite and microscopic images using computers and microscopes. Technology provides us with valuable data, but the data alone have no value at that point. For example, in this research, rocks and satellite images have their own information. They are entirely separate substances and information. However, when people realize that they can fuse the information, a new informational value and scientific perspective is innovated. The students shared and discussed their opinions and compared the satellite images to the rocks on the table. They used a variety of tools to gather evidence and try to support their conclusions. The fusion of science and technology, which forms part of STEM education, can accelerate the development of science education understanding for students.

From the Worksheets, Crosscutting Concepts, and Making Conclusions from Data

Based on the students' worksheets, a number of statements that satisfy the Crosscutting Concepts in STEM education were identified in this practice. Almost all students compared the sand to the rocks and the outcrops and made lists of the similarities and differences. The students' worksheets showed that they found the minerals (sand and rocks) to be similar, and the outcrops and the related sand to be a similar color. The sandy beaches of Niijima have similar features to those of the outcrops and the source rocks, making it easy to identify similarities and differences. Niijima has contrasting geological features, both siliceous and mafic, on one island, making it possible for the students to make comparisons.

After finding patterns of similarities and differences, the students thought about the relationships between the data they had observed. For example, students who discovered that the rocks and sand were similar concluded that the rocks would break down and make sand. When students considered the change in sand from this rock, they simultaneously considered time and spatial scales (e.g., time scale is a geological scale; spatial scales are the mineral scale [μm], rock scale [mm-cm]), and land scale [m-km]). A few students made observations from a physics perspective. For example, student A thought of the energy needed to change the matter (Energy and matter), and student C said that the outcropping was caused by a volcanic eruption (Stability and change, Cause and effect).

Concluding Sentences Written by a Student

Students who claimed they did not know the origin of sand initially were able to explain the development process of sand in the conclusions section of the worksheet based on their observations and thoughts during the practice. In their predictions before the practice, they wrote that they thought the rocks would break; however, the observational activities enabled them to understand how sand is made. In this study, we develop STEM education from the perspective of mineralogy. This case study has shown that STEM education in mineralogy is successful, and with more practice, we might be able to see more effective learning methods.

Geological Mathematics

Geology can be divided into discussions from observations or numerical results. For example, the former involves observing the crystal systems and structure of minerals and rocks and evaluating them relative to each other to find the answer (geometry, e.g., crystal-science). The latter utilizes computers to find answers as numbers (algebra, e.g., instrument analysis). In our practice, students were able to determine the forms of minerals, the types and content of the constituent minerals (no numerical calculations in this case; relative assessments). The next goal of this practice is to measure and calculate their angles and frequencies numerically, which can be applied to algebra.

Conclusions

This study shows that an Earth and Space STEM education specific to Asian geology is viable. The students were able to base their activities on rock science research methods (observation and comparison). For example, they were able to use technology (microscopes and Google Earth) to seek geological conclusions (T), consider issues and observations (E), and compared the shape and frequency of minerals and rocks (M). In the end, the children were able to summarize their conclusions in writing, thinking about them from the observational data.

Minerals are of diverse value in geology, mineralogy, resource-engineering (economic geology) and engineering perspectives. STEM education is the approach that makes a difference in children's learning. For example, in this case we approached it from a geological perspective, but it could also be approached from the perspective of local industrial ores, local glassware, or local ecosystems and geology. Our research results show that STEM education in Asia can be developed by focusing on the unique nature of Asian and Southeast Asian countries in the future. It is a fascinating and important part of science education in order for children to have a rich understanding of the country and region in which they live.

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Engaging College Assistance Migrant Program Scholars in a Virtual STEM Institute During the COVID-19 Pandemic

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Abstract

Salisbury University in the United States received a College Assistance Migrant Program (CAMP) grant to recruit and support migrant agricultural workers to obtain university degrees in the field of education with an emphasis in STEM. As part of CAMP programming, the university facilitated a STEM Institute to 1) Engage CAMP Scholars in STEM curricula and standards, and 2) Highlight Scholar's funds of knowledge and cultural assets as future teachers (teacher candidates). The purpose of this article is to describe the process and products of the STEM Institute. Overall, the STEM Institute appeared successful in exposing Scholars to STEM concepts and creating STEM-based virtual field trips that incorporated K-12 content standards. The authors provide two recommendations for future STEM Institutes serving college level students enrolled in CAMP or with similar background experiences: provide technological assistance and ensure responsive, explicit instruction as well as independent work time.

Key words: STEM education, STEM Institute, migrant agricultural workers, College Assistance Migrant Program

In the United States, the current undergraduate college student population is predominantly White (52.9% White, 20.9% Latinx, 15.1% Black, and 7.6% Asian) (Espinosa et al., 2019). Federal programs such as the College Assistance Migrant Program (CAMP) have been developed to increase the diversity of the student population. In 1975, CAMP grants were created to assist the higher education attainment of migrant workers through the United States Office of Migrant Education (OME) (Madrid, 2019). Migrant workers in the United States are typically people of color who represent culturally, linguistically, and racially diverse populations who may be underrepresented in undergraduate university enrollment. At a national level, CAMP annually serves approximately 2,000 university students who are identified as seasonal or migrant farmworkers by providing support during their freshman year (U.S. Department of Education, 2021). The supports provided through CAMP include personal, academic, and career counseling; tutoring; assisting students in understanding college processes such as admissions and financial aid; and exploration of social and cultural events. In 2016, the last year of available data, 88.1% of CAMP participants completed their first year and 96.5% of CAMP participants continued on to a second year, compared to the national overall first-year freshman completion rates of about 61% for two-year institutes, and about 81% for four-year institutes (U.S. Department of Education, 2018). Based on these data, in comparison to the traditional U.S.

college student population, CAMP is successfully supporting migrant workers in accessing and navigating higher education.

Recently, OME identified the goal of focusing on higher education attainment in the STEM (Science, Technology, Engineering, and Mathematics) fields through the CAMP grant because people of color are underrepresented in STEM occupations (National Science Foundation, 2021). To illustrate, Black workers make up 9% of the STEM workforce and Latinx workers represent 8% (Kennedy et al., 2021). With this in mind, the university received a CAMP grant to recruit and support migrant workers in the Mid-Atlantic area of the United States to obtain university degrees in the field of education with an emphasis in STEM. The writers of the grant believe opportunities to participate in STEM educational activities throughout elementary and secondary education play an important role in the future decision to work in STEM related fields (Genareo et al., 2018). In addition, teachers of color who represent culturally, linguistically, and racially diverse populations, such as migrant workers, can serve as role models that possibly inspire students who are underrepresented in university enrollment and STEM fields.

As part of its CAMP programming, we, the CAMP staff, facilitated a STEM Institute for the first time, and it occurred during the COVID-19 pandemic. Though originally planned to be face-to-face, the restrictions required the Institute to be done virtually. The purpose of this article is to describe the processes and products of the STEM Institute. The objectives of the STEM Institute were: 1) Engaging CAMP Scholars in STEM curricula and standards, and 2) Highlighting Scholars' funds of knowledge and cultural assets as teacher candidates.

Literature Review

STEM Education

Teacher candidates, or those studying to be teachers, need to understand how to engage in, and later integrate, STEM concepts and pedagogies. STEM education goes beyond presenting content material; it engages learners to seek new solutions with evolving knowledge and tools by providing learners with the opportunity to solve authentic problems through a multi-faceted lens of disciplines (Moore et al., 2014; Kennedy & Odell, 2014; Venville et al., 2012). This is complex and challenging. Teacher candidates are themselves sometimes forced to grapple with understanding and applying new academic content and unfamiliar innovative technology with their students or in their own teacher learning. In addition, candidates must learn to simultaneously scaffold and model the use of integrated disciplines with their students.

In order to accomplish the complex tasks of integrating the interdisciplinary solution-focused approach often required in STEM education, teacher candidates must not only demonstrate strong content knowledge and skills but also have the opportunity to practice and develop skillful teaching strategies to share this knowledge with others. This is especially true regarding the aspects of efficient use of technology (Montero-Fleta, 2017; Roshdi, 2017). Research has found that facilitating successful informal STEM learning experiences (hands-on, play-based experiences grounded in real-world learning) is an essential part of STEM education (Dani et al., 2017). Therefore, integrating technology into STEM education creates a learning environment that teacher candidates must learn to navigate. Furthermore, it is imperative that teacher candidates learn to successfully facilitate STEM learning opportunities through technology. Effective and relevant STEM teaching might encourage young students to be interested in, and pursue, STEM careers (Genareo et al., 2016).

STEM Institutes

One way to assist teacher candidates to learn STEM pedagogies and content is through the implementation of STEM Institutes. These Institutes can focus on the specific needs of teacher candidates and provide opportunities to participate in authentic STEM educational activities. The University CAMP staff believed STEM Institutes for teacher candidates should intentionally include teachers of color who represent culturally, linguistically, and racially diverse populations, such as migrant workers, to serve as role models to possibly inspire students who are underrepresented in university enrollment and some STEM fields.

Few extant articles describe efforts to introduce migrant students into the STEM field through STEM Institutes. The existing studies tend to focus on highlighting possible STEM careers during secondary education (grades 6 -12) to a general population and demographic location (rural). To illustrate, the University of Washington implemented three annual Yakima Valley Science and Engineering Festivals in a rural area in central Washington (Munn et al., 2018). The authors of this study argued that people living in rural communities were not as likely to have the opportunities to meet STEM professionals and visit the science centers, museums, zoos, and aquariums as the people living in urban areas. They cited geographical isolation, socioeconomic disadvantages, and in many cases, language barriers as reasons for the lack of opportunity. This study mentioned inviting migrant workers to the festival but did not focus specifically on serving their unique needs as part of the event. In another study, the Oklahoma State University sponsored a STEM Institute that served Latinx students ages 13-19 through animal science education and was designed to introduce Latinx youth to college life and STEM-based career opportunities (Sallee et al., 2019). The students were identified as rural Latinx youth, but they were not specified as being involved in migrant agricultural work. Both studies reported that the results indicated a positive impact on students' perception of STEM as a career option.

Description of the CAMP STEM Institute

This article addresses the gap in the discourse regarding the STEM educational experiences of CAMP Scholars who were raised in families that performed migrant or seasonal agricultural work. Scholars were engaged in a STEM Institute over five days, which was led by two STEM professors at Salisbury University located in the Mid-Atlantic region of the United States. All sessions took place virtually over Zoom™ due to the limitations caused by the COVID-19 global pandemic. Each day's session lasted three and a half hours and was broken down into three parts: content instruction, Scholar application and implementation, and review. This STEM

Institute focused on having Scholars use Google Earth™ technologies and place-based geoscience education (Semken, 2005) to develop virtual field trips to a location that they had previously lived in that it provided a sense of home. Place-based geoscience education (Semken, 2005) highlighted not only the geological and natural attributes of place, but also the diverse meanings regarding the sense of place through authentic learning experiences and cultural sensitivities shared by individuals connected to the given place. Scholars were guided to look at environmental and cultural sustainability and the ways that policies and practices reinforce that sustainability.

Scholars were supported in a variety of ways during the development of a virtual field trip. First, they were introduced to an abbreviated list of relevant K-6 content standards in language arts, science, mathematics, social studies, and the arts. The K-6 content standards were from the Common Core State Standards and the Next Generation Science Standards. These two frameworks provide a guide toward National Curriculum Standards. Next, they were assisted in choosing a grade level focus that best aligned with their field trip goals and their teaching interests. Additionally, Scholars were engaged in the process of conceptualizing how imagery could support the planning and development of their virtual field trip. Finally, they were asked to use science, math, and at least one other content area (art, architecture or engineering, social studies, and language arts) to consider how to represent the diverse meanings regarding the sense of place with cultural sensitivity.

The Scholars were encouraged to develop virtual field trips in ways that were personally meaningful while considering the educational and experiential value to students. Through an inquiry-based design process, Scholars developed individual needs for content knowledge such as architectural elements, weather, plants and animals of a given region, culture, food, historical timelines, etc. specific to their identified place. Beyond the content addressed above, Scholars also acquired knowledge associated with technology use. To begin, Scholars were provided a completed Google Earth™ technology project as a model. They were then engaged in guided practice as a whole group to complete essential steps for setting up the STEM project. These essential steps included how to set up their Google Drives, launch Google Earth, and navigate within Google Earth and Google Earth Projects. They were also introduced to the specific features of the digital platform required to create the virtual field trip such as inserting maps, adding images, and utilizing Street Views with 360-degree capabilities.

At the conclusion of the STEM Institute, Scholars had the opportunity to share and discuss their virtual field trips with a group of individuals from the university and the community who attended the biannual CAMP meeting. This experience was a culminating event that allowed the Scholars to share their personal connections to place as well as their STEM content knowledge and technology skills (See Figures 1 and 2).

Methodology

STEM Institute Participants

The participants of the STEM Institute were two first-year CAMP scholars who were raised by parent(s) who worked as migrants in seasonal agricultural fields, as well as the Institute Director who planned and led the Institute. The Scholars were both declared education majors. They had varying degrees of comfort with technology required for university such as Zoom, email, online learning management systems, and navigating university-wide required programs and sites. They also had limited STEM learning opportunities as provided through their high school classes. The Institute Director was a mathematics education professor and a key CAMP personnel.

Data Sources

Three data sources informed the description and analysis of the Institute. A reflective journal kept by the Institute Director highlighted the processes of the STEM Institute, including her experiences with the Scholars, the planning decisions they made, and her experiences during the Institute. The CAMP Scholars also generated artifacts of the virtual field trips that provided insight into the application of STEM content, K-12 STEM learning standards, and how they applied their cultural knowledge to the place of interest. Finally, CAMP Scholar presentations were observed and recorded to further analyze any additional information that was verbally shared beyond the artifact.

Data Analysis/Measures

The data were analyzed inductively and deductively as a case study using grounded theory (Merrian & Tisdell, 2016). Codes were developed based on the STEM Institute outcomes using a descriptive coding strategy (Saldana, 2016) that helped understand the type of engagement of the scholars. The codes developed for the first objective, engaging CAMP Scholars in STEM Curriculum, were *STEM engagement, problem-based learning, and content standard integration*. The codes identified for the second standard were *family*, *home*, and *self*.

Results

The analyzed data provided promising findings related to the Institute's objectives, both presented below.

Objective 1. Engaging CAMP Scholars' STEM Curricula and Content Standards.

The first objective appeared successful. Scholars were engaged in STEM curricula during the Institute and were able to integrate K-12 STEM content standards in their virtual field trips. The Scholar engagement with STEM curricula included conversations and virtual investigations into region-specific flora and fauna, regional geography, designing and interpreting graphs and charts, and technology presentation, integration, and development. For teacher candidates, the Institute followed a project-based learning model. The Scholars were involved in authentic teaching practices (content integration, teaching, and presentations) through inquiry processes of asking and answering questions as they developed a project – their Google Earth presentation – that demonstrated their understanding of the content; this pedagogy is often noted as being effective in science education (Krajcik & Blumenfeld, 2006).

Each Scholar worked throughout the Institute on creating a virtual field trip focused on a given grade level that aligned to curricular standards. In developing their virtual presentations, Scholars engaged in a number of Next Generation Science Standards (2021) science and engineering practices: *Analyzing and Interpreting Data* through their use of graphs and maps embedded in their virtual field trip presentations; *Developing and Using Models* as they created interactive mapping; and *Obtaining, Evaluating, and Communicating Information* through their presentations of the virtual field trips. Additionally, the Scholars engaged in mathematics curricula by utilizing the Common Core State Standards for Mathematics (2010). They developed tables and graphs analyzing average temperatures and yearly climate data (CCSS.MATH.CONTENT.3.MD.B.3; NGSS 3-ESS2.1). They also calculated distances through the conversion of miles and kilometers (CCSS.MATH.CONTENT.7.RP.A.1) in the Google Earth maps they developed.

Figure 1

Images from Scholar Presentations

Image 1. Scholar presentation discussing geographic features of Guatemala.

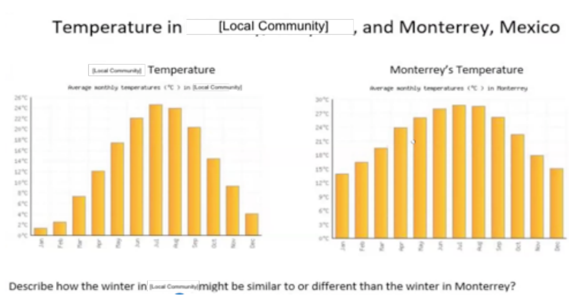

Image 2. Scholar presentation comparing temperatures of the local community and in Mexico.

Scholars were also able to identify and integrate not only the aforementioned STEM content standards, but other K-12 content standards into their presentations. With assistance from the Institute staff, they created content appropriate for specific grade levels of their choice. For example, the Scholars were able to incorporate Common Core State Standards for English Language Arts (2010) by presenting typed questions in the virtual field trip that children could read and answer (CCSS.ELA-LITERACY.SL.3.3). These questions served three purposes: encouraging future K-12 student comprehension through making self-to-text and self-to-world connections; addressing Semken's (2005) recommendations for teaching Geoscience; and facilitating inquiry learning as directed by the NGSS (Wright & Gotwals, 2017).

Objective 2. Highlighting Scholars' Funds of Knowledge and Cultural Assets as Future Teachers.

The second objective, highlighting the Scholars' funds of knowledge and cultural assets, appeared successful as scholars integrated their home communities and cultures in virtual field trips and presentations. Due to the fact that Scholars were able to choose the place of focus for their virtual field trip, each chose a place associated with their family's cultural and/or indigenous roots. They integrated personal photos from the place and researched topics of interest based on their own experiences or the experiences of their family members. One Scholar shared a picture of his grandfather in a *plaza*. He then explained that plazas hold an important significance to the Latinx community as a location to gather and socialize as well as buy and sell goods. The Scholars took great efforts and pride to create a virtual field trip that highlighted their chosen place in meaningful ways. They expressed excitement in sharing their passions for their places with instructors and with others.

Figure 2

Images by Scholars using Google Street View

Image 3. Scholar presentation embedding Google Street View of street with his grandfather in view.

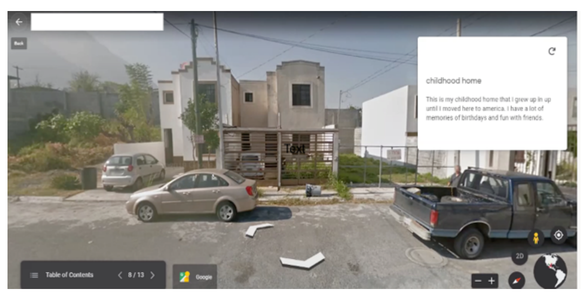

Image 4. Scholar presentation embedding Google Street View of the elementary school he attended.

Discussion and Implications

Overall, the implementation of a STEM educational experience, attended by two CAMP Scholars enrolled in a university in education fields, to develop a virtual field trip during a STEM Institute appeared successful. However, after analyzing the data, we have recommendations for future STEM Institutes serving college level students enrolled in CAMP or with similar background experiences. The first recommendation is to provide technological assistance. The second recommendation is to ensure responsive, explicit instruction, as well as independent work time.

Recommendation One: Provide Technological Assistance

Successful STEM Institutes that serve CAMP Scholars should provide strong technological assistance in addition to providing content knowledge. The opportunity to practice and develop the required skills to share this knowledge with others through the efficient use of technology is an essential component of STEM Institutes and STEM education (Montero-Fleta, 2017). Throughout this STEM Institute, it was discovered that CAMP Scholars needed technological assistance beyond those associated with creating virtual field trip projects. For example, assistance was provided to find images online; understand and adhere to copyright laws; download documents and organize folders; create and save YouTube™ videos; create voice recordings; and create and utilize tables. CAMP Scholars also benefited from a focused introduction to online resources relevant to STEM and cultural content.

Recommendation Two: Responsive, Explicit Instruction and Work Time

STEM education is an integration of disciplines to present a solution process with current tools and technologies (Kennedy & Odell, 2014). Therefore, a successful STEM Institute requires students to grapple with understanding and applying new academic content and unfamiliar, innovative technology. STEM Institute facilitators need to be responsive to the needs and interests of the participants. Instructional content must be planned in an ongoing manner to effectively respond to these needs and interests. These needs may span across areas such as academic content, technology, clarifying ideas, goals, and project purpose. One approach that provided collaboration between the facilitators and the CAMP Scholars was to have the Scholars develop a list of resources that they wanted to gather along with information that they wanted to present to bring their presentation to life. The facilitators then shared possible resources with the Scholars to enhance the project. The Scholars were also given time to work independently and then share their progress for direct feedback as well as ask questions. The combination of these strategies created space and opportunity for learning STEM content and technology and the nuance of its application.

Limitations and Conclusion

The STEM Institute facilitators, CAMP Scholars, and key stakeholders who viewed virtual field trip presentations reported on a survey afterward that the virtual field trips were well designed and presented. We also found that the STEM Institute was promising in meeting the stated objectives. Still, there was room to contemplate improvements. First, it would be helpful if the Institute was extended over the course of two weeks rather than one week to balance and enhance the introduction of STEM content and technology. Additionally, due to the level of support with technology required by the CAMP Scholars, compounded by difficulties created by distance requirements of COVID-19, it would be beneficial to hold the STEM Institute in person rather than virtually to enhance the professional learning community connectedness. In-person dialogue may have also allowed for more comfort in the sharing of students’ funds of knowledge and cultural assets with the entire group. The STEM Institute is planned to be offered in-person in future sessions with additional CAMP Scholars taking part as our recruitment increases the number of participants.

It is vital that we continue to increase the access and attainment of higher education to historically underserved populations in the United States. This has implications for underrepresented populations in other countries as well. In addition, it is important to recruit with and promote the STEM field occupations to underrepresented populations. Opportunities to participate in effective STEM activities throughout elementary and secondary education can play an important role in the future decision to work in STEM related fields. We feel STEM Institutes for teacher candidates may develop their comfort in STEM area content and pedagogy, which, we hope, can improve their STEM work with future students and encourage future generations to choose STEM careers.

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Nina Soto Ramirez, the Project Director for the USDE CAMP at Salisbury University, graduated from Pennsylvania State University. She has a rich history of supporting seasonal, migrant, and temporary workers gain access to higher education in the northeastern United states.

Alejandro Tovar, the Recruitment Specialist for the USDE CAMP at Salisbury University, graduated from Adams State University. As an alumnus of the USDE CAMP, he is a dedicated advocate working to improve the working and living conditions of agricultural workers across the country through educational opportunities.

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Appropriating the Next Generation Science Standards in Secondary Science and Engineering Education Contexts in China

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Abstract

This paper discusses how recent developments related to secondary science education focused on engaging students in both science and engineering in the United States (U.S.) can be appropriated in China. The discussion begins by describing important features of the Next Generation Science Standards (NGSS) related to science and engineering practices and the corresponding appeals of Compulsory Education Middle School Science Curriculum Standards (CEMSSCS) in China. This is followed by the explanation of how the NGSS can be understood and leveraged in interrelated and important ways that are consequential for STEM teaching and learning. Then, an example of how an Earth science teacher in a Chinese high school is provided to help demonstrate how the NGSS could be applied in Chinese classrooms and what further considerations might be given to integrating engineering into Earth science classrooms. Finally, this brief consideration of the NGSS in Chinese contexts concludes as attention is given to some obstacles to this approach.

Keywords: secondary science education, NGSS in China, engineering practices, STEM, talk moves

Beginning from the publication of *A Framework of K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012) (subsequently referred to as the Framework), the compendium document that supported the development of the *Next Generation Science Standards* (NGSS) (NGSS Lead States, 2013), a new approach to science teaching and learning was proposed. In this, three-dimensional learning was envisioned that involved an integrated focus on engaging students concurrently in science and engineering practices, crosscutting concepts, and disciplinary core ideas. More specifically, three-dimensional learning has been defined as students engaging in science and engineering practices to use disciplinary core ideas and crosscutting concepts to explain phenomena or solve problems (Krajcik, 2014). Subsequently, the NGSS was developed around three-dimensions with the important aim of engaging students in more authentic representations of science that is both more coherent day-to-day in classrooms and year-to-year across their K-12 education. Guided by NGSS, learning is situated in the problem space of explaining events that happen in the world or solving problems of consequence so that *knowledge in use* is prioritized as students apply science and engineering ideas and practices in meaningful STEM pursuits. Explicit in the Framework, a coherent and consistent approach throughout grades K-12 is key to realizing the vision for science and engineering education embodied in the framework. More specifically, students, over multiple years of school, actively engage in science and engineering practices and apply crosscutting concepts to deepen their understanding of each field's disciplinary core ideas and knowledge production practices (NRC, 2012).

Desired State of Incorporating the NGSS

This new vision of teaching and learning in the NGSS not only reimagines how students learn about and use science concepts, while also focusing on integrating engineering experiences for learners in classrooms, it consequently redefines collaborations within teacher groups. More specifically, the NGSS affords educators working collaboratively in professional learning communities an opportunity to reflect on their teaching and curriculum to consider how they might re-design a curriculum that positions them to elicit and build upon student ideas and sensemaking over time. In this, teachers identify phenomena that can be investigated and explained with science practices or problems that can be resolved with engineering practice in ways that will support students in engaging in science and engineering practices to work at knowing through the application of crosscutting concepts and disciplinary core ideas.

At least with respect to re-envisioning science learning experiences in classrooms, this vision for teaching and learning outlined in the Framework and the NGSS corresponds to educational commitments in China, even as we realize how shifts aligned to the NGSS in China are constrained by, among other things, demands related to high-stakes standardized testing. More specific to the educational commitments in China, in 2011, the *Compulsory Education Middle School Science Curriculum Standards* (CEMSSCS) was published, which highlighted the importance of developing students' scientific literacy by engaging students in science curricula that positions them to "[k]eep curiosity and the thirst of knowledge about nature phenomenon, through science inquiry experience, frame a holistic understanding of nature and view the world through a scientific lens" (CME, 2011, pp. 10-12). Researchers in China have previously identified the alignment between NGSS and CEMSSCS in relation to the overall approaches of the standards (Ming-quan, 2011), developing evaluations (Cai & Ma, 2015), and the urgency of demanding for change (CME, 2011, pp. 59-60). However, to date little attention has been paid to integrating engineering into science classrooms. Instead, the discussion has been kept to refining and reintroducing new methods in science learning and teaching.

Yet, even with some researchers identifying the congruence between the NGSS and the CEMSSCS, many of the particulars related to teaching or the facilitation of sensemaking experiences for learning in science classrooms envisioned by the NGSS are left unexplained, while engineering has not yet been considered as an integrated enterprise in science classrooms in China. Additionally, given this we outline three areas related to teaching and learning environments that we think can serve as either intersections between the commitments found in the NGSS and the CEMSSCS or that can support and extend the CEMSSCS commitments: preparing more connected and coherent instructional materials, engaging students in situational learning, and supporting student sensemaking.

Preparing More Connected and Coherent Instructional Materials

Around the world, there is a consistency across disciplines in how instructional materials are designed to connect learners to the disciplinary core ideas of each discipline (e.g., Earth science, chemistry, biology) in ways that are understandable to students. The differentiation that comes in how disciplinary core ideas are made accessible to learners across contexts internationally, nationally, and locally arises from how teachers take into consideration and personalize instruction that is attuned to students' local, place-based, and globally situated prior experiences and knowledge. This focus on prior experiences and knowledge as an important stepping stone for learning necessitates moving away from traditional lecture-based instruction, since it is recognized that learning involves constructing knowledge by supporting learners to make connections between those ideas previously learned in school and in everyday life to new ideas as attempts are made to apply and refine the connections between ideas and evidence in a meaningful pursuit (e.g., explaining phenomena and solving problems). This focus on recursively trying out and refining the application of ideas over time also more closely aligns with what scientists, engineers, and other STEM professionals (e.g., mathematicians) do as they construct and critique explanations of how things happen in the world (Ford, 2008) and develop solutions to problems (Cunningham & Kelly, 2017).

Given this reframing of learning, attention has been paid in the U.S. in connection to the NGSS to reconstructing instructional materials. More specifically, science educators create units that position students to explain a complex phenomenon or solve a problem. These phenomenon-based units engage students in answering a central driving question through engaging in a series of sensemaking practices (e.g., planning and carrying out investigations, developing and using models, and designing solutions to problems). The coherence of the instructional materials, where coherence is understood as a set of activities (e.g., investigations or readings) aimed at resolving uncertainty in relation to questions or problems, supports both students' understanding of science ideas (i.e., disciplinary core ideas, cross cutting concepts) and practices (i.e., science and engineering practices) and how they are used to construct knowledge or solve problems. In this view of teaching and learning, teaching is reframed so that teachers move away from considering how to teach one complex idea in isolation, and instead consider how anchoring a unit of instruction around explaining a phenomenon or solving a problem over multiple days by engaging in sensemaking experiences supports students in learning scientific ideas as they apply them to resolve some uncertainty highlighted by the central driving question of units of instruction. In the end, these types of instructional materials help students build an interconnected web of knowledge that is grounded in a more accurate representation of the scientific and engineering enterprises, especially in relation to how knowledge in science is constructed and refined over time, how engineering problems and solutions are intrinsically and systemically entangled in sociotechnical relationships between people, communities, and the built environment (McGowan & Bell, 2020), and how they might responsibly participate in the enterprises of science and engineering specifically and STEM more broadly.

Engaging Students in Situational Learning

The Framework emphasizes the importance of a focus on a more engaging learning environment in science classrooms, by explaining how "students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined" (NRC, 2012, p. 218). Closely connected to how we described the importance of coherence in connection to phenomena and problems, since the release of the Framework and the NGSS in the U.S., engaging students in situational learning like explaining phenomena (e.g., why the hurricane season of 2017 was particularly devastating in the U.S. in comparison to years past) or solving problems (e.g., ways to understand and propose solutions to the disproportionate impact of COVID-19 on racial and ethnic minority populations) has been emphasized. While this may seem like a problematic shift to undertake in China, especially in the context of Chinese science classrooms that are densely concentrated with concepts, such a shift toward emphasizing real-world phenomena or problems to explain or solve is necessary if teachers expect to promote students' scientific literacy and consider the possibility of a more integrated science and engineering curriculum. Here, situational learning that uses explaining real world phenomena or solving societal problems of consequence as the problem space for learning, are important since it affords students the opportunity to connect their prior knowledge and experiences outside of the classroom to learning inside the classroom. Additionally, the focus on life-connected, naturally occurring phenomena and problems are already well-aligned with approaches of the contemporary standardized exams-based educational system in China. More specifically, numerous science exam questions are based on real-world scenarios or cases that require students to apply science ideas in context. In the end, the situated learning emphasized in the Framework and the NGSS provides a promising approach for supporting educators in China in enhancing their students' ability to draw connections between classroom learning and their everyday lives, while concurrently preparing them for an exam that is already oriented to real-world scenarios.

Supporting Student Sensemaking

In *Ambitious Science Teaching* (AST) (Windschitl et al., 2018), the authors dedicate a large number of chapters to explaining how students' ideas and thinking can be made explicit as one way of accomplishing the aims of the Framework and the NGSS in the U.S. As part of AST, the importance of students publicly representing and refining their ideas over time is emphasized. Typically, this is accomplished as students develop and revise models (i.e., their pictorial and textual explanations of phenomena), either through the use of posters or digital media (see Figure 1), or by creating public representations summarizing what they have learned across a unit (see Figure 2). Related to AST, when considering engaging students in engineering, researchers like McGowan et al. (2017) propose a reverse-engineering model of instruction consisting of the following five steps:

1. Introduce the engineering design challenge or project. Before giving direct instruction related to the project, have students reflect on ways that everyday objects have previously solved this design challenge. Group discussions, reflection activities, pictures from home, and internet research can all support this step.
2. Allow students to design solutions to the engineering project based on their everyday observations and experiences. Encourage students to test their designs early and often, so they can identify design weaknesses and work toward better solutions.
3. After students have tested their designs, bring the class together as a whole group and ask students to identify what worked in their solutions. Engineering discussions often focus on learning from failure, but we found that project-related science principles also emerged from the working parts of students' designs. Scaffold a whole-group discussion to help students connect their solutions to related science concepts.
4. If there is time, allow students one more opportunity to redesign and test their engineering projects using the newly defined science principles. We found that students improved their projects when they were able to combine their everyday knowledge with more general science concepts.
5. Have students share their engineering solutions through a final design challenge or gallery walk. During this time, ask students to explain how they used both everyday and scientific knowledge to meet their engineering design goals (pp. 68-69).

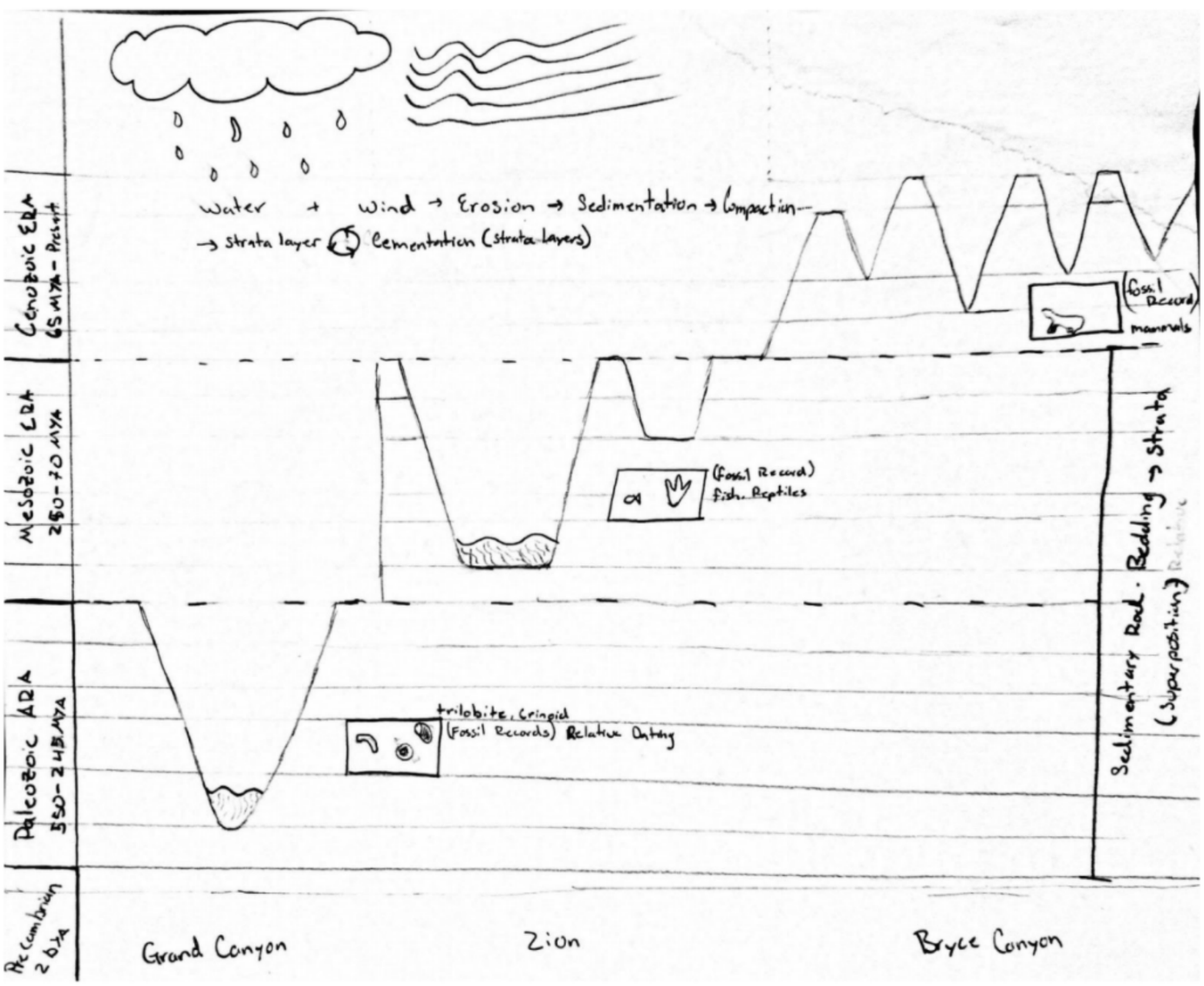
In this model, like in AST, it is apparent that learning is envisioned as a recursive or iterative process that supports students both in learning science and in engineering disciplinary concepts and practices. In addition, as with AST, a public representation (see Figure 3), can support learners by eliciting students' prior knowledge before starting design challenges, while also supporting learners to make connections between their everyday experiences and science concepts as they are engaged in engineering design. While this is possible in many U.S. classrooms, especially with class sizes that range from an average of 15-25 students, this might prove to be problematic in classrooms in China where in middle or high schools the class sizes are between 30 to 50 students. To address these challenges, we believe one approach could be to initially focus on eliciting and supporting students to share and refine their ideas and proposed designs verbally using teacher "talk moves." In the U.S., researchers like Michaels and O'Connor (2012) have introduced the following talk moves to support sensemaking in both science and engineering tasks:

- Individual students share, expand, and clarify their own thinking.
  - Can you say more about that?
- Students listen carefully to one another.
  - Who can rephrase or repeat that?
- Students deepen their reasoning.
  - Why do you think that?
- Students think with others.
  - Can anyone take that idea and build on it?

Through the use of talk moves like these proposed by Michaels and O'Connor, students' ideas are elicited, connected to those of other classmates, and refined in a classroom environment where students feel comfortable expressing themselves. Strategies like these elevate the importance of student sensemaking and can help transform science classroom learning experiences in China where limited space has traditionally been afforded for collective sensemaking.

Figure 1

An example of a model created to explain why there are different rock layers across the canyons of the Grand Staircase in the Colorado Plateau in the U.S.



Note: This example model was used with permission from Model Based Inquiry (MBI): http://modelbasedinquiry.com

Figure 2

An example of a public representation summarizing what students learned across a unit of instruction

Activity	What we learned	How it helps us explain the phenomenon
Geological Timeline	The Earth is 4.6 billion year old, but evidence of multicellular life is contained within the last 500 million years.	The Grand Staircase provides evidence of 1.7 billion years of Earth's 4.6 billion year history
Who's on First	Relative dating is the method scientist use to know the ages of layers relative to each other. Index fossils are widespread, abundant, and only existed for a limited time, which makes them useful markers for different time periods. The law of Superposition states that younger rocks are at the top and older rocks are at the bottom.	Relative dating is the method geologists use to know the approximate ages of the canyons. The layers at the bottom of the Grand Canyon are the oldest at 1.7 billion years old and the top of Bryce Canyon is the youngest at 1.8 million years old.
Build a Grand Canyon	Different depositional environments lead to the formation of different types of rock layers.	Each layer of the Grand Staircase is linked with a specific past environment which can be used to explain its geological history. The Colorado Plateau has gone back and forth between a number of different environments including ocean, deserts, and lakes and rivers.

Note: This summary table example was used with permission from Model Based Inquiry (MBI): http://modelbasedinquiry.com

See Figure 3 on the following page—Ed.

Figure 3

An example of student responses on the reverse engineering chart (McGowan et al., 2017, p. 70)

Challenge	Personal Experience	What Worked?	Science Concepts
Stay Between the Lines	Gliders turn slower than bikes. It is easier to make a glider go straight.	We removed the front axle so that car could not turn as fast.	A go-kart needs balanced forces to go straight.
Make a Turn	Turning the handlebars on a bike or scooter also turns the front axle.	We made the go-kart turn when we tightened one rubber band more when we were winding it up.	Unbalanced forces make a go-kart turn.
Bust a Barrier	When I ride my bike downhill and hit a fence, the fence falls over. My bigger toy car can knock down barriers, but not my smaller one.	We added books to the go-kart to make it heavier and wound the rubber band tighter so it would go faster.	The amount of force an object has is related to how heavy it is and how fast it is moving. $F = ma$
Go the Distance	Bikes for grown-ups have bigger wheels and go faster than bikes for kids.	If the wheels are bigger, the bike goes farther.	Bigger wheels cover more area with each rotation.

An Example and Extension of an Earth Science Teacher in China

From the personal experience of the first author, a focus on strategies outlined above and aligned with the Framework and the NGSS could enhance the traditional way science and engineering is experienced in classrooms in China. An Earth science teacher in the Hangzhou First High School, who has been teaching Earth science for over 20 years, has in many ways accomplished the goals of the Framework and NGSS in her classroom in ways that can provide an example of how others might support students to develop and critique explanations of how things happen in the world. Students who have graduated from her class maintain a profound interest in Earth science even as they pursue different university majors outside of Earth science. Moreover, students from her class still remember what she taught about Earth science during their three years of high school. From the author's perspective, through a few main approaches, she provided opportunities for her students to find success in Earth science. She provided stories and details when explaining Earth science concepts and linked them to natural phenomena that were happening or had historically happened in the world. For instance, when the temperature decreased suddenly in winter and students in her class complained about the chilliness outside, she took advantage of the chance to enhance students' understanding of how a cold front followed by a warm front created a phenomenon of temperature rising at the beginning initially, before dramatically decreasing. She also incorporated other potential weather conditions in these situations, when she helped students think about what might happen when different amounts of humidity were in the air at the time. She engaged students in sensemaking discussions with questions. As an example, she asked students to predict what would happen when the air contained more water or less water vapor as the cold front proceeded to the warmer front. Through this, students recognized how increased humidity during warmer temperatures would lead to precipitation in the form of rain or possibly hail, while increased humidity in colder temperatures would lead to sleet or snow. The entire sensemaking experience was facilitated through verbal interactions similar to the talk moves described by Michaels and O'Connor (2012). In these sensemaking sessions the teacher helped students make connections between what students previously experienced and knew to new Earth science concepts introduced in classes (e.g., cold and warm fronts) to explain weather events. This example indicates that it is possible to integrate NGSS into secondary science education in China.

Conversely, the first author could not recall experiences engaging in engineering-related practices as a student in high school in China. Given this and connected to our proposed consideration of integrating science and engineering instruction, one possible extension to engage students in engineering design are considerations of the complex and significant interdependencies between humans and the Earth's systems. As an example, this could involve learners exploring pollution data locally or across the globe and proposing solutions for mitigating the disproportionate impact of pollution on more vulnerable populations. An introduction to the immediate issues of air pollution in India and a small example data set for starting such discussions could come from reviewing public media articles like the following:

- Polluted Air Cuts Years Off Lives of Millions in India, Study Finds (https://www.nytimes.com/2015/02/22/world/asia/polluted-air-cuts-years-off-lives-of-millions-in-india-study-finds.html)
- Who Gets to Breathe Clean Air in New Delhi (https://www.nytimes.com/interactive/2020/12/17/world/asia/india-pollution-inequality.html)

Here, it is envisioned that students in Earth science classrooms might consider designs or proposed policies that can be considered based on their personal experiences they may have encountered trying to mitigate exposure to pollution in their community, propose or explore existing designs locally, and then work to connect what they learned might be effective in mitigating pollution to explanatory science ideas like their understanding of the Earth's atmosphere, which can help to explain the soundness of proposed approaches. In the end, we recognize that there are some foreseeable obstacles that we consider next to the kind of teaching and learning outlined in the Framework and the NGSS when contemplating whether these shifts are attainable in Chinese classrooms.

Current Challenges and Obstacles to Implementing Visions from the NGSS in China

The lack of professional development and high-quality resources or curricula are foreseeable obstacles for appropriating the NGSS in the secondary education context in China. Secondary science teachers in China are not familiar with NGSS. They, like their students, are under strict pressure from the standardized exams, which might prohibit them from investing time and resources in learning more about the NGSS in the U.S. or other trends in science or STEM education across the globe. In the U.S., researchers like Penuel and Reiser (2018) recognize that ambitious aims of transforming science (and engineering) instruction in classrooms will likely fall short if professional learning opportunities for teachers are not coupled with high-quality curricula designed specifically for supporting NGSS implementation. We believe the same case can be made about the prospect of shifts in science and engineering teaching and learning in China. Specifically, limited time combined with a lack of professional learning anchored in curricula that can be subsequently used in classrooms will likely stymie any similar ambitions in secondary education contexts in China. In the end, while researchers have compared curriculum and education standards in science between the U.S. and China (e.g., Cai & Ma, 2015; Ming-quan, 2011), none have unpacked what it might take in terms of teacher professional development and high-quality curricula.

Conclusion and Implications

Many of the compelling shifts called for in the Framework and the NGSS correspond to educational appeals in China. *The Compulsory Education Middle School Science Curriculum Standards* (CEMSSCS) highlighted how when aiming at developing students' scientific literacy, science curricula should allow students to "[k]eep curiosity and the thirst of knowledge about a natural phenomenon, through science inquiry experience, frame a holistic understanding of nature and view the world through a scientific lens." (CME, 2011, pp. 10-12) Research studies in China have compared and discussed the urgency of drawing on the commitments found within the NGSS to consider changes that might be beneficial in the educational system in China (Cai & Ma, 2015; Ming-quan, 2011). This paper further examined nuanced details previously not discussed including an integrated approach to teaching science and engineering in science classrooms and how to appropriate the following three important commitments of the NGSS in the context of China: preparing more connected and coherent instructional materials, engaging students in situational learning, and supporting student sensemaking. This was followed by an example by an Earth science teacher in a Chinese high school who related it to what the NGSS might look like in the Chinese secondary education context. Ultimately, although there are foreseeable obstacles, we believe the potential of appropriating the NGSS to the secondary science education context in China is promising and has the potential to better support a more engaging experience for students in science in Chinese classrooms.

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