Applying STEM Instructional Strategies to Design and Technology Curriculum

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Keywords: STEM, Instructional Strategies, Silo Instruction, Embedded Instruction, Integration Instruction, Technology Education

Abstract
Proponents for STEM education argue it has potential to contribute to student learning, their lives, and global economies. STEM's promise is viewed with enough credibility that some nations have begun to adopt its principles through mandates and funding. If STEM is seen as a practical solution for future learning, then it is necessary for design and technology instructors to consider how to incorporate STEM strategies into their curriculum. The purpose of this paper is to illustrate three approaches that can be used in STEM education (*Silo, Embedded, and Integration*) and apply them within the context of a technology education course.

Introduction
As a growing trend in the academic world, STEM education is used to address real-world situations through a design-based problem-solving process, much like those used by engineers or scientists (Williams, 2011). STEM advocates argue approaching education through these strategies enables students to recognize their education as applicable and essential (Banks, 2009).

This is significant for technology education as it is presented with an opportunity to increase its validity (Kelley, 2010). Although technology education programs continue to enhance students' school experiences, they must dispute a stigma of irrelevance for those learners who desire to pursue an academic course of study (Wendy Fox-Turnbull, personal communication, October 20, 2011). To offset this vocational image, technology education instructors can increase the presence of academic content into their curriculum through including STEM, design-based learning strategies.

Three approaches for teaching STEM education are currently being practiced. The distinction between each of these methods lies in the degree of STEM content used. They include *silo, embedded*, and *integrated* approaches. Following a discussion of each of these strategies, the researchers provide an example lesson, *Infection Detection*, where each approach is applied.

The Silo Approach

The s*ilo* approach to STEM education refers to isolated instruction within each individual STEM subject (Dugger, 2010). Emphasis is placed on "knowledge" acquisition as opposed to technical ability (Morrison, 2006). Concentrated study of each individual subject allows the student to gain a greater depth of understanding of course content. This focused instruction stirs appreciation for the beauty of the content itself (Jenny Chiu, personal communication, September 27, 2011). This is how science, technology and engineering, and mathematics education been approached in curriculum design and teaching.

Silo STEM instruction is characterized by a teacher-driven classroom. Students are provided little opportunity to "learn by doing", rather they are taught what to know (Morrison, 2006). Morrison (2006) suggests the prevailing belief behind s*ilo* STEM instruction is to increase knowledge which generates judgment. An instructor operating within the confines of their discipline can produce quality instruction for students which must not be overlooked. It is propelled by mandates for students to learn content and pass tests. Figure 1 depicts the s*ilo* approach.

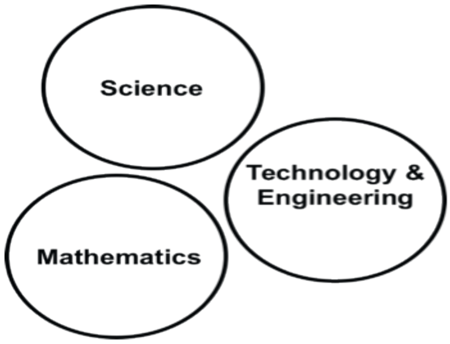

Figure 1. Silo approach to STEM education. Each circle represents a STEM discipline. The disciplines are taught separately which keeps the domain knowledge within the confines of each discipline.

There are potential shortcomings associated with a purely *silo* method to STEM instruction. First, Dickstein (2010) suggests s*ilo* instruction has the propensity to isolate prospective STEM contributors to the field. It has been observed females are less likely to participate in courses containing the word "engineering" within the title, e.g. Civil, Mechanical, and Electrical Engineering. The lack of female participation limits valuable perspectives which could enhance STEM related fields (Bour, Bursuc, & Konstantinidis, 2011).

Secondly, it is possible *silo* instruction may encourage students to maintain a segregated perception of content courses. Without practice students may fail to understand the integration which naturally occurs between STEM subjects in the real-world (Breiner, Harkness, Johnson, & Koehler, 2012).

Finally, the *silo* approach can unintentionally inhibit students' academic growth. It may tempt teachers to rely on a lecture-based methodology rather than a hands-on approach, which research indicates is more desirable for student learning (Dickstein, 2010; Deslauriers, Schelew, & Wieman, 2011). While an instructor may choose to implement a variety of teaching strategies, in a *silo* classroom, the content would likely remain the focus of study. This may limit the amount of cross-curricular stimulation and student understanding of the application of what they must learn.

The Embedded Approach

Embedded STEM instruction may be broadly defined as an approach to education in which domain knowledge is acquired through an emphasis on real-world situations and problem-solving techniques within social, cultural, and functional contexts (Chen, 2001). In practice, e*mbedded* teaching is effective instruction because it seeks to reinforce and complement materials that students learn in other classes (ITEEA, 2007). A technology education teacher uses embedding to strengthen a lesson which benefits the learner through understanding and application.

In a STEM *embedded* approach, the technology education content is emphasized (just as it would be if taught in the *silo* approach), thereby maintaining the integrity of the subject matter. Yet, *embedding* differs from the *silo* approach in that it promotes the learning through a variety of contexts (Rossouw, Hacker, & de Vries, 2010). However, the *embedded* material is not designed to be evaluated or assessed (Chen, 2002). Figure 2 depicts the *embedded* approach to STEM education.

Figure 2. Embedded approach to STEM education. Each circle represents a STEM discipline. Domain knowledge from at least one discipline is placed within the context of another. The embedded components are not usually evaluated or assessed.

Although *embedding* can be a valuable instructional strategy, there are challenges that must be considered. For example, the *embedded* approach may lead to fragmented learning (Hmelo & Narayanan, 1995). If a student cannot associate the *embedded* content to the context of the lesson, the student risks learning only portions of the lesson rather than benefiting from the lesson as a whole. Additionally, it is essential to ensure the *embedded* components are something the student has prior learning and are grade level appropriate. If the instructor has to stop and teach or remediate a student on the *embedded* knowledge, the students' learning may be disrupted (Novack, 2002).

The Integrated Approach

An *integrated* approach to STEM education envisions removing the walls between each of the STEM content areas and teaching them as one subject (Breiner et al., 2012; Morrison & Bartlett, 2009). *Integration* is distinct from *embedding* in that it evaluates and assesses specified standards or objectives from each curriculum area that has been incorporated within the lesson (Sanders, 2009).

Ideally, integration enables a student to gain mastery of competencies needed to resolve a task (Harden, 2000). Training students in this way is perceived beneficial as it is a multidisciplinary world reliant on STEM concepts, which students must use to solve real-world problems (Wang, Moore, Roehrig, & Park, 2011). Additionally, instructing through *integration* produces the expectation of increased interest in STEM content areas, especially if it is begun when students are young (Barlex, 2009; Laboy-Rush, 2010). Two common approaches to integrative instruction are *multidisciplinary* and *interdisciplinary integration* (Wang et al., 2011).

Multidisciplinary integration asks students to connect content from various subjects taught in different classrooms at different times. It relies on corroboration between faculty members to ensure content connections are made (Wang et al., 2011).

Wang et al. (2011) explain *interdisciplinary integration* begins with a real-world problem. It incorporates cross-curricular content with critical thinking, problem-solving skills, and knowledge in order to reach a conclusion. *Multidisciplinary integration* asks students to link content from specific subjects, but *interdisciplinary integration* focuses students' attention on a problem and incorporates content and skills from a variety of fields. Figure 3 depicts the *integrated* approach.

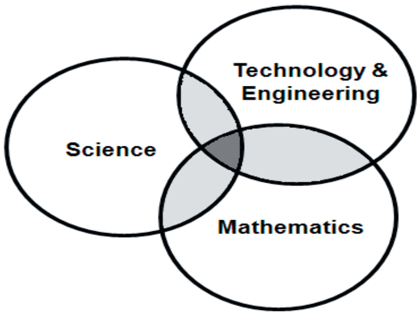

Figure 3. Integration approach to STEM education. The STEM content areas are taught as though they were one subject. Integration can be done with a minimum of two disciplines but is not limited to two disciplines. The lines indicate the various options in which integration could be achieved.

Proponents of STEM education may suggest integration is the best approach for STEM instruction (Laboy-Rush, 2011; Wang et al., 2011). However, it is important to remember individual STEM disciplines "are based on different epistemological assumptions" and integration of the STEM subjects may detract from the integrity of any individual STEM subject (Williams, 2011, p. 30). In other words, as Harden (2000) explains, "subjects and disciplines give up a large measure of their own autonomy" when working within the confines of integration (p. 555). Therefore, instructors must consider how these potential effects can inhibit the integrity of their content and decide if integration is the most beneficial method of instruction.

Additionally, instructing through integrative approaches requires pedagogical training. Teachers often struggle to instruct through integration (Williams, 2011). This may hinder students' understanding due to a lack of general structure within the lesson, a phenomenon referred to as the potpourri effect (Jacobs, 1989). In the potpourri effect, teachers incorporate material from each discipline, but they fail to create one common objective.

Perhaps even more detrimental than the potpourri effect is the polarity effect. Teachers may become territorial over specific subject matter limiting the incorporation of other content. This may lead to a lack of understanding by students (Jacobs, 1989). Careful consideration must be made when choosing the appropriate method of instruction. Each method discussed offers strengths and challenges which must be addressed when implemented.

Infection Detection Activity

This activity was designed using the International Technology and Engineering Educators Association's (2007) *Standards for Technological Literacy*. Standard 14, Medical Technologies, stipulates students will develop an understanding of and be able to select and use medical technologies. A technology education teacher would use this standard while teaching their appropriate grade level content.

In this lesson, students are told to assume the role of an immunologist and investigate a new virus which is making people ill in a remote Amazon village. They are tasked with designing a vaccine to alleviate the spread of this virus. Each team creates a portfolio containing the components listed in Table 1.

A technology and engineering laboratory using the *silo* approach emphasizes the activities centered on developing the virus model, vaccine administration devices, or the packaging. Through an *embedded* approach a technology education teacher can *embed* domain knowledge from science by exposing students to microscopic images of diseases, vaccines, and viruses or they can *embed* mathematics when students use measurement to determine the amount of vaccine to be administered, a dosage schedule for vaccine administration, or the design of a box for delivering the vaccines.

Finally, this lesson (Table 1) can become an example of the *interdisciplinary* approach if all components are taught by the technology education teacher. However, if technology education teachers were instructing through a *multidisciplinary integrative* approach, each teacher (the technology educator, science, and/or mathematics teacher) would address the same lesson through their specific course content during their instructional time period on the same day. They would evaluate and assess those learning requirements associated with their learning objectives. Table 2 illustrates the learning outcomes for the *Infection Detection* activity by grade level.

Table 1. Operation Infection Detection

	Operation Infection Detection – ITEEA Standard 14 – Medical Technologies			
	K-2	**3-5**	**6-8**	**9-12**
	Vaccinations	*Vaccines & Medicine*	*Immunology*	*Telemedicene*
	Students will create a portfolio containing the following:			
Science	Collage of items needed to care for infected people and belongings	Virus symptom card detailing virus name and symptoms	Medical disease webpage with virus name, pictures, symptoms, plan of action, vaccine information, and how to prevent additional spread	Medical disease webpage with virus name, pictures, symptoms, plan of action, vaccine information, and how to prevent additional spread
Technology and Engineering	Create a three-dimensional model of the virus within these constraints: Free standing, 6”x12” Create a prototype of a vaccine administration device	Create a three-dimensional model of the virus within these constraints: Free standing, 6”x12” Create a prototype of a vaccine administration device	Create a prototype of the virus within these constraints: free standing, 12”x12”, and placed on a structure that can be rotated so that all angles of the virus may be seen Create a prototype of a vaccine administration device	Computerized, prototype of the virus; image must rotate so that all angles of the virus can be seen, and it must be in various colors Create a prototype of a vaccine administration device Packaging for an air drop of vaccine. Limited to a box size of 2’x4’. Included in this box must be the device for vaccine administration
Mathematics	A way to measure amount of vaccine administered Three-dimensional model measurement	A way to measure amount of vaccine administered Three-dimensional model measurement	A Chart/Rubric for vaccine effectiveness Three-dimensional model measurement A way to measure amount of vaccine administered	A Chart/Rubric for vaccine effectiveness Dosage schedule A way to measure amount of vaccine administered

Note: This table summarizes a STEM activity for students in grade levels K-12 that utilized ITEEA (2007) Technology Standard 14 – Medical Technologies. It is entitled *Operation Infection Detection*. It is strongly recommended by the authors that the activity be read prior to reading through the strategies. The full detailed activity can be found by visiting the following website: www.operationinfectiondetection.yolasite.com

Table 2. Learning Outcomes for Infection Detection by Grade Levels

	K-5	*6-8*	*9-12*
		Students will be able to:	
Science	• Identify scientific characteristics of viruses • Explain how a virus infects its host	• Identify scientific characteristics of a virus to help prevent additional spread • Diagram a virus • Explain how a virus infects its host	• Identify scientific characteristics of a virus to help prevent additional spread • Diagram a virus • Explain how a virus infects its host
Technology & Engineering	• Define characteristics of Immunology • Demonstrate understanding of vaccination usage and administration tools	• Define Immunology • Demonstrate understanding of vaccination usage and administration tools • Demonstrate understanding of products and systems used to provide information about viruses	• Define Immunology • Demonstrate understanding of vaccination usage and administration tools • Demonstrate understanding of products and systems used to provide information about viruses • Define Telemedicine • Construct a plan for delivering and administering vaccines by airdrop through telemedicine
Mathematics	• Measure prototype size • Demonstrate dosage amount estimations	• Measure prototype size • Measure dosage amount	• Measure prototype size • Measure dosage amount • Create a viable dosage schedule • Apply constraint size and weight to configuration of vaccine box

Note: This table illustrates learning outcomes for the *Infection Detection* activity. Each discipline has learning requirements which can be effectively taught through any of the three approaches. Depending on the subject and approach, the appropriate grade level standards that align with the learning requirements would be identified and used in the lesson.

Conclusion

As society seeks a technologically literate and STEM proficient student, it is important to evaluate and pursue methods for delivering technology education instruction. This paper was written with the intent to provide technology education teachers with an improved understanding of STEM including three distinct STEM instructional approaches (*silo*, *embedded*, and *integration*) that can be used to enrich and differentiate the content that is being delivered. Each approach was defined, strengths and shortcomings were described, and ideas for implementing the STEM approaches were presented through the *Infection Detection* activity. Teaching any of these strategies requires technology education teachers to evaluate their content and determine how best to serve students through each approach. Although interests are forming about the significance of STEM and technology education, and steps have been made through instructional practices, additional work is necessary. The researchers suggest further studies in STEM curriculum mapping, pre-service STEM teacher education, creation of professional development activities to enhance the use of STEM instructional approaches, and the development of assessments to determine the effectiveness of STEM instructional approaches on student learning. We must proceed to enhance the potential of technology education as a primary through secondary school subject.

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