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ASSISTing with STEM Education: Promoting Argument-based Strategies for STEM Infused Science Teaching

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Abstract

Science teachers are faced with an ever increasing list of requirements in helping students develop true science literacy. In addition to focusing on developing conceptual understanding, use of science and engineering practices, communication skills, and an appropriate view of the nature of science, STEM initiatives now encourage teachers to integrate mathematics, engineering, and technology into their science instruction. The Argument-based Strategies for STEM-Infused Science Teaching (ASSIST) approach attempts to provide both an overall framework and practical tools to help science teachers accomplish the many goals associated with engaging students in effective science learning environments. In this article, we present a brief description of the research supported ideas that provide the framework supporting the approach, as well as an overview of some of the tools we have developed with teachers to help them implement the approach. We conclude by describing some initial reactions from these in-service teachers with whom we have worked in professional development activities. These reactions are included as a way to highlight benefits and challenges associated with the approach, as well as suggest future work.

The growing momentum promoting the integration of science, technology, engineering, and mathematics (STEM) is unmistakable (ACT, Inc. 2014). The reasons for encouraging integrated STEM education are numerous. For some proponents, advocacy results from a desire to increase interest in STEM related careers, while for others, the goal is more aligned with improving the general abilities of all students to understand complicated, multi-faceted real world problems (Asghar, Ellington, Rice, Johnson, & Prime, 2012; Becker & Park, 2011; Glancy & Moore, 2013; Vasquez, Sneider, & Comer, 2013). Regardless of the specific intent, the emphasis on STEM education has led to a variety of initiatives, programs, curricula, seminars, and other resources. While this focus on STEM education certainly has led to improvements in educational experiences for students of all ages, it can also prove daunting and overwhelming at times for teachers. In this article, an overall teaching approach is presented that attempts to provide teachers with a framework that can be applied to the development of any targeted science concept and promotes an integrated STEM perspective. After describing the research supporting the approach, some of the tools that have been developed through work with practicing teachers to help implement the approach will be described. Finally, some initial reactions from teachers who have utilized the approach will be provided as a way to point out benefits and challenges associated with the approach, as well as suggest future areas of inquiry.

Overview of the Approach

The Argument-based Strategies for STEM Infused Science Teaching (ASSIST) approach is built on several research-supported areas. In this section, a description of the overall intent of the approach will be provided, followed by an overview of the research-supported characteristics framing the approach. Finally, the specific characteristics of the approach will be presented.

STEM Perspective

As previously mentioned, the perspectives supporting STEM education are numerous and varied. No single, universally accepted definition exists that adequately summarizes what STEM education involves. In working with in-service and pre-service educators, as well as surveying STEM education literature (Akaygun, & Aslan-Tutak, 2016; Breiner, Harkness, Johnson, & Koehler, 2012; Becker & Park, 2011; Vasquez et al., 2013) several categories have emerged to describe differing conceptions of what STEM education involves. These categories are presented in Table 1 below.

Table 1. Overview of Emerging Categories of STEM Education

STEM Perspective	General Intent and Philosophy of the Perspective
STEM "Umbrella"	STEM education involves educational activity within any one of the STEM disciplines. Often, efforts at improving undergraduate STEM education are focused on one specific STEM discipline (for example biology) and are identified as STEM because the discipline is one of the four STEM areas.
STEM "Integration"	To be considered STEM education from this perspective there must be purposeful integration of at least two of the individual STEM disciplines. Several variations of STEM integration perspectives exist.
Problem-based	A STEM problem-based perspective promotes the engagement of students in authentic, real-world problems. The overarching goal is to develop solutions to the problem. Ideally, specific understanding in science, mathematics, technology, and engineering are improved through engagement with the problem, but no specific conceptual development frames instruction.
Engineering focus	Engineering focused STEM has instruction starting with an engineering challenge. As students attempt to create a product or process to meet the challenge, they also develop understanding of science, mathematics, and technology that are related to the challenge.
Technology focus	Technology focused STEM education typically involves coding, robotics, or some other technological application. Students engage with technology as a motivating setting for interaction with STEM concepts.
Science focus	A targeted science concept or "big idea" is the specific intent of instruction. Students engage in the use of mathematics and technology to better understand the science concept and are asked to apply scientific understanding in an engineering context.

The ASSIST approach, although applicable to any of the perspectives above, is most directly connected to the Science focus STEM Integration philosophy. The overarching goal is to engage students in rich, argument-based learning environments that encourage the development of understanding of key science concepts through the use of science practices. However, emphasis is placed on the awareness (ideally from the instructors who plan classroom activity as well as from students who are engaged in the classroom activity) that true development of a deep understanding of fundamental science concepts necessitates use of mathematical principles, engagement with technology, and the ability to apply scientific understanding to develop products or processes. Therefore, while targeted science concepts drive instruction, purposeful and meaningful integration of the other STEM disciplines becomes both an advocated part of the planning process and a natural outgrowth of supporting student conceptual development. This perspective aligns with the intent of the Next Generation Science Standards (NGSS, 2013) and the *Framework for K-12 Science Education* on which the standards are based. Our position is not to argue for the primacy of this STEM perspective over other viewpoints, but rather to clarify the specific intent of this STEM related approach.

Foundational Aspects of ASSIST

The ASSIST approach is framed on three areas of emerging and on-going research: argument-based instruction, multimodal communication, and characteristics of STEM learning environments. In this section we briefly describe how each area has influenced and is represented in the overall ASSIST approach.

Argument-based Instruction

The core of the ASSIST approach is the argument-based instructional approach known as the Science Writing Heuristic (SWH). The SWH is a research-supported framework for developing classroom learning environments in which students use science practices as epistemological tools to develop understanding of science concepts (Hand, 2007). Overarching understandings referred to as "big ideas" are developed and clarified as students answer questions about the natural world through collecting data and observations as a part of student designed tests. The critical aspect of the approach is the development of claims, supported by evidence, to help answer the driving questions. Students engage in both personal and social negotiation to support and refute claims as a mechanism for explaining the natural world. These student generated claims are compared to sources of "expert" information as a further clarifying step. Finally, student reflection on their learning is encouraged to help summarize the overall learning that has taken place (Hand, Norton-Meier, Staker, & Bintz, 2009; Norton-Meier, Hand, Hockenberry, & Wise, 2008). Importantly, students are continually asked to justify and provide a rationale for the questions they seek to answer, the testing processes they employ, and the claims and evidence they provide (Hand, Cavagnetto, Chen, & Park, 2016). This framework can be applied to development of any targeted science concept.

Multimodal Communication

A second research-supported aspect emphasized in the ASSIST approach is the purposeful use of multimodal communication. Scientists consistently engage in communication with various audiences and for a multitude of purposes (National Research Council, 2012). This communication is enhanced through the use and integration of different modes of representation (text, diagrams, charts, graphs, etc.). For scientists, the process of representing scientific information with different modalities is not only a tool for effective communication to outside audiences, but also a tool for clarifying and further developing their own understanding of nature (McDermott & Hand, 2013). Engaging students in this type of multimodal communication not only models the type of communication scientists engage in, but also has been shown to improve student understanding (McDermott & Hand, 2015). Investigations of classroom tasks in which students utilize multiple modes to communicate about science concepts have indicated that greater degrees of integration in student writing tend to be related to greater student understanding. Instructional approaches that help students develop strategies for linking multiple modes of communication together lead to improved student understanding (Gunel, Kingir, & Aydemir, 2016). The ASSIST approach encourages instructors to develop methods for helping students realize the benefit of communicating in this way about science as well as ways to infuse this type of communication throughout the SWH sequence previously described.

Characteristics of STEM Learning Environments

As the momentum for STEM education has grown nationally and internationally, some research initiatives have begun to focus on identifying critical components of effective STEM learning environments. A summary of the characteristics identified through various investigations of STEM learning environments (LaForce, Century, Noble, Holt & King, 2013; Yager & Brunkhorst, 2014) that have demonstrated positive student results and are advocated in the ASSIST approach include a focus on cognitively demanding tasks, curriculum developed by the teachers who will use it, and the development of inter-disciplinary teams. In addition, student activity is focused on authentic, real-world problems that encourage student collaboration and use of technology.

Overview of the ASSIST Approach

The aforementioned foundational areas have formed the theoretical underpinning of the ASSIST approach, as well as informing the development of the practical aspects of what the approach looks like in a classroom. Figure 1 below provides a summary of the current vision of the approach.

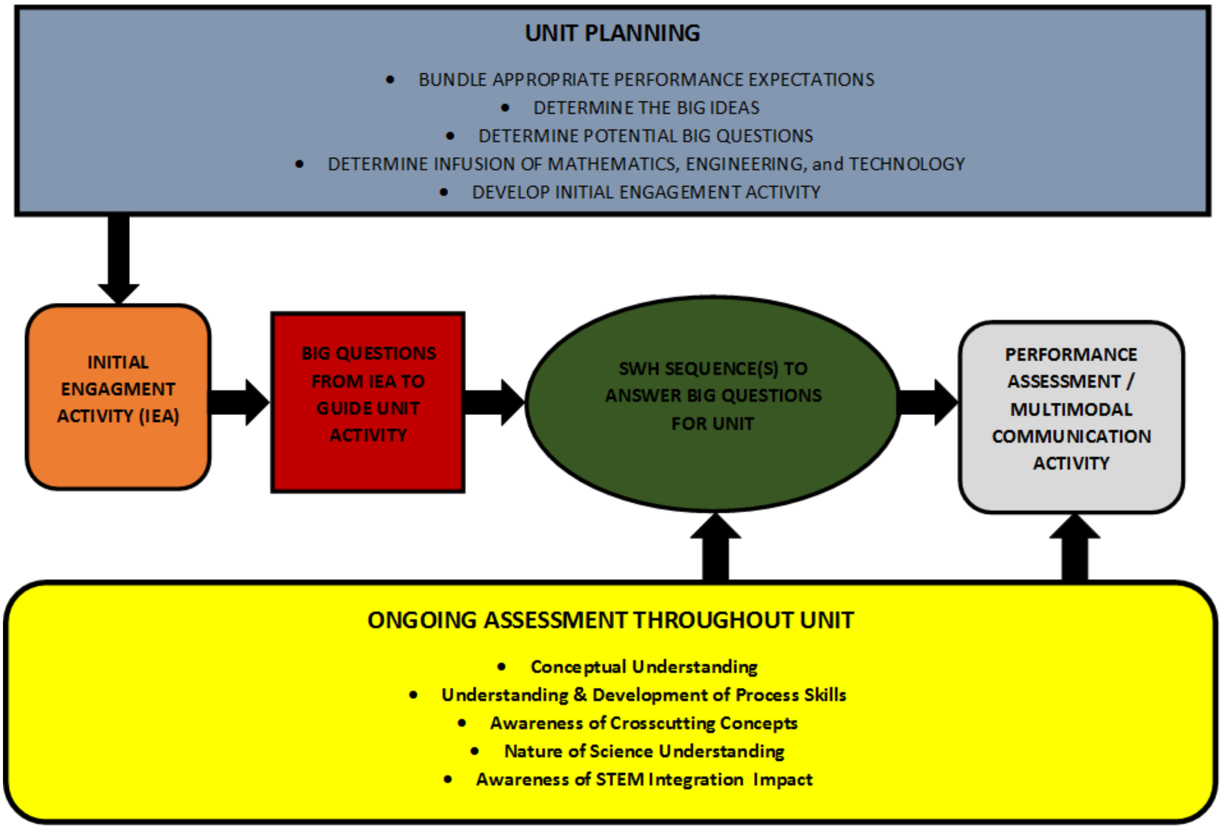

Figure 1. Overview of Aspects of the ASSIST Approach

The middle row in Figure 1 consisting of the four separate shapes demonstrates the classroom activity that is encouraged throughout a cohesive instructional sequence or unit. Ideally, students are engaged in some activity or event that results in questions related to the targeted unit concepts or big idea. These questions can then be answered, as scientists would answer questions about nature, through the utilization of the SWH characteristics (tests, observations, claims, and evidence). Ideally, as classroom activity progresses, opportunities for STEM integration, for argument and negotiation, and for multimodal communication are capitalized on. Ultimately, the student understanding that is developed will be demonstrated through some sort of performance assessment or through the development of a multimodal communication piece. In this way, not only does the student experience a summative event in which they are able to truly reflect on how their overall understanding has progressed and changed, but the teacher has an opportunity to assess student conceptual and procedural understanding.

While the overarching goal of the ASSIST approach is to encourage this type of immersive, argument-based learning environment (Hand et al., 2016), recognition exists that teacher planning to develop this sort of classroom situation is necessary, and is often quite challenging. The top blue rectangle in Figure 1 summarizes the key areas of consideration teachers are encouraged to focus on in their planning prior to the classroom activity. Importantly, teachers are encouraged to start with Performance Expectations (PE) from the NGSS and bundle these to develop overarching "big ideas" that are the focus of instruction. For example, several PEs related to Newton's laws of force and motion could be bundled and summarized in a big idea such as "forces impact motion". Further development of the big idea becomes the focus of student activity. From a planning perspective, the instructor is then encouraged to consider what type of Initial Engagement Activity (IEA) could be developed that would allow for the big idea to emerge and would encourage the development of authentic student questions, related to the big idea, that could drive student activity in the unit. Teachers are also encouraged to anticipate the types of student questions that would likely emerge from this IEA as a way to consider what sorts of SWH sequences could potentially occur in the unit and what materials would be necessary to carry these out. Finally, teachers are encouraged to consider where they can infuse activity related to the other STEM disciplines within this learning sequence, as well as what type of summative experience students will engage in. Figure 2 summarizes the sections in the general unit planning template we have developed for the ASSIST approach. For teachers who feel guidance in more specific areas would be helpful, we have also created supplemental tools, including a tool to help develop big ideas, a tool to help develop the IEA, a tool to help develop SWH sequences of activity, and a tool to help develop multimodal communication tasks.

The final area of emphasis in Figure 1 is assessment. Engaging students in the ASSIST approach offers numerous opportunities for assessment of all aspects of science learning. Again, however, taking advantage of these opportunities can be difficult. Therefore, we have developed tools as a part of the ASSIST approach to provide some guidance for teachers in the assessment process. As indicated in Figure 1, our goal is to provide opportunities to assess throughout the unit of study as students continually refine their understanding and as a way to help teachers make instructional decisions. Currently, in addition to providing tools to help design assessments of student conceptual understanding, we have also developed assessment tools to help in the following areas:

- Science and engineering practices from the NGSS
- Student understanding of the nature of science
- Student awareness of opportunities to engage in STEM disciplines
- Student motivation and interest in science and STEM areas

Efforts are ongoing in the development of tools for different areas of assessment and for modes of delivery of the assessment tools for teachers.

Teacher Feedback and Future Directions

An initial cohort of fifteen K-12 teachers received professional development related to developing an understanding of the ASSIST approach and then implemented at least one unit based on the approach. In addition to providing feedback related to the development of the tools presented here, this group has provided general feedback on the approach itself and the tools developed for implementation. Several areas of student benefit have been noted including:

- *Improvement in student engagement and motivation:* Student interest and level of engagement have improved as students are given greater opportunity to influence the pathway of learning and greater opportunity to interact as they develop conceptual understanding.
- *Improvement in science practices:* Students have demonstrated greater ability to effectively utilize science and engineering practices and are more able to evaluate the validity of tests and the strength of claims and evidence.
- *Improvement in literacy skills:* Not only have students improved their speaking and listening as a result of increased opportunities to argue and negotiate, they have also improved their writing skill as a result of emphasis on multimodal communication.
- *Development of healthy skepticism:* Students have developed a greater level of skepticism of the claims of others and are increasingly insistent on rigor in both the information provided by peers and information provided by expert sources.

SECTION ONE

- What Performance Expectations (PE) from the NGSS will be bundled to frame unit activity?
- What Science and Engineering Practices (SEP) from the NGSS will be emphasized in unit activity?
- What Disciplinary Core Ideas (DCI) will be emphasized in unit activity?
- What Cross-Cutting Concepts (CCC) will be emphasized in unit activity?

SECTION TWO

- What is your Big Idea for the unit?
- What is a general description of the Initial Engagement Activity (IEA) for the unit?
- What are the potential student developed questions that you anticipate will emerge from the IEA that can drive unit activity?

SECTION THREE

- What SWH sequence(s) do you anticipate taking place during unit activities?
  - What question will they answer?
  - What materials are needed for each?
  - What specific DCI, SEP, CCC will be developed?

SECTION FOUR

- What are your ideas for MATHEMATICS integration in unit activities?
- What are your ideas for TECHNOLOGY integration in your unit activities?
- What are your ideas for ENGINEERING integration in your unit activities?
- What community / external partners are available for connection to this unit?

SECTION FIVE

- What is a general description of the assessment students will engage in at the conclusion of the unit to demonstrate targeted understanding?
- What resources are helpful for carrying out this unit?

Figure 2. Overview of General Unit Planning Guide

Feedback has also indicated areas that have provided challenges for the teachers that highlight continuing areas of need:

- *Use of templates & tools:* Some teachers became predominately focused on whether or not they were filling out the tools and templates appropriately, as opposed to focusing on the implementation of the advocated teaching practices.
- *Developing initial engagement activities:* Teachers found it challenging to develop initial engagement activities that invoke curiosity in students while simultaneously providing instructionally rich material likely to lead to appropriate testing situations.
- *Facilitating negotiation and argumentation:* While teachers felt that students improved their ability to argue and negotiate effectively, the teachers struggled with providing helpful and appropriate feedback during argumentation and negotiation.

The use, development, and promotion of the ASSIST approach is ongoing. Along with the engagement with in-service teachers described above, work has also begun in infusing the approach in methods courses for pre-service teachers. As this work continues, an iterative process is in place that provides critical feedback from teachers and other users of the approach as further tools and templates are developed. This process provides the framework for future work in both the instructional and the research realms.

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