# ST?@M Education:
# an overview of creating a model of integrative education.

**Georgette 'george' Yakman**
**Virginia Polytechnic and State University, USA**
**E-mail: gyak@vt.edu**

*Disclaimer:*
*It has been said that 'citation and utilization of scholarly work can be political' (Petrina, 1998b) in this case, please accept that it is not politics, but exposure and the limitations of time that has warranted the inclusion and exclusion of particular authors in this work. I fully welcome receiving additional works to consider, whether they are in-line or in opposition to the concepts explored in this paper.*

*Abstract:* ST?@M is a developing educational model of how the traditional academic subjects (silos) of science, technology, engineering, arts and mathematics can be structured into a framework by which to plan integrative curricula. It includes reviews of the epistemologies of general and discipline specific developments in conjunction with the individual discipline's standards, as related to integrative, or holistic, education. Investigating these educational relationships to one another is currently being explored as a way to find the commons of education in relation to pedagogy and language. Along with the development of commons is the need for the disciplines to work with one another in a structure that is able to be adaptable to the many variations of discipline combinations that make up different directions that people in society pursue. This paper is an introduction to concepts on the development of such a structure.

ST?@M is a developing educational model of how the traditional academic subjects (silos) can be structured into a framework by which to plan integrative curricula. ST?@M is based on STEM education, which can be defined in two ways:

- the more traditional way, I like to write as S-T-E-M education, as it represents the individual 'silo' fields of science, technology, engineering and mathematics education. Each has evolved to formally include elements of the others within their own standards and practices (American Association for the Advancement of Science (AAAS, 1993), International Technology Education Association (ITEA, 2000), National Council of Teachers of Mathematics (NCTM, 1989) & National Academy of Engineering (NAE, 2004).
- the newer trend is the concept of integrative STEM education. It includes the teaching and learning practices when the subjects are purposefully integrated (M. Sanders, 2006; VTSOE, 2007). When planning integrative curriculum, one field may be the dominant base discipline or all may be planned to be more equally represented (J. G. Wells, 2006).

When the argument of discipline-based vs. integrative education has been addressed, there has been disagreement. There is no argument that there are connections between the disciplines, but there is in what balance of content of each discipline to teach so as to not lose the uniqueness of the silos. (Barlex & Pitt, 2000; DeBoer, 1991) Both types of cross-curricular studies can be valuable and reality based. (Barlex & Pitt, 2000) came up with three distinctions of classification for disciplines being taught together; Coordination, Collaboration, Integration. Coordination and Collaboration are both discipline-based (Barlex & Pitt, 2000). It is promoted that multiple methods are needed for comprehension of applications across the disciplines (Berger & Pollman, 1996; M. J. de Vries, 1996; DeBoer, 1991;

Dewey, 1963; Driscoll, 2005; Hickman, 1992; Loepp, 1999; Paterson, 2007; Petrina, 2007; R. C. S. Wicklein, John W. , 1995; Wiggins & McTighe, 2005). This calls for a structure where individual disciplines can still dominate their own realms, but also where there is constructive time where interdisciplinary studies can be addressed to promote transference of knowledge.

These trends are having a significant influence on each of the inclusive fields of science, technology, engineering and mathematics. Leaders in education are heavily promoting the concept that S-T-E-M and STEM programs be developed to produce more scientists, mathematicians and engineers who are capable of leading the discoveries and developments of the future. (AACTE, 2007; Act, 2006; Ashby, 2006; DOE, 2006; Horwedel, 2006; NAE, 2002; National Governors Association. Center for Best, 2007; Porter, 2006; M. Sanders, 2006; Sarlemijn, 1993; Toulmin, Groome, & National Governors' Association, 2007; Tyson, Lee, Borman, & Hanson, 2007). This trend lends itself particularly well to influence the field of Technology Education [TE]. There has been much use of the design loop in the field of TE. It seems now in the age of recognizing the need to include Engineering Education to promote a new face of TE as TIDE (Technology, Idea, Design, Engineering) (ITEA, 2008) or STEM, that the design circle might be useful for the field to use to reinvent ourselves as we did in 1985 when we moved from IA to TE. The goal seems the same as it was then, to ensure that the field is best able to substantiate itself as the area within the structures of the scholastic world where students learn about a rapidly changing reality. In order for that to happen, an adaptable system of discipline relationships would need to be established. Such an adaptable system would have to be primarily structured around the base elements of education that are true for all the disciplines.

**Silo Education**

Before the concept of integrative STEM education came into being, there was a long history of K-12 being taught as individual subjects (silos), primarily revolving around the divisions of mathematics, science, language arts and social studies. In order to understand how the cross-curricular studies of STEM came to be understood and developed, a brief history of recent developments in each silo, including the more recent field of Technology Education, will be reviewed.

**Mathematics Education**

This review begins with Mathematics Education [ME] as it is one of the earliest disciplines to emerge in the structure of modern education and has one of the longest histories of being formally structured for learning. The National Council for Teachers of Mathematics [NCTM] is the primary organization that drives how mathematics has evolved to be taught in the modern K-12 arena. Their promotion of how mathematics should be studied is used across the country and has arisen from the concepts that people need to use mathematics to solve problems in science, technology, and everyday life (NCTM, 1989). The NCTM has published five tenets by which all of their suggested benchmarks, standards and methodologies revolve around. The first is that there should be a concentrated effort to convey mathematics to all kinds of learners (NCTM, 1989). This conveys that everyone needs and understanding of mathematics in order to be functional in society. The second is that now an overall concept of mathematical theory, history and application should be taught in addition to applied mathematics, much more then just the hard facts of math operations (NCTM, 1989). By making this claim, much more than arithmetic needs to be understood, but that for a person to be functionally literate, a concept of how and why mathematics 'is' and 'works' needs to be understood. The third tenet begins to address how to accomplish the first two goals. 'Currently there are reality-based projects and activities incorporated into math learning so that students can understand its relation to other things, not just endless abstract problems (Horton, Hedetniemi, Wiegert, & Wagner, 2006; NCTM, 1989). This brings mathematics away from didactic learning and instills a necessity to investigate mathematics in action for deeper understanding. By saying this, the NCTM broke a major boundary into the structure of traditional modern education, mathematics education has become much more than worksheets and memorization, mathematics has become an understanding of how things are understood and defined by the use of mathematics. The next tenet of ME is that technology is now being more readily used (NCTM, 1989). It is true that calculators and computers have been responsible for proving much of mathematics that was previously only theoretical, however, the inclusion of technology into ME is broader than that (Chris Merrill & Comerford, 2004). In order to explore mathematics through reality-based projects a wealth of technology must be employed. This includes basic tools including; pencils, paper and rulers through to sophisticated machines and devices that measure, record and support all structures of mathematical application. All of this comes together into the last tenet, which says that assessment needs to include projects, constructions, analysis and process work, as well as (instead of solely) results (NCTM, 1989). This seems to be true of all education, students need to be assessed on how far through the learning process they have come (Wiggins & McTighe, 2005). There are many points in the process of learning where mistakes can be made, if students are only evaluated on their product, then how do they know at which point in the process they need more information in order to succeed? But when projects are given and evaluated from start to finish, students are able to demonstrate their understanding of the rules, concepts and applications of many fields and how they can relate together. All five of these ideas correlate with the interdisciplinary trends in STEM education.

It is a definition of the four commons of teaching ME from Schawab where a wider view of mathematics-based integrative education is defined. ' These are the subject (mathematics), the learner of mathematics, the mathematics teacher, and the milieu of teaching, including the relationship of mathematics teaching and learning, and its aims, to society in general (Ernest, 1994). It is this last statement about mathematics' relationship to society, which brings in a wealth of applicable constructivist elements. As Dewey said, "mathematical laws have meaning only in terms of requirements of transformability within the system of maximum substitutability in which they exist (Hickman, 1992)." So in teaching about society and how mathematics can both understand and transform it, it becomes apparent to students how mathematics is applicable and naturally fitting into all other disciplines of study.

Recently, mathematics has rediscovered itself and the study of it now revolves around social constructivism and five related ideas accepted in mathematics:

(1) Mathematics is part of and fits into human culture. (2) Mathematical knowledge isn't by nature infallible. (3) There are different versions of proof and rigour, depending on time, place, and other things. The use of computers in proofs is a nontraditional version of rigour. (4) Empirical evidence, numerical experimentation, probabilistic proof all help us decide what to believe in mathematics. Aristoltelian logic is not necessarily always the best way of deciding. (5) Mathematical objects are certain variety of social-cultural-historical objects (Hersh, 1994).

These concepts in ME have direct ties to all fields, especially when on considers that collectively they make an argument for the essence of mathematics being problem solving, and therefore is needed to define all kinds of problems as well as analyze and solve them.

There is said to have been a Kuhnian revolution in the field of mathematics (Ernest, 1994; Kuhn, 1970) and that it is now time to account for mathematics more fully, including practices, history, applications, place in culture including values and education. It is time to show the human face of mathematics, which is to understand that mathematics is an underlying language that belongs to all fields (Davis, 1994; Ernest, 1994; Hersh, 1994; Putnam & Spiegel, 1995; Tymoczko, 1994; Wang, 2005). That point is very exciting for integrative education in that the basis of communication is the language of mathematics and to understand anything, one must understand the basics of mathematics. This concept has been stated in other ways that illustrate deeper meanings to other fields, both generally and specifically. On how mathematics is used, a call for action has been made. "It's time to let the secret out: mathematics… is a way of thinking and questioning that may be unfamiliar to many of us, but is available to almost all of us (Paulos, 1995)" This statement was meant to promote the use of mathematics for analysis on how the field is used to prove and disprove 'facts' based on what elements of mathematical language are used to address which questions. In other words, it is meant to draw out how mathematics shapes society and how its core elements can be manipulated for a variety of uses. For instance, Dewey claims that science is 'math based productive technology used for analysis of the natural world' (Dewey, 1963). By saying this, he is claiming that science is a human-made language made up to organize and understand the natural world. With this statement, Dewey intrinsically ties the technology of the creating of the mathematics language to the pre-existing elements of the world. Whereas a mathematics scholar points out that mathematics has been called a branch of natural science and that instead of the language of mathematics being created by humans, its facets were discovered as underlying facts of nature (Tymoczko, 1994). Regardless of whether mathematics is a language that was discovered or created, it is arguably the most primal language by which all other communication is regulated, defined and understood.

**Science Education**

Science education [SE] experts have been attesting to the fact that the field of SE has blended borders, which adds insight to other disciplines (AAAS, 1989, 1993; DeBoer, 1991; Matthews, 1997) and these thoughts have been supplemented by experts in other fields who recognize SE's contributions to understanding in their fields (Barlex & Pitt, 2000; M. J. de Vries, 1996; Dewey, 1963; J. Dugger, W. E. , 1993; NAE, 2002). The AAAS went as far as to formally include the 'Nature of Technology' with formal ties to engineering concepts, within their own benchmarks and standards (AAAS, 1993). SE taught as whole fact vs. parts (silos), allows for substantiation with deeper meaning and transference outside the classroom (AAAS, 1989; Driver, Asoko, Leach, Mortimer, & Scott, 1994; Matthews, 1997). It is this transference of knowledge, an ability to apply scientific thought in novel situations, which students need in order to be productive members of society. It is through making sense of science versus just finding out about the facts of science, that students will not only be able to understand science, but be able to apply it in new situations (DeBoer, 1991). The Greek culture did not have an understanding of this concept and it therefore kept them from developing experimental science (Hickman, 1992). Analysis is an important area of science, but without experimental science the field stagnates. Scientific thought itself is said to include inductive thought, deductive thought, processes and attitudes (DeBoer, 1991). Therefore, in order for students to understand science, all of these levels of thought, processes and attitudes need to be formally addressed in SE.

Currently there are three dominant interpretations of teaching science, the first is as a structured bodies of knowledge (content rich), the second as a set of investigative processes and the third is as human activity interconnected with technological application and the rest of society, it is this third way that is necessary for hypothesis generation (DeBoer, 1991; Hodson, 1991; Mellado, 2006) There have been given three arguments for the third type, it provides motivation to learn in familiar contextual way, it offers an ability to become functionally literate and it offers values development in education (DeBoer, 1991). In order to teach this way, there are three curricular needs, there must be an exploration of existing views to promote the creation of new theoretical ideas, there must be experimental work and there must be cross-discipline consensus with approved language styles to promote understanding between the fields of study (Barlex & Pitt, 2000; Hodson, 1991). These curricular needs are primarily provided through the use of guided discovery (DeBoer, 1991; Driver et al., 1994; Froebel, 1947; Furth, 1970). SE itself has direct and strong ties to constructivist learning methods (AAAS, 1993; Matthews, 1997), the three primary ones are that students need to learn to think in a disciplined, rational way in order to strengthen their intellect, that scientific thinking is transferable to non-scientific contents and creates more effective people and that future scientists must know how to think like scientists in order to perform like scientists (DeBoer, 1991). The experts in the field of SE have invited in the field of technology and it's related engineering concepts by formally including them in their benchmarks and have invited in the field of mathematics by promoting the need of analysis and common language and they have even invited in the social arts by claiming that the inter-relation of science and human activity is critical to understand to know how science and society interact and function together.

**Technology Education**

Technology Education [TE] has traditionally been the K-12 venue for cross-curricular studies. This has been true from even before TE was TE, but instead was the field of Industrial Arts (Bonser & Mossman, 1923; P. DeVore, 1976; Foster, 1995; Kirkwood, Foster, & Bartow, 1994; Maley, 1973). TE's relationship with science has been intertwined since the beginning of both fields,' scientific advances are technological advances,' (Hickman, 1992) as they lead to the invention and production of new technologies and 'advances in the uses of tools are needed in order to improve and test inferences in science' (AAAS, 1993). It has been said that science provides the framework by which all technology is developed and structured to function and that even though science precedes technology, and that science and technology are independent disciplines with different goals, methods and outcomes (P. L. Gardner, 1994; P. L. Gardner, 1995), technology ontology predates science and therefore science and technology are in a dialectical relationship, with neither being a dominant partner (P. L. Gardner, 1994). The connection between the two fields is a revolving concept – technology and the engineering involved to create technology, cause permanent changes to science, the natural elements of our universe, of which they are also made up.

The Maley Plan offered itself as a primary means for applying the principles of mathematics and science, where science becomes reality and mathematics the tool whereby student-centered activities revolve around testing, analysis, materials, investigations and process (Maley, 1973). It is this reality and analysis of results where the concepts learned in the silos come together and transference of knowledge results to create the next generation of innovators. It stands to reason, that a full study of technology cannot exclude the study of the science (Bunge, 1966), which it is made up of, the engineering processes that creates it and the mathematics necessary to understand the developments and effects of it. Due to this, since the field became TE in 1985, most TE educational theorists and researchers have put a lot of emphasis on connections to mathematics and science, as they are the traditional 'academic' disciplines which offer the most substantive backing for the positioning of TE in the broad K-12 curriculum structure (Childress, 1996; P. D. DeVore, 1964; P. L Gardner, 1997; Laporte & Sanders, 1993; Lauda, 1980; C. Merrill, 2001; Savage & Sterry, 1990). But, there has been a growing emphasis to substantiate the curriculum from across the S-T-E-M fields and formally tie in engineering as well (Barlex & Pitt, 2000; Clark & Ernst, 2007; Dakers, 2006; M. J. de Vries, 1996; J. Dugger, W. E. , 1993; ITEA, 1996, 2000, 2006; Mitcham, 1994; Petrina, 1998a, 2007; G.L Salinger, 2003; Snyder & Hales, 1986; J. Wells, Pinder, & Smith, 1992a; R. C. S. Wicklein, John W. , 1995). Other experts in the field, further stretched the boundaries of the field to include the development field of engineering as well as the social, creative and aesthetic fields of the liberal and fine arts, especially Delmar Olsen, John Dewey and those involved in Jackson's Mill (Hickman, 1992; Olsen, 1963; Snyder & Hales, 1986; J. Wells, Pinder, & Smith, 1992b). Leaders in the field of biotechnology have promoted related curriculum as interdisciplinary in nature and incorporating math, science, art, design and production (J. Wells et al., 1992b) The field of STS has also been formally linked to the field of TE to draw out the connections to society and its effects on the direction of the field as well as technology's effects on society (Pinch & Bijker, 1994; Karen Zuga, 1991). These forward thinkers have argued that it is not enough to only understand the elements of how the technology works and effects tangible objects, but to understand how such technologies are developed through societal demands and are accepted through the social, economic and aesthetic values of a culture is also vital to produce a knowledgeable citizenry.

Some educators have not focused on specific content but on a way of offering curriculum that would involve any and all subjects that were naturally encountered in the investigative process of instruction. Specifically the IACP focused on problem solving (Lux & Ray, 1971), and some looked at various kinds of alternative curriculum theories and methods (Barlex & Pitt, 2000; Dewey, 1963; Loepp, 1999; Petrina, 1998a, 2007; Raizen, Sellwood, Todd, & Vickers, 1995; R. C. S. Wicklein, John W. , 1995; K. Zuga, 1993). Arguments have been made for using multiple strategies and methods even within one curriculum so as to make it evident to students that there are numerous ways to discover knowledge and solve problems based on that knowledge (Dunham, Wells, & White, 2002; M. Sanders, 2006; Sarlemijn, 1993). Validation that there is not just one best way to teach and learn helps make the case for cross-curricular content and methodology as a way to make the connections between the disciplines stronger and students transference, retention and application skills more substantial and more deeply engrained.

Despite which content, methods and strategies various people in the field of TE have argued for, one thing that is agreed upon is that the overall goal of the leaders in the profession has been to create technically and/or functionally literate people despite the rapid changes that technology and our society produce (Bill, 2006; Dakers, 2006; P. DeVore, 1976; ITEA, 2006). The focus has not been specific content, but on adaptability, therefore the field has based its teachings on conveying an understanding of systems and the connections between them (J. Dugger, W. E. , 1993). In order to accomplish this, 'the technology laboratory, previously conceptualized as a place to make things, graduated into more of a place to learn the interconnections of things' (K. Zuga, 1993). Because of this 'TE became one of the few areas of study to adopt a structure that allows for, and encourages, changes in it's core structure to accommodate changes in the technological world that inter-relate with society in a very reciprocal way' (K. Zuga, 1993). It is this concept that allows the field of TE adaptability to reflect the changing needs of society and its reflection in education. No other field is structured to be as responsive and adaptable and this has been a fallacy of the structure of modern education since its inception. The field of TE has their 'foot in the door,' of K-12 education, but they are not yet situated in a place of acceptance so that all students are given cross-curricular studies to create functionally literate citizens. That is TE's new challenge, to prove their place in the structure of education and to be formally accepted as a substantial field to teach a necessary set of concepts to all students at all levels.

**Engineering Education**

'As developments in science and technology occur, they create new fields together, such as engineering, which has become a science category of its own' (AAAS, 1989). Engineering has been defined as 'the use of creativity and logic, based in mathematics and science, utilizing technology as a linking agent to create contributions to the world (AAAS, 1993). Since engineering is a result of science, technology, and arguably, mathematics as well, its place in education is based on its structure in reality and it has no history of being a silo discipline. It has been most closely aligned with the study of TE, as that is its 'linking' category to the substantiated fields of mathematics and science. When students study design and technology, what they are essentially studying is engineering (Barlex & Pitt, 2000). Engineering Education [EE] is unique in that it does not have a history of being part of the K-12 structure as its own discipline. It is therefore hard to find a place for it to fit within a long-established structure in order to accommodate the urgent call for the development of more engineers to meet the country's demands (Act, 2006; Ashby, 2006; Horwedel, 2006; NAE, 2002). There has been a substantial amount of energy attracting and retaining students into collegiate engineering programs (EAC, 2004). There have traditionally been two primary focuses of engineering programs, a deep investigation of a particular field and a broader scope of numerous engineering fields (EAC, 2004).

More recently larger programs are offering both and allowing their students to decide their own personal scope of engineering education based on their goals (NAE, 2004). Currently there is also a trend to advance into the future of engineering as primarily a team-based enterprise (EAC, 2004), which allows engineering students to work together, sharing their own specialties for the creation of the common good. Although these changes have helped with attraction and retention into collegiate engineering programs, in recent years there as been a call for the K-12 arena to better prepare students to take on these challenging courses of study in post-secondary schools (NAE, 2002; G.L Salinger, 2003; Tyson et al., 2007; R. C. Wicklein, 2006). EE based programs are getting a lot of attention in hopes of bringing EE to the K-12 level ( Salinger, 2005). It is debatable as to if EE is the most appropriate venue of study to fulfill these needs at the K-12 level, or if a broader more interdisciplinary approach would be a better venue with which to deliver such contexts.

Students are in need of understanding EE abilities at a younger age in order to be able to be competitive in the related collegiate and professional arenas. They must learn to apply the techniques and skills associated with mathematics and scientific principles in order to obtain an ability to be life-long learners, design and conduct experiments, analyze and interpret data, design systems, components or processes, work on multi-disciplinary teams, identify contemporary issues and problems, formulate and solve engineering problems, show responsibility, and communicate in order to impact the world in positive ways (Grasso & Martinelli, 2007; NAE, 2004). Since that is a lot for one discipline to accomplish, the formation of relationships between the fields of STEM have become a vital movement in the educational world in the United States (Act, 2006). For EE to be successful, it is necessary for the field to draw on and understand the advances made in other fields (NAE, 2004). Within the STEM education relationship, the act of using science and mathematics to design new technology has become the general definition of EE (Dugger, 1993). Much discussion has taken place on whether the field of TE should become blended with the field of EE, just this month a survey on this topic was sent out to the Intenational Technology Education Association members and over 400 people responded on the topic in a single day (Litowitz, 2008), also the American Association for Engineering Education started a new branch in their association last year called the K-12 Engineering Division which includes an election of three Technology Educators to the nine member board (M. Sanders, 2008). However, if EE were to become dominant over TE in K-12 education, a disadvantage could take place in that EE could suffer from a focus on a narrower view of practice without the broader spectrum of social and physical developments and impacts being studied. When one realizes that engineering is the research and development involved in the creation of technology (AAAS, 1989) and therefore is a subset of the larger field of TE, then TE becomes the K-12 venue where the impacts and directions of EE is evaluated and understood. EE still remains the best venue for content specific studies at the post-secondary level.

**STEM Education**

The 'hard sciences' club has received so much recent emphasis that it has created a new educational branch, STEM. This concept is a result of a struggle of hierarchy within education by the individual branches involved. A scholar in TE summed it up well when he said, 'STEM is a politically good move, philosophically, mathematics and science don't want to adopt technology and neither does technology want to adopt mathematics and science. There are pitfalls and opportunities with all of these options. We [TE] are moving towards engineering education and STEM versus becoming part of science (J. Dugger, W. E., 2007).' This concept of disciplines having a fear of being lost within other disciplines encouraged me to find a way to create a framework which all disciplines could be represented in without fear of being dominated by more politically or economically powerful disciplines.

**STEM to STEAM Education**

While studying the common factors of teaching and learning across the disciplines of S-T-E-M, the influences of the arts disciplines became more apparent, especially those already strongly promoted in the K-12 atmosphere, language arts and social studies. I started thinking of how to develop an educational framework that could formally link the study of the hard sciences to that of the divisions of the arts.

**Arts Education**

Within the arts there are many divisions. Upon reviewing many educational works related to teaching the arts, I was unable to find a universal definition of them. I quickly found that within articles having to do with the arts in education there were distinctly different meanings of 'arts education.' Despite this, I was able to find a way to fit established meanings into categories of an organizational structure. As I read through articles, I began to sort them into those that were related to more broadly related realms of education. Those that revolved around English, ESL, sign language or some other form of art primarily related to communication were put into a category of the language arts. Those that revolved around things that are traditionally addressed in 'art' classes, such as paintings, sculpture, color theory and tangible creative expressions were put into the category of fine arts. Those topics that included personal or collective movement, sports, dance and performance were put into the category of physical arts. Topics that related to particular physical skills or techniques necessary for manipulating objects were categorized as manual arts. The broadest category was that of the liberal arts, this one included the social sciences such as sociology, philosophy, psychology, theology, history, civics, politics and to educators, one of the most important classifications, the field of education itself. It was then that I realized the oversight that the field of education itself had not been previously formally included in the structure of the K-12 silos of education.

Within the categories that emerged from this survey, the language arts and social sciences were the two that had a strong history of being independent disciplines within the structure of modern education. The fine and physical arts have a place in the structure, but are not traditionally considered 'academic' subjects and have been subdivided into specific categories and marginalized in importance. The manual arts have had a history of being vocational in nature and primarily addressed within the field of industrial arts, or more recently, TE. The common linking agent among all these fields is that they have not been invited into the 'hard sciences' club of STEM and have not been formally included into the structure deemed vital to the creation of more highly skilled citizens. I started reviewing the educational research from these fields to see if there were arguments to be made for the inclusion of these fields for such a goal.

The field of Language Arts [LA] is seen as universal to all other branches of knowledge, as without it, the ability to communicate is severely limited (Brown, 2005(Clerk & Rutherford, 2000)IRA-NCTE, 1996). Despite the fact that mathematics is needed to understand any language, it is the structure of vocabulary based languages that provides the context by which to understand individual disciplines (J. D. Bransford, Brown, A.L., & Cocking, R.R. , 1999; Brown, 2005; Paterson, 2007). However, it is also such structures that help narrow people's abilities to communicate across disciplines and fully understand the deeper meanings that each silo gives to particular words and concepts (Huber & Hutchings, 2005; Shulman, 2005b). It is with this understanding that an argument is made for creating a commons of language across the fields of education so that deeper understanding and transference of knowledge becomes more natural for all students and educators (Brown, 2005; Paterson, 2007; Ruggiero, 1988). There are numerous writings specific to each field that promotes this concept, including mathematics (Barwell, 2005), science, (Douglas, Worth, & Klentschy, 2006; McKee & Ogle, 2005; Sutherland & Dennick, 2002; Torres & Zeidler, 2002; Zmach et al., 2007), engineering (Grasso & Martinelli, 2007), technology (ITEA, 2006; J. Wells et al., 1992b), history (Kornfeld & Leyden, 2005) and even the field of LA itself promotes its need to be understood by other fields for understanding, communication, entertainment, analysis and problem solving (IRA-NCTE, 1996). The underlying argument for the inclusion of LA being formally addressed in all other fields is that, if you can't communicate effectively, then how can you prove your conceptions, understandings, designs and ideas in any other field.

The field of the Liberal/Social Arts [SA] is also important to be understood as a base of other fields. It is within this context that an understanding of each field's developments is housed (Featherstone, 1986; NCSS, 1994). Whether one believes that mathematics was discovered with an investigation of the laws that prove it to work or created as a means to classify and organize things, its means of application is one of the oldest applications that humankind has worked with (Ernest, 1994). Without an understanding of those developments, one cannot truly understand how and why the ordering of other fields happened when they did. Likewise, the structures of science, technology and engineering were originally formally created by white men as black people and women were not formally recognized in the field of discovery until fairly recent times and even within the structure of the white male development of the hard sciences, society played a large role in the direction of what developments were promoted or pushed aside. Galileo is a prime example of this, as when he proclaimed that the earth was not the center of the universe, those in power in the society had him put under house arrest for daring to make such a statement, whereas had they proclaimed his brilliance and offered him ways to promote his studies, that field of science would have developed more rapidly. There have been ten thematic strands developed by the National Council of Social Studies in which to revolve the teaching of the social sciences around in the structure of K-12 education, they include; 1) culture, 2) time, continuity and change, 3) people, places and environment, 4) individual development and identity, 5) individuals, groups and institutions, 6) power, authority and governance, 7) production, distribution and consumption, 8) science, technology and society, 9) global connections and 10) civic ideals and practices (NCSS, 1994). It is quite apparent from this list, that this field has strong connections to all other fields. Recently there has been a flood of papers generated in this field, on the topic of strengthening the education of students to understand the implications that society, and all its complicated facets of psychology, politics and social interactions, have on the development of the world (Feldmann, 2007; Macedo, 2004; Walling, 2007). All of these articles call for the need for students to understand the basic elements of how society develops with its attitudes and customs in the past, present and future. This is arguably a cornerstone of the knowledge necessary for students to become education citizens able to understand the directions that they are responsible for guiding the world to go in.

The fields of the Fine Arts [FA], Physical Arts [PA] and Manual Arts [MA] are not without significant bearing on the developments of society and culture as well. Despite these fields having a marginal place in the structure of K-12 education, they have maintained a place in the structure. That fact, in and of itself, establishes a level of importance to the necessity of those fields, otherwise the inclusion of their formal study would have vanished from the K-12 landscape long ago. However, specifically, each of these fields offers different strengths to education as a whole. Since MA has been incorporated into the field of TE (Foster, 1995), the arguments for its inclusion have already been made in this paper. It is here that I will address the cross connections of FA and PA to the rest of the silos. The field of physical education is usually defended in terms of fitness, especially in a time when obesity is a growing concern in our country(NASPE, 2004). However, substantial arguments have been made for a healthy active body attributing to healthy, active mental capabilities as well (Kalyn, 2006; NASPE, 2004; Vail, 2006). Although the physical arts are promoted heavily in after school activities, that level of participation cannot be required of all students, so an inclusion in the K-12 structure becomes even more important if all students are to achieve an appreciation and understanding of its contributions to their overall physical and mental development. Likewise, the fine arts have been sectionalized in the K-12 arena into the musical arts and the structural fine arts. Recently there have been more and more arguments being made to take the direction of such curriculum in the opposite direction so that within the fields of science (Bopegedera, 2005; Coy, 2007), mathematics (Tan & Chua, 2006; Ward & Muller, 2006), language arts (Sutherland & Dennick, 2002), social studies (Kornfeld & Leyden, 2005), technology (J. Wells et al., 1992b) and engineering (Lewis, 2005), students are exposed to an appreciation of how sound and aesthetics are represented and influence each of these fields (Appel, 2006; Chedid, 2005; Daniel, Stuhr, & Ballengee-Morris, 2006; Ebner, 2006; Marshall, 2005, 2006; Mishook & Kornhaber, 2006; Rohrer, 2005; Strokrocki & National Art Education Association, 2005). The national standards of art includes connections to all fields in the categories of dance, music, theater and visual arts, (CNAEA, 1994) making it easier for all educators to formally incorporate direct links to appreciating the roles that the arts take in their particular disciplines.

**STS**

Studying these linkages pointed me towards investigating the movement of STS. I soon became intrigued by that field's divisions of the study of Science and Technology Studies versus Science and Technology in Society (Bugliarello, 1988; Pinch & Bijker, 1994; Truxal, 1984), and within each of those divisions the classifications of 'scholars' versus the 'activists' Additionally, I was introduced to philosopher's perspectives on the nature of science, ethics, constructivism, co-constructivism, positivism and post-positivism (Kuhn, 1970; Zammito, 2004) and Bruno LaTour's Actor Network Theory, (Latour & Woolgar, 1986) all of which, ,includes implications for the field of education (Karen Zuga, 1991). Although, the inclusion of the STS movement is still new to the development of this framework, its inclusion in TE (ITEA, 2000; Karen Zuga, 1991) and SA (NCSS, 1994) have helped establish a place for it in the K-12 learning environments.

**Holistic Education**

While investigating how each discipline related to each other and provided support for cross-connections and deeper understanding, I kept being led to studying aspects of attempts at formal and informal holistic educational models such as those of; Montessori (Maria Montessori, 1914, 1975; Mario Montessori, 1992), Ruggiero, ((Ruggiero, 1988), Waldorf's Anthroposophy (AWSNA, 2008) Reggio Emilia (Firlik, 1996) and alternative schooling movements (Eisler, 2005; Minnis & John-Steiner, 2005). The most successful institutions of purposefully holistic education include Montesorri and Waldorf. Maria Montessori attributed holistic learning theories to young children and said they needed to have a 'prior interest in the whole; so that they can make sense of individual facts' (Maria Montessori, 1914, 1975) Her educational system is one of the most successful systems of 'holistic' education established (Mario Montessori, 1992). It was based on fully integrated curricula, delivery and assessment methods. Waldorf Education is based on Rudolph Steiner's Anthroposophy theory. The goal is to help produce a person 'who is knowledgeable about the world, human history and culture, who has many varied practical and artistic abilities, who feels a deep reverence for and communion with the natural world, and who can act with initiative and in freedom in the face of economic and political pressure' (AWSNA, 2008). A common misconception in our time is that education is merely the transfer of information. From the Waldorf point of view, true education also involves the awakening of capacities—the ability to think clearly and critically, to empathetically experience and understand phenomena in the world (AWSNA, 2008). Since these two structures of education have proven to develop functional and universally literate students who have gone on to all areas of post-secondary educational success, they are models of success for integrative education.

I will define my use of holistic education as denoting life-long learning; therefore I consider all purposefully planned programs of teaching that have been called holistic education, an attempt at it. I argue that holistic learning cannot be controlled or planned; it is the interpretation of each person's sphere, or universe, of influence. It significantly helps to shape what people do with what they are exposed to and what they understand (J. D. Bransford, Brown, A.L., & Cocking, R.R. , 1999; J. D. Bransford, M.S. , 2005; Gagne, 2005; Ruggiero, 1988; Smith, 1998; Wiggins & McTighe, 2005). Since each person's perspective is different, holistic education cannot be delivered equally to students. I would consider indigenous tribal learning and some home learning settings, to be as close as possible to intended holistic education. Otherwise, educational trends geared at educating the whole learner, tend to have their pedagogy and curriculum fall under the titles of integrated, themed, inquiry, discovery or reality-based education.

**Functional Literacy**

A significant common thread that became apparent is that each primary discipline promotes a need for students to develop a proficiency in the subject that would make them literate enough in the discipline to be able to continue to adapt to and learn about the basic developments that the field takes. It led to a conclusion that students need a literacy of a breadth of the primary disciplines, which would include an ability to transfer knowledge with higher order thinking between disciplines (Freire, 1996; Huber & Hutchings, 2005; Ruggiero, 1988), or to use Dewey's term, students need to obtain a *functional literacy*(Hickman, 1992). In order for a person to be functionally literate, they have to be able to adapt to their surroundings, which means observing, thinking, changing and acting constantly. It was this connection that sealed the argument that more than individual contexts, education needed to find a way to place emphasis on developing student's abilities to think across the disciplines. 'The idea that it is impossible to teach people to think,… did not proceed from scholarly research, but from an unscholarly assumption that if thinking was not being taught, and had not been taught, it therefore could not be taught (Ruggiero, 1988).' This seemed like a tragedy. However, it also stood to reason, that if each discipline purposely pointed out the naturally occurring connections to other disciplines, that students would develop the ability to recognize these connections and that would foster the creation of cross-disciplined thinkers. This meant that there was no reason to radically change the structure of K-12 education, but simply to promote the progression of cross-discipline connection that each field had already been making individually.

At this point, cooperation, not structure, became the limiting factor. There were significant arguments for the creation of commons in language and pedagogy that would promote more universal understandings across disciplines. Cooperation among disciplines would provide realistic dynamics and influences that would allow students to learn how to accommodate to the real world. Co-operation could 'also have the effect of encouraging the use of common language, common analogies and an appropriate level of detail across the subjects thus avoiding misconceptions and regression' (Barlex & Pitt, 2000). But in order for students to be able to understand cross-disciplinary concepts, educators have to find ways to present the information that make sense. 'Scholars of teaching and learning must address field-specific issues if they are going to be heard in their own disciplines, and they must speak in a language that their colleagues understand (Huber & Morreale, 2002), however, they must also speak in a language that can be understood by those based in other disciplines (Huber & Hutchings, 2005; Shulman, 2005a). Keeping a structure of disciplines is still essential for creating a depth of knowledge within specific fields, however a breadth and context of knowledge is equally important. In this way, they are useful for reinforcing each other. There should be a simultaneous awareness of the interconnectedness (or commons) among subject matter and pedagogies. Instruction should be purposefully planned to reflect reality (Ruggiero, 1988). The common goal of education should be to produce functionally literate people who know how to learn and are adaptable to their rapidly changing environments.

**ST?@M Framework**

Once I had been convinced that the fields of the arts were important to the overall creation of knowledgeable and well-rounded citizens, this investigation led me into a deeper study of each of the main subject areas with the hope that I would be able to find established definitions and classifications of the finer educational divisions within each silo. My goal was to find a way to broadly classify all areas of study into a structure that would allow students to understand the importance of the relationships of the fields and hopefully come to respect their need to acquire skills in all areas if they were to become well-rounded citizens. My other goal was to afford academe a structure by which to help organize the teaching of the fields that would not establish hierarchy, but instead establish a reflection of how fields of study interconnected with one another in reality so that those connections could be reflected in scholastic arenas. Such a structure would allow for subjects to be taught based in one subject with naturally occurring cross-curricular elements to be explored or for topical studies to be taught through more universally integrative methods.

The following definitions and classifications are the result of that investigation:

**Science** what exists naturally and how it is affected.

Physics, Biology, Chemistry, Geosciences, Space Science & Biochemistry (including history, nature of, concepts, processes and inquiry) (AAAS, 1993; Hodson, 1991)

(mixed) Biotechnology & Biomedical (ITEA, 2000)

**Technology** what is human-made

Nature of Technology, Technology and Society, Design, Abilities for a Technological World, The Designed World (including: Medical, Agriculture & Biotechnology, Construction, Manufacturing, Information and Communication, Transportation, Power & Energy) (ITEA, 2000)

**Engineering** the use of creativity and logic, based in mathematics and science, utilizing technology as a linking agent to create contributions to the world

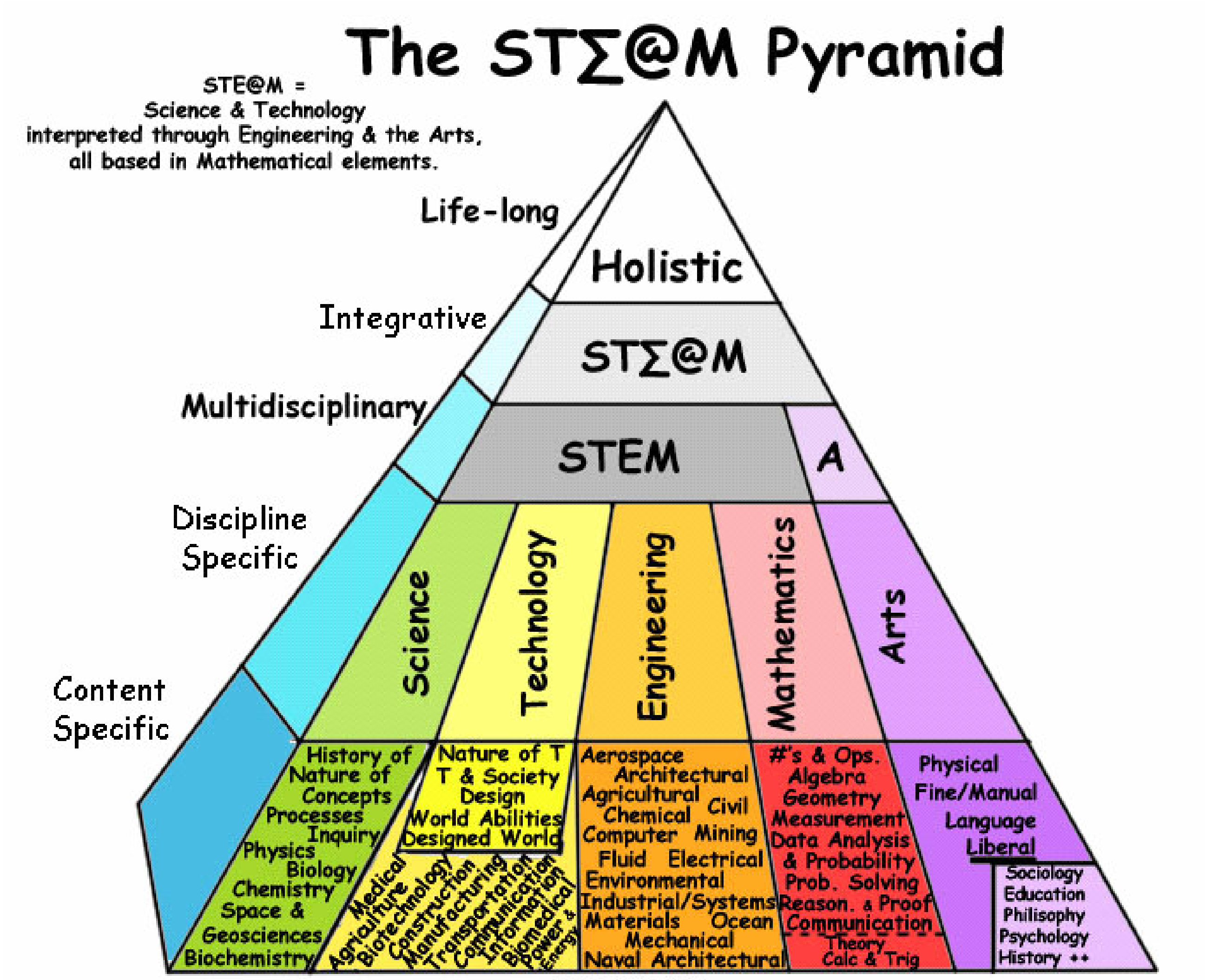
Aerospace, Architectural, Agricultural, Chemical, Civil, Computer, Electrical, Environmental, Fluid, Industrial/Systems, Materials, Mechanical, Mining, Naval Architectural, Nuclear, Ocean (AAAS, 1989; ASEE, 2008; NAE, 2004)

**Mathematics** Numbers and Operations, Algebra, Geometry, Measurement, Data Analysis & Probability, Problem Solving, Reasoning & Proof, Communication, (including Trigonometry, Calculus & Theory) (NCTM, 1989)

**Arts** how society develops, impacts, is communicated and understood with its attitudes and customs in the past, present and future

Physical, Fine, Manual, Language & Liberal (including; Sociology, Education, Politics, Philosophy, Theology, Psychology, History & more…) (CNAEA, 1994; Featherstone, 1986; IRA-NCTE, 1996; ITEA, 2000; NASPE, 2004; NCSS, 1994)

From all of these investigations, I created the following diagram in order to establish a framework for giving structure to and analyzing the interactive nature of both the practice and study of the formal fields of science, technology, engineering, mathematics and the arts.



C.2008 G. Yakman

My first interpretation of how to explain the **STEAM** linkages was: 'We now live in a world where; you can't understand **Science** without **Technology**, which couches most of its research and development in **Engineering**, which you can't create without an understanding of the **Arts** and **Mathematics**.' This statement was an adaptation of: **'**The study of Technology and Engineering is not possible without the study of the natural sciences. This in turn cannot be understood in depth without a fundamental understanding of Mathematics (J. Dugger, W. E. , 1993).' My adaptation was colorful, but contrived. Therefore, I persisted on meandering through the silos looking for more structural links. I returned to reinvestigate the recent Kuhnian revolution in the field of mathematics education (Davis, 1994; Ernest, 1994; Hersh, 1994; Tymoczko, 1994).This led me on to explore the intrinsic element that mathematics is among the other silos. The fact that kept coming up was that mathematics, and mathematics alone is essential for the study of the other silos, it is even the base of the study of languages, which is the next strongest category to provide structure for the other silos. Mathematics is the primal language that cuts across all other field's boundaries. It is not just a primal language but a network of practical and theoretical divisions that interact both with other subjects as well as stands alone. I had found something that set apart the study of mathematics from that of science, technology and engineering, that thing was the need for it to be included in the other disciplines. Since mathematics is the underlying language of all communication, it therefore becomes the linking agent between concept and understanding in education.

This became a pivotal point in my framework system, but it still did not explain how the arts fit into the structure. I revisited the literature on the arts and looked for a deeper meaning within all the individual reasons to include the various fields of art into cross-curricular studies. The answer came when investigating the field of education itself. At that point my argument became that since the arts discipline houses the study of education, how can education itself be formally excluded from the study of STEM education? But, more then that, it became apparent that how interpretation and application associated with the arts linked things together was the social construction of society. This led me back to investigate the field of engineering as the division of research and development of technology and the last piece of the frameworks puzzle became apparent. T*he arts and engineering contain all of the divisions that interact with the pure possibilities of the other fields to shape the direction of development.* That was the missing element to this paradigm. A new interpretation of how all the fields of STEAM linked together, and due to it, STEAM became ST**?**@M. The new definition of the framework became;

**ST**?@**M**: **' Science** and **Technology**, interpreted through **Engineering** and the **Arts**, all based in a language of **Mathematics**.'

**Application**

Hopefully, this is where you, the reader, says… how does that apply to the practice and education of my field?... and how does that effect my concepts of and interactions with other fields? What applications does this framework have in practical reality? The possibilities of answers to these questions and more have only begun to be explored.

As you may notice, the pyramid has other labels along its sides as well. These are the keywords that I have associated with the concepts that I am working on affiliating with the various levels of the classifications that I have assigned to the fields. Let me explain my definition of the levels.

At the very top of the pyramid is the *universal* level. This correlates to the concept of holistic education, which I described earlier, as being the interpretation of each person's sphere, or universe, of influence. It cannot be planned or avoided, even when sleeping, people are constantly learning from and adapting to their environmental influences. The results of these influences, both internal and external, greatly shape what people do with what they are exposed to and what they understand. For these reasons, I have associated this first level of the pyramid with *life-long* education.

**Integrated Level**

The second level of the pyramid I have labeled the *integrated* level. It is at this level where students can obtain a broad scope of all the fields and a basic overview of how they inter-relate in reality by teaching them with a purposefully planned and reality-based interdependence. An excellent way to teach about natural inter-relations in practice is to teach thematic concepts that allow for transference to the realm of education. For example, teaching a unit on biotechnology would allow for broad or in-depth studies (J. Wells et al., 1992b) of;

- the science of the biological, chemical and physical elements involved,
- the technology of machines, concepts and skills that allow for the construction, production, transportation, communication and power and energy of the systems studied,
- the engineering of planning and designing with given constructs,
- the mathematics needed to comprehend and develop the project and its results,
- the physical, manual, fine and liberal arts used for both large and intricate elements of the related topics including the history and politics and
- the language arts to research, convey and report on all of this knowledge.

It is at this stage that students begin to understand what and how to explore all areas of opportunities in the educational realm. Instructors have the choice of focusing in depth on specific areas or covering a broad scope of the topic. Teams of teachers can work together to provide in depth coverage of their areas of expertise while reinforcing what students are learning in other specific areas. For these reasons, I have associated this second level of the pyramid as being most relevant to *primary and middle school* education. However, I find the integrated ST?@M approach to be appropriate for all levels of education.

**Multidisciplinary Level**

The third level of the pyramid I have labeled the *multidisciplinary* level. It is at this level where students can obtain a scope of specifically chosen fields and a concentrated overview of how they inter-relate in reality. An excellent way to teach about natural inter-relations in practice is to teach reality-based/authentic units. When purposefully planned to cover certain fields and concepts, instructors can still easily use themed education, however, fields not focused on should not be all together excluded from the curriculum, but instead, at least explained as being an element of the scope that would occur in reality. Any of these methodologies, and more, helps allow for transference of learning from the realm of specific topics to all related topics.

Current trends in education have already established STEM as a relevant block of core fields. Trends have also shown many of the branches of the arts being more and more marginalized. In public education, only the language arts and social studies are still formally given substantive attention as having importance outside of the STEM areas. To me, this is a tragedy, as it eliminates many primary ways for students to obtain contextual understanding. Therefore, as students are exposed to prominent and marginalized fields, they begin to understand the hierarchy and politics of both education and practice. It is here that students might begin to have a concept of specific areas of interest to explore as potential career paths. For these reasons, I have associated this third level of the pyramid as being most relevant to current *transitional or middle-school education*.

**Discipline Specific Level**

The forth level of the pyramid I have labeled the *discipline specific* level. It is at this level where individual silo divisions of fields, or disciplines, are taught at focus levels. It is where individual subjects are the primary topic of focus, or base-discipline. This is not to say that other subjects are excluded, subjects should still be covered contextually, however, the primary subject is explored significantly more in depth then the related fields. It is as this level where the specific divisions of each silo should be given an overview. This is the level at which to explore what areas of expertise a person wishes to acquire as career and hobby. Since this is very appropriate for young adults, I have associated this forth level of the pyramid as being most relevant to *secondary* education.

**Content Specific Level**

The fifth level of the pyramid I have labeled the *content specific* level. It is at this level that specific content areas are studied in detail. It is here where *professional development* happens and students delve into the tighter realm of the specific content areas of their choice, usually in post-secondary studies. Areas can be studied alone or in specifically grouped clusters from within their own silos or from across the fields. Again, this should still be relevant and contextual to the world at large, but this is the point where educational and professional practices most fully interrelate with each other's developments.

**Marketing**

When one looks at the field of Technology Education [TE], it is sadly apparent that the average person does not understand the scope of the field. The common person thinks of it in one of two primary ways; the more traditionally common, as the realm of manual and industrial arts, the newer common perception trend is that it is the study of information technology. Although both of these concepts are, in part, true, neither come close to defining the breadth or depth of this field. In an effort to avoid the complications that TE has faced, I have plans to integrate catch-phrases and definitions into the introductory literature about this newly developing framework. For fun, I have played around with catch phrases. Although, these are not as academically relevant pursuits as the rest of the scope of my inquiry, they are imperative for marketing this new theory. Among them, I have tried to appeal to students (young and mature), parents and guardians, community members, educators, administrators, business leaders, politicians and agencies. I have also tried to make them succinct so they can be easily remembered and used in various forms. Some early examples of catch phrases include; ST?@M Powered, Full ST?@M Ahead, Power up with ST?@M, Don’t Waste Your ST?@M, Don’t Blow Off ST?@M,…

S T Σ @ M

Science Technology Engineering Arts Math

**Middle and High School Programs**

Recently I have been thinking about development of ST?@M-based middle and high school programs and schools. I am currently putting more emphasis on transitioning a Technology Education middle-school level program to a ST?@M-based program called ‘What’s Your Point?’ This program would be a stand alone ST?@M course which could be introduced to any middle school. It could be used as a seed for developing integrated curriculum throughout a school.

It would be initially implemented as a way to expose students to a large range of skill sets and career choices through reality-based integrated learning. Students would perpetually evaluate their points of interest, experience and talents in relation to a diverse spectrum of careers and the related discipline skills. They will also be involved in evaluating local, regional, national and international career path opportunities and developments in historical, current and potential contexts. A portfolio process would help organize students to further explore potential career paths through projects and assist them in planning a program of study to meet their personal long-term goals. It will be promoted to have these personal goals align with regional and national goals as well.

This would allow all students to learn from one another as well as from the person responsible for the structure of the class. It would allow advanced students to further investigate topics and tangents. Their interests and skills could be explored and other students would be exposed to their discoveries. This would both promote others to explore topics further as well as allow students unwilling or unable to explore those pursuits to at least have an exposure to them and be able to recognize more elements of understanding which they may encounter later in life. This structure also allows challenged students a way to fully participate, learn and even teach others. It offers a place of value in the school society for all members and teaches all levels of learners that they have a part in the world. Integrative learning empowers students with fewer capabilities to explore a particular area of a field and/or find a niche in the field which they can excel at. It also creates an understanding for students with more capabilities that teamwork is needed for things to function properly. In relation to various types of learners, it directly supports theories that since different people learn better from different methods (P. L Gardner, 1997), by learning from one another, as a collective team and through multiple disciplines, it is more likely that the cross-connections with result in deeper levels of meaning for all types of learners .

**School Buildings**

I have also thought about the physical structure for a school to support integrated learning. I have been perpetually working on combining a lifelong interest in architecture and spending a lot of time in local K-16 schools/universities to continually refine ideas for tangible spaces to support a structure designed for integrated learning. I have also worked on ideas to support the transitions for traditionally structured schools become integrated learning centers. However, all of these thoughts are mute points until the structure of K-12 education is adaptable enough to start to move towards a structure of integrative leaning.

**School Day Structure**

The nature of integrated learning has led has led me to have more realistic thoughts on how to solve some current issues with school day scheduling structures. Many teachers dislike trying to fit their subject into individual time slots, as it doesn't afford enough time to get into depths of topics. Others have a dislike for the four-block system, as it allows students to go a whole semester, and sometimes a year, without taking a subject (sometimes math and science, the subjects that this country's students are least able to grasp.) Integrated learning centers would allow for students to have a more uniform exposure to all of the disciplines (Chirichello, Eckel, & Pagliaro, 2005; Miller, 1992; Pedersen & Digby, ; L. Rogers & Newton, 2001; Ruggiero, 1988). It is through this argument that I feel integration has the most viable chance of acceptance. The best way to make an argument for inclusion is to address the current problems that the exclusion of certain subjects are currently creating.

**Conclusion**

If hundreds of collective years of research in epistemology and educational psychology keep reinforcing that integrative education helps with transference as well as the depth and breadth of knowledge acquisition and retention, then why isn't it being used everywhere? Admittedly, it takes more time to plan and implement and well as costs more money than the traditional structure in place in K-12 education today. However, 'the idea that it is impossible to teach people to think, is an assumption that if thinking has not been taught, it therefore could not be taught. (Ruggiero, p. 3) That is an assumption that is not conducive to the needs of society. If society needs more advanced thinkers to fulfill the needs of the S-T-E-M industries, then it is up to society to find a way to create citizens who are capable of advanced thinking.

'Experience that is integrated – that which attains the fullest possible meaning – is a primary goal of human activity… growth under the circumstances of life as an ongoing experiment involves risk and the willingness to relinquish the authority of tradition but it should enable the person as well an entire society to look critically at previously accepted believes in the light of new experience (Dewey, 1963).'

Although the development of this framework is far from over, enough educational giants have spoken to warrant a conversation on whether the paradigm of modern education itself is ready for a Kuhnian revolution. From all the information I have gathered thus far on the topic, it seems as though the giants have spoken, continue to speak, and prove, through research and publication, enough evidence that now could be the time for the theorists, researchers, practitioners and users of K-12 education to synthesize the collective works and evidence in order to cross-substantiate all fields of education and market to administrators and government officials the need for an integrative structure of education. From the information that I have gathered, the framework of STE@M has been emerging, but the writing of this article is only done as a means to give a starting point by which to find the naturally existing connections between the fields so that a structure by which to teach them can arise. I am promoting that the field of TE not become EE, but remain the discipline where other disciplines come together to be taught through reality-based application of problem posing and solving, to do this, TE needs to promote a structure by which they can represent all the other fields. Thus far, such a structure has developed here enough to show that there are definite inter-connections between the various fields of education and the simplest way for me to convey them has boiled down to the following definition. **ST?@M Education**: **' Science** and **Technology**, interpreted through **Engineering** and the **Arts**, all based in a language of **Mathematics**.'

.

**References**

**AAAS, A. A. f. t. A. o. S. (1989). *Science for all Americans*. Washington, DC: AAAS.**
**AAAS, A. A. f. t. A. o. S. (1993). *Benchmarks for Science Literacy*. Washington, DC: AAAS.**
**AACTE, A. A. o. C. f. T. E. (2007). *Preparing STEM Teachers: The Key to Global Competitiveness*. Washington D. C.: American Association of Colleges for Teacher Education.**
**Act, I. I. C. I. A. (2006). *Developing the STEM Education Pipeline*: ACT, Inc.**
**Appel, M. P. (2006). Arts Integration across the Curriculum. *Leadership, 36*(2ov-Dec), 14.**
**ASEE, A. S. o. E. E. (2008). *Engineering: Go for it! Make a difference, change the world*. Washington, DC: American Society of Engineering Education ASEE.**
**Ashby, C. M. (2006). *Higher Education: Science, Technology, Engineering, and Mathematics Trends and the Role of Federal Programs. Testimony before the Committee on Education and the Workforce, House of Representatives.* (Testimony before the Committee on Education and the Workforce, House of Representatives. No. GAO-06-702T). Washington D. C.: Government Accountability Office: General Accounting Office.**
**AWSNA, T. A. o. W. S. o. N. A. (2008). Why Waldorf Works: Everything you need to know about Waldorf education.**
**Barlex, D., & Pitt, J. (2000). *Interaction: the relationship between science and design and technology in the secondary school curriculum.* London: Engineering Council.**
**Barwell, R. (2005). Integrating Language and Content: Issues from the Mathematics Classroom. *Linguistics and Education: An International Research Journal, 16*(2), 205.**
**Berger, E. H., & Pollman, M. J. (1996). Multiple Intelligences: Enabling Diverse Learning. *Early Childhood Education Journal, 23*(4), 249.**
**Bill, H. (2006). What Does It Mean to Be Globally Competent? *Journal of Studies in International Education, 10*(3), 267-285.**
**Bloom, B. S. (1974). An introduction to mastery learning theory. In J. H. Block (Ed.), *Schools, society and mastery learning*. New York: Holt, Rinehart and Winston.**
**Bonser, F. G., & Mossman, L. C. (1923). Chapter 1. In *Industrial arts for elementary schools*. New York: Macmillan.**
**Bopegedera, A. M. R. P. (2005). The Art and Science of Light: An Interdisciplinary Teaching and Learning Experience. *Journal of Chemical Education, 82*(1).**
**Bransford, J. D., Brown, A.L., & Cocking, R.R. . (1999). *How people learn: Brain, mind, experience,***
***and school*. Washington, DC: National Academy Press.**
**Bransford, J. D., M.S. (Ed.). (2005). *How students learn: History, mathematics, and science in the classroom*. Washington, D.C: National Academy Press.**
**Brown, J. E. S., E. C. (2005). *A Handbook of Content Literacy Strategies*. Norwood, MA: Christopher-Gordon.**
**Bugliarello, G. (1988). *The Science-Society Matrix*: Science, Technology, and Society.**
**Bunge, M. (1966). Technology as applied science. *Technology and Culture 7*(3), 19.**
**Chedid, L. G. (2005). Energy, Society, and Education, with Emphasis on Educational Technology Policy for K-12. *Journal of Science Education and Technology, 14*(1), 75.**
**Childress, V. (1996). Does Integrating Technology, Science, and Mathematics Improve Technological Problem Solving? A Quasi-Experiment. *Journal of Technology Education, 8*(1), 11.**
**Chirichello, M., Eckel, J., & Pagliaro, G. (2005). Using Concepts and Connections to Reach Students with Integrated Curriculum. *Middle School Journal, 36*(5), 37.**
**Clark, A. C., & Ernst, J. V. (2007). A Model for the Integration of Science, Technology, Engineering, and Mathematics. *Technology Teacher, 66*(4), 24.**
**Clerk, D., & Rutherford, M. (2000). Language as a confounding variable in the diagnosis of**

misconceptions (Vol. 22, pp. 703 - 717): Taylor & Francis.
CNAEA, C. o. N. A. E. A. (1994). *The National Standards for Arts Education*. Reston, VA: National Association for Music Education.
Comenius. (1947). The Development of Modern Education. In R. Ulich (Ed.), *Three thousand years of educational wisdom: Selections from great documents* (pp. 614). Cambridge, Massachusetts: Harvard University Press.
Coy, M. (2007). Finding Art in the Science Room. *SchoolArts: The Art Education Magazine for Teachers, 106*(7).
Dakers, J. R. (2006). *Towards a philosophy for technology education. Defining Technological Lieteracy: Towards an epistemological framework*. New York: Palgrave Macmillan.
Daniel, V. A. H., Stuhr, P. L., & Ballengee-Morris, C. (2006). Suggestions for Integrating the Arts into Curriculum. *Art Education, 59*(1), 6.
Davis, P. J. (1994). Mathematics and art: Cold calipers against warm flesh? . In P. Ernest (Ed.), *Mathematics, education and philosophy: An international perspective.* . Washington, D.C.: Falmer Press.
de Vries, M. J. (1996). *Science, technology and society: A methodological perspective*. Paper presented at the Second Jerusalem International Science and Technology Education Conference.
de Vries, M. J. (1996). Technology education: Beyond the technology is applied science. *Journal of Technology Education, 8*(1), 7-15.
DeBoer, G. E. (1991). *A History of Ideas in Science Education: Implications for practice*. New York: Teachers College, Columbia University.
Descartes. (1947). The New Method of Thinking. In R. Ulich (Ed.), *Three thousand years of educational wisdom: Selections from great documents*. Cambridge, MA: Harvard University Press.
DeVore, P. (1976). *Technology and the new liberal arts. (SO 009 637)*. Cedar Falls, IA: University of Northern Iowa (ERIC Document Reproduction Service No. ED 133 260).
DeVore, P. D. (1964). *Technology: An intellectual discipline. Bulletin Number 5*. Washington, DC: American Industrial Arts Association.
Dewey, J. (1963). *Experience and education*. New York: Macmillan Publishing Company.
DOE, U. S. D. o. E. (2006). *Answering the challenge of a changing world strengthening education for the 21st century*: U.S. Department of Education.
Douglas, R., Worth, K., & Klentschy, M. (2006). *Linking Science and Literacy in the K-8 Classroom* (No. 9-781-9335-3101-4): National Science Teachers Association.
Driscoll, M. P. (2005). Constructivism. In *Psychology of learning for instruction*. New York: Pearson.
Driver, D., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational Researcher, 23*(7), 8.
Dugger, J., W. E. (2007). Technology Education at Virginia Tech. In V. T. s. T. E. G. Students (Ed.). Blacksburg, VA.
Dugger, J., W. E. . (1993). *The relationship between technology, science, engineering, and mathematics. (ERIC No. ED 366 795).*
Dunham, P., Wells, J., & White, K. (2002). Biotechnology education: A multiple instructional strategies approach. *Journal of Technology Education, 14*(1), 17.
EAC, E. A. C. (2004). *Criteria for accrediting engineering programs*. Baltimore, MD: ABET, Inc.
Ebner, A. (2006). Making Connections through Visual Arts. *Leadership, 36*(2ov-Dec), 26.
Eisler, R. (2005). Tomorrow's children: Education for a partnership world. In S. K. J. P. Miller, D. Denton, D. Orr, & I. C. Kates (Ed.), *Holistic learning and spirituality in education: Breaking*

*new ground*. New York: State University of New York Press.
Ernest, P. (Ed.). (1994). *Mathematics, Education and Philosophy: An international perspective*. Washington, D.C.: Falmer Press.
Featherstone, J. L. (1986). Forward. In B. Kimball (Ed.), *Orators & philosophers: A history of the idea of liberal education*. New York: Teacher College Press.
Feldmann, D. (2007). Citizenship Education: Current Perspectives from Teachers in Three States. *Educational Research Quarterly, 30*(4), 3.
Firlik, R. (1996). Can We Adapt the Philosophies and Practices of Reggio Emilia, Italy, for Use in American Schools? *Early Childhood Education Journal, 23*(4), 217.
Foster, P. (1995). Industrial arts/technology education as a social study: The original intent? . *Journal of Technology Education, 6*(2), 15.
Freire, P. (1996). *Pedagogy of the oppressed*. New York: Continuum International Publishing Group Inc.
Froebel. (1947). Froebel. In R. Ulich (Ed.), *Three thousand years of educational wisdom: Selections from great documents*. Cambridge, MA: Harvard University Press.
Furth, H. G. (1970). *Piaget for teachers*. Englewood Cliffs, NJ: Prentice-Hall Inc.
Gagne, R., Wager, W., Golas, K. & Keller, J. (2005). *Principles of Instructional Design* (5th ed.). Belmont, CA: Wadsworth/Thomson Learning.
Gardner, P. L. (1994). The relationship between technology and science: Some historical and philosophical reflections. Part 1. *International Journal of Technology and Design Education 4*(2), 33.
Gardner, P. L. (1995). The relationship between technology and science: Some historical and philosophical reflections. Part 2. *International Journal of Technology and Design Education 5*(1), 33.
Gardner, P. L. (1997). The Roots of Technology and Science: A Philosophical and Historical View. *International Journal of Technology and Design Education, 7*(1-2).
Grasso, D., & Martinelli, D. (2007). Holistic Engineering. *Chronicle of Higher Education, 53*(28).
Herbart. (1947). Herbart. In R. Ulich (Ed.), *Three thousand years of educational wisdom: Selections from great documents*. Cambridge, MA: Harvard University Press.
Herman, W. E. (1995). *Humanistic influences on a constructivist approach to teaching and learnin*. Potsdam, NY: State University of New York.
Hersh, R. (1994). Fresh Breezes in the Philosophy of Mathematics. In P. Ernest (Ed.), *Mathematics, education and philosophy: An international perspective* Washington, D.C.: Falmer Press.
Hickman, L. A. (1992). *John Dewey's Pragmatic Technology* (First Midland Book Edition ed.). Bloomington: Indiana University Press.
Hodson, R. (1991). Philosophy of science and science education. . In M. M. R (Ed.), *History, philosophy, and science teaching: Selected readings*. New York: OISE Press
Horton, R. M., Hedetniemi, T., Wiegert, E., & Wagner, J. R. (2006). Integrating Curriculum through Themes. *Mathematics Teaching in the Middle School, 11*(8), 408.
Horwedel, D. (2006). Operation STEM. *Diverse: Issues in Higher Education, 23*(20ov), 36.
Huber, M. T., & Hutchings, P. (2005). *The advancement of learning: Building the teaching commons*. San Francisco: Jossey-Bass.
Huber, M. T., & Morreale, S. P. (2002). *Disciplinary styles in the scholarship of teaching and learning: Exploring common ground*. Washington, D.C.: American Association for Higher Education and The Carnegie Foundation for the Advancement of Teaching.
IRA-NCTE, I. R. A. a. N. C. o. T. o. E. (1996). *Standards for the English Language Arts*. Newark,

**DE: International Reading Association and National Council of Teachers of English.**
**ITEA, I. T. E. A. (1996). *Technology for all Americans: A rationale and structure for the study of technology*. Reston, VA: International Technology Education Association**
**ITEA, I. T. E. A. (2000). *Standards for technological literacy: Content for the study of technology.* Reston VA: International Technology Education Association**
**ITEA, I. T. E. A. (2006). *Technology literacy for all: A rationale and structure for the study of technology*. Reston, VA: International Technology Education Association**
**ITEA, I. T. E. A. (2008). *Teaching TIDE with pride.* Paper presented at the International Technology Education Association, Salt Lake City.**
**Kalyn, B. (2006). Integration. *Teaching Elementary Physical Education, 16*(5), 32.**
**Kirkwood, J. J., Foster, P. N., & Bartow, S. M. (1994). Historical Leaders in Technology Education Philosophy. *Journal of Industrial Teacher Education, 32*(1).**
**Kornfeld, J., & Leyden, G. (2005). Acting out: Literature, Drama, and Connecting with History. *Reading Teacher, 59*(3ov), 230.**
**Kuhn, T. S. (1970). *The structure of scientific revolutions* (2nd ed.). Chicago: University of Chicago Press.**
**Laporte, J., & Sanders, M. (1993). The T/S/M integration project. *The Technology Teacher, 52*(6), 5.**
**Latour, B., & Woolgar, S. (1986). *Laboratory life: the construction of scientific facts*. Princeton, NJ: Princeton University Press.**
**Lauda, D. P. (1980). *Technology Education: A Concept in Transition.* Paper presented at the Technology Education Symposium 80**
**Lewis, T. (2005). Creativity—A Framework for the Design/Problem Solving Discourse in Technology Education. *Journal of Technology Education, 17*(1).**
**Litowitz, L. S. (2008). Engineering/Technology Education - Re:Bylaws Question. In ctte@listproc.appstate.edu (Ed.): International Technology Education Association: Council of Technology Teacher Educators.**
**Loepp, F. L. (1999). Models of Curriculum Integration. *Journal of Technology Studies, 25*(2), 21.**
**Lux, D., & Ray, W. (1971). *Industrial arts curriculum project* Bloomington, IL: McKnight & McKnight Publishing**
**Macedo, S. (2004). Crafting Good Citizens. *Education Next, 2004*(2), 10.**
**Maley, D. (1973). *The Maryland plan*. New York: Benziger, Bruce and Glencoe.**
**Marshall, J. (2005). Connecting Art, Learning, and Creativity: A Case for Curriculum Integration. *Studies in Art Education: A Journal of Issues and Research in Art Education, 46*(3), 227.**
**Marshall, J. (2006). Substantive Art Integration = Exemplary Art Education. *Art Education, 59*(6ov), 17.**
**Marzano, R. (2007). *The Art and Science of Teaching: A Comprehensive Framework for Effective Instruction*. Alexandria, VA: Association for Supervision and Curriculum Development.**
**Matthews, M. R. (1997). Introductory comments on philosophy and constructivism in science education. *Science & Education, ?*(6), 10.**
**McDevitt, T. M. O., J. E. . (2004). *Child Development*. Upper Saddle River, NJ: Merrill Prentice Hall.**
**McKee, J., & Ogle, D. (2005). *Integrating Instruction: Literacy and Science. Tools for Teaching Literacy Series*: Guilford Publications.**
**Mellado, V., Ruiz, C., Bermejo, M. L. & Jimenez, R. . (2006). Contributions from the philosophy of science to the education of science teachers. *Science & Education 15*(5), 27.**

**Merrill, C. (2001). Integrated technology, mathematics and science education: A quasi-experiment. *Journal of Industrial Teacher Education, 38*(3).**
**Merrill, C., & Comerford, M. (2004). Technology and Mathematics Standards: An Integrated Approach. *Technology Teacher, 64*(2).**
**Miller, R. (1992). Introducing Holistic Education: The Historical and Pedagogical Context of the 1990 Chicago Statement. *Teacher Education Quarterly, 19*(1), 5.**
**Minnis, M., & John-Steiner, V. (2005). The Challenge of Integration in Interdisciplinary Education. *New Directions for Teaching and Learning, 2005*(102), 45.**
**Mishook, J. J., & Kornhaber, M. L. (2006). Arts Integration in an Era of Accountability. *Arts Education Policy Review, 107*(4), 3.**
**Mitcham, C. (1994). *Thinking through technology. The path between engineering and philosophy*. Chicago: University of Chicago Press.**
**Montessori, M. (1914, 1975). *Dr. Montessori's Own Handbook* (14th, 1st Schocken Edition ed.). New York: Schoecken.**
**Montessori, M. (1992). *Education for human development: Understanding Montessori*. Oxford, UK: Clio.**
**NAE, N. A. o. E. (2004). *Educating the engineer of 2020: Visions of engineering in the new century*. Washington, D.C.: The National Academies Press.**
**NAE, N. A. o. E. (Ed.). (2002). *Technically speaking*. Washington, D.C: National Academy Press.**
**NASPE, N. A. f. S. a. P. E. (2004). *Moving into the Future: National Standards for Physical Education* (2nd ed.). Reston, VA: National Association for Sport and Physical Education.**
**National Governors Association. Center for Best, P. (2007). *Innovation America: A Compact for Postsecondary Education*: National Governors Association.**
**NCSS, N. C. f. t. S. S. (1994). *Expectations of Excellence: Curriculum Standards for Social Studies*. Silver Spring, MD: National Council for the Social Studies.**
**NCTM, N. C. o. T. o. M. (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: NCTM.**
**Olsen, D. W. (1963). *Industrial Arts and Technology*. Englewood Cliffs, NJ: Prentice-Hall.**
**Paterson, J. (2007). Teaching Literacy across the Curriculum. *National Middle School Association*.**
**Paulos, J. A. (1995). *A mathematician reads the newspaper*. New York: Basic Books – Harper Collins.**
**Pedersen, J. E., & Digby, A. D. *Secondary schools and cooperative learning : theories, models, and strategies*. New York: Garland**
**Pestalozzi. (1947). Pestalozzi. In R. Ulich (Ed.), *Three thousand years of educational wisdom: Selections from great documents*. Cambridge, MA: Harvard University Press.**
**Petrina, S. (1998a). Multidisciplinary technology education. *International Journal of Technology and Design Education, 8*(2), 36.**
**Petrina, S. (1998b). The Politics of Research in Technology Education: A Critical Content and Discourse Analysis Of the Journal of Technology Education, Volumes 1-8. *Journal of Technology Education, 10*(1).**
**Petrina, S. (2007). *Advancing Teaching Methods for the Technology Classroom*. Hershey, PA: Information Science Publishing.**
**Pinch, T., & Bijker, W. E. (1994). Social Construction of Facts and Artifacts: Or How the Sociology of Science and the Sociology of Technology Might Benefit Each Other. In W. E. Bijker, Hughes, T. P. and Pinch, T. J. (Ed.), *The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology*. Cambridge, MA: MIT Press.**

Porter, R., Oliver, & Johnson. (2006). A Systems Model of Innovation Processes In University STEM Education *Journal of Engineering Education 2*(2), 12.
Putnam, J. W., & Spiegel, A. N. (1995). Future directions in education and inclusion of students with disabilities: A Delphi investigation. *Exceptional Children, 61*(6), 553.
Raizen, S. A., Sellwood, P., Todd, R. D., & Vickers, M. (1995). *Technology education in the Classroom*.
Rogers, C. (1969). *Freedom to Learn: A View of What Education Might Become* (1st ed.). Columbus, OH: Charles Merill.
Rogers, L., & Newton, L. (2001). Integrated Learning Systems - an open approach (Vol. 23, pp. 405 - 422): Taylor & Francis.
Rohrer, K. (2005). Leave No Arts Behind. *SchoolArts: The Art Education Magazine for Teachers, 105*(1).
Rousseau. (1947). The Development of Modern Education. . In R. Ulich. (Ed.), *Three thousand years of educational wisdom: Selections from great documents.* (pp. 614). Cambridge, Massachusetts: Harvard University Press.
Ruggiero, V. R. (1988). *Teaching thinking across the curriculum*. New York: Harper & Row.
Salinger, G. L. (2003). Engineering in the K-12 curriculum. Initiatives in technology education: Comparative perspectives. In G. a. M. Martin, H. (Ed.): Technology Foundation of America.
Salinger, G. L. (2005). The engineering of technology education. *The Journal of Technology Studies*.
Sanders, M. (2006). *A rationale for new approaches to STEM education and STEM education graduate programs* Paper presented at the 93rd Mississippi Valley Technology Teacher Education Conference. Section IV: Issues in STEM Education.
Sanders, M. (2008). K-12 Sessions at ASEE 2008 in Pittsburgh. In ctte@listproc.appstate.edu, ideaGarden@lists.iteaconnect.org & Hemisphere@lists.iteaconnect.org (Eds.): International Technology Education Association.
Sarlemijn, A. (1993). Designs are cultural alloys, SteMPJE in design methodology. In M. J. de Vries, Cross, N. & Grant, D. P. (Ed.), *Design Methodology and relationships with science*. Dordrecht: Kluwer Academic Publishers.
Savage, E., & Sterry, L. (Eds.). (1990). *A conceptual framework for technology education*. Reston, VA: International Technology Education Association.
Shulman, L. S. (2005a). Pedagogies of Uncertainty. *Liberal Education, 91*(2), 8.
Shulman, L. S. (2005b). Signature pedagogies in the professions. *Daedalus*(Summer), 8.
Smith, F. (1998). *The book of learning and forgetting*. New York: Teacher's College, Columbia University.
Snyder, J., & Hales, J. (1986). *Jackson's Mill industrial arts curriculum theory*. Charleston, WV: West Virginia University of Education.
Strokrocki, M., & National Art Education Association, R. V. A. (2005). *Interdisciplinary Art Education: Building Bridges to Connect Disciplines and Cultures*: National Art Education Association.
Sutherland, D., & Dennick, R. (2002). Exploring culture, language and the perception of the nature of science (Vol. 24, pp. 1 - 25): Taylor & Francis.
Tan, K. C., & Chua, B. L. (2006). The Sound of Music and Its Link with Mathematics. *Teaching Mathematics and Its Applications: An International Journal of the IMA, 25*(4), 181.
Torres, H. N., & Zeidler, D. L. (2002). The Effects of English Language Proficiency and Scientific Reasoning Skills on the Acquisition of Science Content Knowledge by Hispanic English Language Learners and Native English Language Speaking Students. *Electronic Journal of*

*Science Education, v6*(n3).
Toulmin, C. N., Groome, M., & National Governors' Association, W. D. C. (2007). *Building a Science, Technology, Engineering, and Math Agenda*: National Governors Association.
Truxal, J. G. (1984). *Technology in Liberal Education*. Paper presented at the Sloan Foundation Conference.
Tymoczko, T. (Ed.). (1994). *Structuralism and post-modernism in the philosophy of mathematics*. Washington, DC: Falmer Press.
Tyson, W., Lee, R., Borman, K. M., & Hanson, M. A. (2007). Science, Technology, Engineering, and Mathematics (STEM) Pathways: High School Science and Math Coursework and Postsecondary Degree Attainment. *Journal of Education for Students Placed at Risk (JESPAR), 12*(3), 243.
Ulich, R. (Ed.). (1947). *Three thousand years of educational wisdom: Selections from great documents*. Cambridge, MA: Harvard University Press.
Vail, K. (2006). Is Physical Fitness Raising Grades? *Education Digest: Essential Readings Condensed for Quick Review, 71*(8), 13.
VTSOE, V. T. S. o. E. I. E. (2007). ISTEM Education information page.
Walling, D. R. (2007). The Return of Civic Education. *Phi Delta Kappan, 89*(4), 285.
Wang, J. (2005). Relationship Between Mathematics and Science Achievement at the 8th Grade. *Online Submission*.
Ward, R., & Muller, D. (2006). Algebra and Art. *Mathematics Teaching Incorporating Micromath*(198), 22.
Wells, J., Pinder, C., & Smith, J. (1992a). Algae, electronics and ginger beer. *Technology, Innovation & Entrepreneurship for Students (TIES) Magazine*(March-April), 6.
Wells, J., Pinder, C., & Smith, J. (1992b). Algae, electronics and ginger beer. Technology, Innovation & Entrepreneurship for Students *(TIES) Magazine, 6*(March-April), 27-32.
Wells, J. G. (2006). VT STEM Curriculum Class. In M. o. Class (Ed.). Blacksburg, VA.
Wicklein, R. C. (2006). Five Good Reasons for Engineering Design as the Focus for Technology Education. *Technology Teacher, 65*(7), 25.
Wicklein, R. C. S., John W. . (1995). Case Studies of Multidisciplinary Approaches to Integrating Mathematics, Science and Technology Education. *Journal of Technology Education, 6*(2).
Wiggins, G. P., & McTighe, J. (2005). *Understanding by design* (2nd ed.). Alexandria, VA: Association for Supervision and Curriculum Development.
Zammito, J. H. (2004). *A Nice Derangement of Epistemes: Post-positivism in the study of science from Quine to LaTour*. Chicago: University of Chicago Press.
Zmach, C. C., Sanders, J., Patrick, J. D., Dedeoglu, H., Charbonnet, S., Henkel, M., et al. (2007). Infusing Reading into Science Learning. *Educational Leadership, 64*(4), 62.
Zuga, K. (1991). The technology education experience and what it can contribute to STS. *Theory Into Practice, XXX*(4).
Zuga, K. (1993). A role for alternative curriculum theories in technology education. *Journal of Industrial Teacher Education, 30*(4), 19.