STEM Pedagogical Commons for Contextual Learning:

How Fewer Teaching Divisions Can Provide More Relevant Learning Connections

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Throughout modern education, epistemologists and theorists have promoted the concepts of interdisciplinary studies as being a more advantageous way for learning to occur. In the 17th century, Comenius (1947) said that students “should get accustomed to penetrating to the real roots of things and to take into themselves their true meaning and usage, rather then read, perceive, memorize, and relate other people’s opinions.” Centuries later our school systems are not reflecting that penetrating learning, but instead are primarily based on rote memorization. This has resulted in things such as, *A Nation at Risk* where it was said that there is ‘a rising tide of mediocrity that threatens our very future as a nation and as a people’ (National Commission on Excellence in Education, 1983). If mediocrity is threatening, then what has been called for is an outcry to more universally educated citizens. The future calls for well educated citizens who are able to use higher order thinking skills and creative abilities through the understanding and synthesis (Addams, 2002, Ayers, 1996, DeBoer, 1991, Herman, 1995, Hickman, 1990, ITEA, 2000, McDevitt & Ormrod, 2004, Ruggiero, 1988) of technology, science, engineering, and mathematics to anticipate and solve the problems of tomorrow (Dugger, 1993). Each discipline has addressed their own ideas of functional literacy within their own realm.

The debate, going on for quite a while now, is on how to achieve functional literacy across the disciplines. In 1952, the Grinter Report de-emphasized the 'art and practice' approach to engineering and provided more focus on the science of engineering. It called for: 'an integrated study of engineering analysis, design, and engineering systems… and making full use of the basic and engineering sciences.' *(ASEE)* (Dugger, 1993). This was a good start for engineering education to reach out and encompass elements from other fields. In the 1980’s the field of science spent a lot of energy discussing this topic as well. The co-chair of the NSB Commission on Precollege Education in Mathematics-Science-Technology (1983) stated that the ‘commission recommended criteria for improving and changing instruction in the sciences with emphasis being placed on observations, student inquiry, and 'hands-on approaches to learning.' (Dugger, 1993). Technology education [TE] has had this debate internally for its whole existence with the argument over whether to align itself with vocational or instructional educational pedagogy. This debate is so engrained in the field of TE that the field itself has changed its name more
then once in the past century, to accommodate different structures, it has been vocational education, industrial arts and is currently TE.

It is agreed on that ‘the study of systems is a key component in the disciplines of technology and engineering. By studying technology and engineering, one develops… divergent as well as convergent thinking processes… crucial in learning how to solve practical problems as contrasted to just solving scientific, mathematical and other types of problems (Dugger, 1993). The task given to current educators to solve this problem is certainly taxing their convergent thinking processes. The National Research Council (NRC, 1992) on Science Education Standards and Assessment stated that the integration of school science, mathematics, social studies and technology curricular should be the joint responsibility of these school disciplines. Slow progress has been made in finding common ground to teach these disciplines in an integrated fashion.

This paper will focus on the predominating and congruent pedagogies and supporting theories recognized in each of the individual disciplines to show which commonalities make logical arguments in favor of interdisciplinary science, technology, education and mathematics [STEM] studies. Evidence will be given to show some of the ways in which STEM is currently in a position to be a leading venue for moving towards a more holistic approach to teaching and learning [T&L]. The reasoning behind STEM education is to purposefully address the natural inter-connections between the individual disciplines of science, technology, education and mathematics [S-T-E-M].

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 [technology educators] are moving towards engineering education and STEM versus becoming part of science (W. Dugger, Jr., personal communication, October 17, 2006).

This statement sums up the feelings of many disciplinarians in that they see the benefits of joining forces with other subject areas, but at the same time do not wish to loose the autonomy that their field currently has. There have been different approaches to this issue for as long as formal education has existed. For
instance, 'some view technology as a part of science,… others [closely align it] with engineering. Some countries place technology [within] vocational education. Others believe that technology should be taught in an integrative manner with mathematics, science, social studies and other subjects' (Dugger, 1993). These types of relationships between the disciplines fall into different categories that define their levels of connection. Barlex and Pitt have broken it down into three types of categories that inter-connected curriculum fall into, co-ordination:.. the timing of topics within each subject to correspond with each other, collaboration:… curricula [has] some, but not all activities within each subject… designed to establish an effective relationship and integration: involves forming a single subject. This is an inappropriate form of the relationship. Barlex and Pitt (2000) argue that submersing fields within one another loses the uniqueness of the field that makes it worth studying. This addresses the reason why the branches of disciplines (silos) of S-T-E-M continue to have a solid existence. It is now time for a reflection on the commonalities that allow for interdisciplinary STEM in the collaborative sense.

Despite educational leaders having access to acquired knowledge about T&L; economics, politics and tradition have hindered the progress of incorporating interdisciplinary studies into public and private educational systems. The idealized concept of holistic learning is rarely the most efficient, cost-effective and/or socially or politically promoted view of what form educational programs should take. (Ruggiero, 1988) For these reasons, and more, our current educational system has developed with silo disciplines; neatly packaged curriculum and very little room for teachers to promote reality-based, inter-connected learning versus memorizing isolated facts. “Teachers who employ only facts seldom integrate them with other aspects of the subject matter…. Facts by themselves rarely touch the individual or his life in any significant ways. … It is possible for students to memorize any concept without really understanding it” (Harmin, Kirschenbaum, and Simon, 1976). Aside from a strong history of decontextualized learning, politicians promote making changes that reflect only part of the idealized goals. Take for instance, a United States Department of Education [USDE] STEM program currently trying to ‘determine which federal education programs are most effective in raising achievement in math and science, which deserve more funding, which should be consolidated… [and] align these education programs with the goals and
aims of the NCLB Act (USDE, 2006). By only evaluating federally affiliated education programs, as well as those that align with ‘the goals and aims of the NCLB Act,’ a skewed result of ‘best programs’ will result. This will give false justification to continuing on with promoting programs that are the ‘best of the currently used’ which is different from the best promoted and practiced programs. Instead, evaluating all predominant educational programs, would lead to finding the most effective ones to promote. Since, it is only when overwhelming doubt arises that these more convenient modes of education are reviewed and revamped to more closely meet idealized concepts of education, it is up to those who understand these discrepancies to publicize their doubts to the general public as an appeal to change the policies that govern educational changes.

Freire (1996) has made fervent public appeals revolving around such notions. His broad statements such as; “disconnected content narration versus reality-based education result[s] in students as memorization depositories. Acting as though students are without knowledge… negates education and knowledge as processes of inquiry, [which] develops critical consciousnesses enable[ing] them to be more directed world transformers.” He speaks not only to the culture of educational development, but also to the culture of world development. This is quite appropriate as the goal of education, as stated by a well-known politician, is to provide[s] the necessary tools, equipment by which we learn how to learn... to give every one of us an instrument, which we can use to acquire information at any time we need it” - You Learn by Living, 1960 – Eleanor Roosevelt (Ayers, 1996). Given this, what is needed is the development of a knowledgeable population of people best able to comprehend and shape the next generation of world developments and perpetuate education to those that come after them. Unfortunately we are not producing those types of people on average. Harvard’s David Perkins has found that though most students are deficient in reasoning skills, they are even more deficient in the ability to produce ideas (Ruggiero, 1988).

Growing numbers of students are not prepared to do college work. Luckily the disciplines have recognized their roles in this problem and “are in transition” (Huber and Hutchings, 2005).

In recent years the growing percentage of ill-prepared students has been having a major impact on businesses. There has been a significant lacking of skilled workers in this country; while at the same time
there has been a vast amount of skilled workers being trained abroad (Freedman, 2005). “Globalization is pushing similar [pedagogical] developments in countries everywhere” (Huber & Hutchings, 2005). Globalization has added to a need to unify more practices in T&L. Businesses are becoming more and more involved in promoting STEM initiatives in the hopes of realigning the educational efforts with the needs of industry today. A good example are the grants given to Texas by the Texas High School Project by business and educational partners including the Bill & Melinda Gates Foundation, the Michael & Susan Dell Foundation and other business affiliated members to create the T-STEM program (Texas Education Agency [TEA], 2006). This is not an isolated occurrence, more and more businesses, politicians and educators are working together to promote common goals. In academia and industry both groups [technologists and scientists] saw a relationship that is both dynamic and influential; but the relationship in secondary schools appeared to both groups to be almost non-existent (Barlex & Pitt, 2000). They argue that cooperation among disciplines provides realistic dynamics and influences that allow students to learn how to accommodate to the real world. Co-operation… can also have the effect of encouraging the use of common language, common analogies and an appropriate level of detail across the two [or more] subjects thus avoiding misconceptions and regression (Barlex & Pitt, 2000). The easier it is to engage other subjects, due to factors like common language, the easier it is for students to realize how to apply knowledge from one curriculum to another. Recently the concept of STEM education has surfaced as a way to connect the silos. Concurrently, a large effort had been initiated by Carnegie Academy for the Scholarship of Teaching and Learning (CASTL) to research the common factors across all fields of signature pedagogies (Huber & Hutchings, 2005). These results will be excellent for assisting in the creation of contextual learning environments that support elements of all types individual and hybrid disciplines. Scholars of T&L must ‘speak in a language that their colleagues understand,… the literature of one field … may be hidden from the view of others by its languages, methods, and specific concerns, but these literatures are now becoming known more broadly’ (Huber & Morreale, 2002). Now that the disciplines are being offered a better way to communicate and work together, the task at hand will seem less daunting.
Guiding Position

STEM education is currently in the best position to give contextual meaning to teaching and learning the concepts of the four disciplines because it provides relevance not previously achieved in the traditional silo approach.

Traditional Isolated Silos

Unrelated silo disciplines are like fish in nets, you can see what they look like, but you really no idea what they can do and what they’re like. They are however, much easier to control. Only through letting discovery exist in reality can the true depths of things be learned about. Dewey said, "We learn, but only at the end, that instead of discovering and then connecting together a number of separate realities, we have been engaged in the progressive definition of one fact" (Hickman, 1990). With education divided in to rigid silos, a true understanding of content cannot be achieved out of context with the other fields. The disciplines standards have helped to regulate ‘turf wars’ (DeBoer, 1991) between the disciplines, but until curriculum can reflect the nature of integrated subjects that exists in reality, there will be inevitable struggles for hierarchy among the disciplines to be recognized as dominant in integrated curriculum. These politics are another reason why it is suggested that each discipline incorporate elements of the others into their own versus trying to establish a fully blended curriculum to fit the needs of all the disciplines involved (DeBoer, 1991). Thematic cooperation among the disciplines is a predominating suggestion on how to obtain cross-curricular cooperation without forfeiting the unique characteristics of each discipline involved.

Signature pedagogies are also characterized by what they do not impart. For instance, there are hidden pedagogies in what is not paid attention to, the message of being unimportant is sent versus the message of time restraints or whatever else might have influenced the omission. (Shulman, 2005b). Sometimes pedagogical elements are chosen for specific reasons that will assist students learning, but most of the time, these are formed from habit of professional practice or ease of instruction. “Teachers can be creative within the boundaries of signature pedagogies, but the frameworks are very well engrained in their individual disciplines” (Shulman, 2005b). This is good in the sense that once students
are “aware of the patterns, they can open their minds to think on problems versus structure, but it is bad in
the sense that it may not be the best way to teach and learn. This in turn, distorts some knowledge”
(Shulman, 2005b). Teachers need to understand what they are sacrificing in T&L within the pedagogical
structures they establish for ease of execution. There must be a balance of convenience and purposeful,
supported signature pedagogical components.

Science Education [SE] as a Silo

Traditionally the field of science has been based on the thought that the world around us is
comprehensible (DeBoer 1991). Basing the study of science simply on making sense out of the world is
what John Dewey said kept the Greek culture from developing experimental science (Hickman, 1990).
Nor did they seem to have the view that the natural or mathematical sciences could serve societal
functions (Hickman, 1990). Following this philosophy, the study of science would be based upon making
sense out of the world. The focus of teaching science was utilitarian but focused on science study as a
means to some end other than the satisfaction of the natural desire of humans to know and to understand
(DeBoer, 1991). This quest for ordering the world is the root of science, but hardly represents the breadth
of science. The traditional disciplines [biology, chemistry, physics, earth and space sciences] are the
“intellectual territory from which the content of school science is drawn. Such a perspective dictates in
large measure the structural organization (by discipline) of the science content.” (NRC, 1992, p. 4) In
school science the standard curricular offerings have not yet expanded to incorporate the every growing
realms of science. Neither does the current educational system purposely afford the learners the
opportunity to apply knowledge across fields, not even within the divisions of science itself.

It is when technology, and its imperfections, combines with the exactness of science that actual
human-based potentials can be realized. “Technological knowledge has to be contextualized. Science
knowledge is decontextualized, abstracted, built on unreal, perfect model. …Technological knowledge
has to take the earth as it is” (Layton 1933 p. 59) (Barlex & Pitt, 2000). It is this abstracted quest for
perfection that can hinder the advancement of science and why, when teamed with technology, the
potentials within the field of science are expounded. ‘Science has its small, logical steps, in which
dispassionate people gradually advance knowledge;… but the milestones in science have been made by individuals with commitment and creativity, thinking divergently, apparently illogically, and by huge leaps of the imagination (Barlex & Pitt, 2000). This is oppositional to the didactic way in which science has been taught. The element of creative discovery has been significantly lacking in the teaching of science.

There are three dominant interpretations of what it means to teach science: (1) as structured bodies of knowledge… easiest to implement (2) as a set of investigative processes (3) as a human activity closely interconnected with its technological applications and with the rest of society (DeBoer, 1991 p. 219). The current system primarily uses the first type, despite the fact that it is not the best way of T&L. Teaching a structured body of knowledge lends itself to content rich curriculum containing isolated hands-on sessions used to show specific scientific practices and methods. In practice, scientists believe that through the use of the intellect, and with the aid of instruments that extend the senses, people can discover patterns in all of nature (Rutherford & Ahlgren, 1990). Based on this, it is could be argued that a scientist must also have knowledge of such extension instruments, and the advantages and limitations they impose on science, in order to fully understand the observations that can be made. This concept leads to an initial reasoning for a foundation in cross-curricular studies, if knowledge of one field cannot be understood more deeply without knowledge of another field, then learning elements from both fields would provide the best basis for the learner.

Technology Education [TE] as a Silo

The [technology] laboratory, previously conceptualized as a place to make things, graduated into more of a place to learn the interconnections of things (Zuga, 1991). The fundamental comprehension of technological content broadened further as ‘human adaptive systems’ were categorized more formally. As technological innovations occur, these systems are redefined and added to. (Dugger, 1993). 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 (Zuga, 1991).
During the history of TE, different taxonomies promoted varying levels of integration with different fields of study. (Zuga, 1991, Dugger, 1993). Despite which combination of disciplines were chosen, it became difficult to avoid incorporating elements of science and technology. This integration has led the epistemologies of technology, science and social studies to diverge farther and farther from the ancient Grecian philosophy that the ‘thinkers’ had little in common with the ‘doers’ of the world (Zuga, 1991). Seeing as the western world revolves around the development and use of technology, it makes it necessary that all citizens understand inter-connections between the fields in order to be proficient in the use of technology and the decisions that affect their own lives and that of their environments. The lack of the use of structured textbooks and curricula made TE more easily able to adapt then it was for other individual disciplines (Zuga, 1991). Also the lack of standard’s based tests, used in the traditional disciplines, allowed for teachers to have more autonomy in their content and methods. For a large part, individual technology teachers are quite in control of the depth and breadth of integrated subject matter within the TE discipline.

Engineering Education [EE] as a Silo

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). It has not yet become a recognized discipline of it’s own in the public K-12 school systems in the United States have as the S-T-M are have. In England’s school system, when students study ‘design and technology’, what they are essentially studying is engineering (Barlex & Pitt, 2000). Within the STEM relationship, the act of using science and math to design new technology is the definition of engineering. Since engineering is a result of science, technology, and arguably, mathematics as well, it has no history of being a silo discipline.

Mathematics Education [ME] as a Silo

“The foundations of mathematics are not as secure as was claimed by Euclidean thought. As in science, mathematics was originally based on a desire to make order; mathematics has since expanded to include the investigation of mathematics in infinite ways”(Ernest, 1994). As with mathematics, ME was also based on making order. If you wish to understand why professions develop as they do, look at their
forms of professional preparation. Most professions are taught in-line with how the research aspect of them is conducted (Shulman, 2005b). Traditionally mathematics has rarely been ‘let out of its box’ to interconnect with other disciplines. “It’s time to let the secret out: mathematics is not primarily a matter… performing rote computations. It is a way of thinking and questioning that may be unfamiliar to many, but is available to almost all” (Paulos, 1995). Feynman, in *The Character of Physical Law* stated that, ‘mathematics is a language plus reasoning; it is a language plus logic. Mathematics is a tool for reasoning.” (Dugger, 1993) Eye-opening statements, like this one made by mathematicians, are leading the way for ME to follow the lead that mathematics research has taken. Only when there are significant changes in the industry side of things are the education aspects altered significantly as well (Shulman, 2005b). Mathematics as a way of thinking denotes universal application, which breaks down thoughts of mathematics being disconnected from S-T-E, but rather makes it a base from which the disciplines, including itself, can operate and explore.

**Connected Silos**

TE may have initially developed as a discipline in a naturally interdisciplinary manner, but EE, by its nature, soon followed. SE influenced ME to throw open the doors for the disciplines that represented fundamental knowledge of the universe to join those that represented constructed knowledge. It wasn’t long before the whole field of mathematics was released from the being a base discipline of ‘what is’ and let far out of the box to become a fully integrated contributor to ‘what can be.’ Each of the silo disciplines are now open to cross curricular content and methods incorporation into their own fields.

**Pedagogical Changes Across the Disciplines**

*Current Trends in SE*

The current predominant epistemological trend in science has shifted dramatically in the past quarter century ‘from teaching science as a body of knowledge to that of experimenting with scientific theories’ (Hodson, 1991). This broadening of the accepted field of teaching science has added many more conceptual and contextual areas of investigation into the promoted curriculums. In doing so, science has itself welcomed in the study of other fields. The list of agreed upon points in SE include thoughts on
observations, theories, factual knowledge, invention, evidence, results, process and the continual evolution of theories (Hodson, 1991). The disagreement does not come in what to teach, as it is apparent that in order to teach invention, engineering is included, and to teach results, mathematics is needed and to teach the basics of process and the depth of any of the other fields, technology is needed. The disagreement comes in what balance of content to teach from each area. Perceptions of some is that socially relevant science is not as rigorous as disciplinary science… thus it lacks the status needed to make it more popular with college-bound students (DeBoer, 1991, p. 234). When technology is seen by students as being considered important to teachers, administrators, politicians and industry, they will put value into pursuing knowledge in that content area. In England, “science educators described the science/technology relationship in industry as highly variable, depending on the industry, with technology as applied science figuring largely. Their view was echoed by the design & technology educators (Barlex & Pitt, 2000). They were also asked which model they would like to see as the basis for developing the science/design & technology relationship in schools. Here the response from both groups was mixed, with most commenting that the exact nature of the relationship would depend on the topics being studied by pupils (Barlex & Pitt, 2000). This is reasoning for interdisciplinary studies based in individual disciplines. Using this method allows a subject to remain dominant and lead the inquiry, but accommodates the views, methods, content and context of other fields of study. This concept was already known back in the 1600’s; when Comenius (1947) said, the “individual sciences are badly taught unless a simple and general survey of the total knowledge is given before. … never instruct anybody in such a way that he/she becomes perfecting one branch of knowledge to the exclusion of others.” There are few current areas of the S-T-E-M disciplines taught in K-12 that are not exclusionary in definition, two examples of branches of science that are intimately woven with other disciplines follow. “Geography (is an) example of a science for which training in other branches of learning is useful, for in geography, mathematics, the natural sciences and history are combined” (Herbart, 1947). Physics is another example. “The study of the lawful, predictable parts of the physical world has a name. The name is ‘physics’. The study of the lawful, predictable parts of the social-conceptual world has a name, the name is ‘mathematics’” (Hersh,
1994). In this definition the strong interconnection between physics and mathematics is evident, as well as the basic difference. With both of these examples, geography and physics their connections to other disciplines were easy to recognize, but no direct path between the two contents or methodologies were evident. Since it is impossible to teach these subjects without crossing discipline boundaries, having an understanding of the interconnections between disciplines would make the instruction more meaningful.

SE itself now promotes the merits of interdisciplinary teaching to provide a deeper understanding for all learners. The American Association for the Advancement of Science (AAAS, 1989) has included a section on the nature of technology in *Science for All Americans*. Within that section the primary points covered include the ideas that; technology draws and contributes to science, engineering combines scientific inquiry and practical values, technologies always have side effects and can fail, the human presence, technological and social systems interact strongly, social systems restrict technology, technology decisions are complex (AAAS, 1989). These are only a few of the ways in which the SE community formally welcomed in the disciplines of technology, mathematics and engineering.

Virtually everyone accepts some form of social relevance in the science curriculum as long as it does not threaten long-held traditional values about the integrity of the science disciplines themselves. DeBoer has given three reasons for teaching socially relevant science.

1. the student is motivated to learn the science from familiar contextual science…

2. school subjects… should inform and enrich the lives of individuals,…[accomplished] best by teaching things in everyday life,… this creates functional citizens

3. it is important for the health and well-being,… and perhaps even the survival,… of the human race…. It [offers a] values education (DeBoer, 1991, p. 234-7).

This view extends beyond the classroom and into community effects as well.

In order for science learners to feel comfortable in multiple types of situations, it is necessary to teach using multiple types of situations so that learners are able to get a foundation that will allow them to understand the scope of science and recognize when and how they are engaging in it.
The construction of a philosophically more valid science curriculum requires that adequate attention be devoted to each of the following: (1) the exploration of… existing views… and the creation of new theoretical ideas. (2) experimental work…. (3) recording and reporting of findings and ideas using language styles approved by the community and the achievement of consensus by discussion and criticism” (Hodson, 1991).

When other disciplines are brought into the realm of science, it is necessary to make sure that the language adapts appropriately to both be understood by the science community as well as accurately represent the information from other fields. Each discipline holds common views about its own subject, but within each there are varying views “about the other subjects, few of which coincide with the view from inside that other group. This indicates that if there is to be a useful relationship between science and design & technology in secondary schools a first necessary step will be to find ways by which the two communities can begin to understand one another (Barlex & Pitt, 2000). “What is preferred is that science education includes teaching a process of learning as well as the content of the field. This allows the learners to understand the cultural tools and conventions [languages] and how to use them….. It … teaches them how to apply the knowledge of such concepts outside the classroom in the future” (Driver, 1994, p. 6). This contributes to the creation of life-long learners.

The National Science Education Standard’s [NSES] (National Research Council, 1996) gave significant fuel to the development of a STEM movement by making concerted overt efforts to include other disciplines in their own standards. By doing this, they are themselves, promoting that interdisciplinary STEM studies are intrinsic to the advancement of the study of science. The goals for school science that underlie the NSES are to educate students who are able to: experience the richness… of knowing… and understanding the natural world; use appropriate scientific processes and principles;… engage intelligently… about matters of scientific and technological concern; and increase their economic productivity through [being a] scientifically literate person (National Committee on Science Education Standards and Assessment [NCSESA], 1996). These goals define a scientifically literate society. Based on these goals, the eight categories of content standards developed are; (1) unifying concepts and
processes in science, (2) science as inquiry, (3) physical science, (4) life science, (5) earth and space science, (6) science and technology, (7) science in personal and social perspectives and (8) history and nature of science (NCSESA, 1996). With the promotion of these goals and content categories, the organization realized a shift from a silo pedagogy to that of an interdisciplinary pedagogy. Embedded in their standards is a statement acknowledging this. They say that the current standards put more emphasis on many things including the following; ‘learning subject matter disciplines of inquiry in technology,… integrating… aspects of science, implementing inquiry,… abilities, activities that investigate and question,… using multiple process skills in context, using evidence and strategies and results for explanation and argument,… communication’ (NCSESA, 1996). All of these items correlate to other subject matters in one way or another. For instance, understanding matters of scientific and technological concern directly calls the realm of technology into that of science. The categories of content including science in personal, social, historical and the nature of science give reference to the inclusion of engineering. The standards involved with investigating, questioning and using evidence directly correlate to utilizing elements from mathematics. By drawing in the fields of T-E-M as well as referencing the inclusion of the social science the goals and content of the standards are framed with contextual meaning in mind. Each of the other three disciplines have relied on these ground-breaking SE standards to help guide their own standard’s development in revolutionizing their previously silo epistemologies to include formal connections to the field of science within their own realms.

Current Trends in TE

If science is the study of the natural world and is justified as being important, then TE which is the study of “the man-made world has just as much content to study…There is a need to maintain hands-on for all students. The content should be the same, technological literacy, but the delivery can be different to accommodate the needs of the students” (W. Dugger, Jr., personal communication, October 17, 2006). TE (has) as a central tenet, the notion of technological literacy (Dakers, 2005). With a rapidly changing world, the content of technological literacy also changes, but the definition stays the same, being someone who can function in a rapidly changing world, who can continue to learn from building on
the knowledge already acquired. To be adaptable and technically literate, one must understand the basis of systems and connections. (Dugger, 1993). This knowledge usually extends to an understanding of connections to other disciplines.

There are many threads of the nature of technology that directly align with the nature of science. The two fields have become interdependent on each other. Despite the fact that science still exists without technology, there are few instances where it can be deeply understood, developed, tested, verified and/or applied without technology. There are few instances where science has not been affected/changed by technology including its natural laws, theories and principles. Dewey states that scientific advances are technological advances: they are advances in the uses of tools in order to improve and test inferences (Hickman, 1990, p. 116). Science provides the framework by which all technology is developed and structured to function. Likewise, technology provides motivation and direction to all the fields of science (AAAS, 1989). Developments in science lead to new technology, which leads to new discoveries, and the cycle spirals out in all kinds of directions. Technology and science are both “intricately woven into human activity and the developments and understanding of each is influenced by human capabilities, cultural values, public policies and environmental constraints. Both fields use similar methods for understanding and developing new concepts and theories” (AAAS, 1989). Not only do both fields figure out the world in similar ways, but often both various technologies and scientific elements are combined for the development of new products and discoveries.

Due to the fact that technology inter-relates with science so deeply, it can affect science to the point of changing it that is where the separation of the differences in the two become vague. It is hard to understand this revolving concept that man-made technology and engineering factors can cause permanent changes to the natural elements of our universe. Similarly engineered technology has changed the scope of mathematics especially with the development of computers that have offered new possibilities for mathematics. These types of interactions are relatively new investigations for these. “It is true that engineered technologies usually have a more significant
impact on society, yet things such as natural disasters can have a more immediate impact (AAAS, 1989). We are constantly reminded that engineered technologies may frame our society and may change science but we are still at the mercy of nature.

Paul Gardner (1994) offers a framework for analyzing the relationship between science and technology. He proposes four possible models.

1. Science precedes technology. Technological capability grows through applied science - thus as scientific knowledge expands, so does technology. This view of technology as applied science (or TAS) is widely held, and clearly some key technological advances have been made possible through scientific discoveries.

2. Science and technology are independent disciplines or domains, with different goals, method and outcomes.

3. In the materialist view, technology is seen as historically and ontologically prior to science. Technology precedes science. Indeed, scientists cannot push forward conceptual development without the tools, instruments and other artifacts created by technologists.

4. Finally, there is the interactionist view in which science and technology are seen in a dialectical relationship, with each informing and being challenged by the other. This view recognizes their differences but also their inter-relationships, with neither science nor technology being seen as the dominant partner. Gardner, Paul. (1994) (Barlex & Pitt, 2000, p. 16-17).

It is the interactionist view that supports the basic concept of STEM in the sense that it is desired that the hierarchy of the disciplines will be broken down so that each has the chance to be an equal contributing member.

The Technology for All Americans Project [TfAAP] developed the standards which naturally include the necessary elements of the other fields associated with STEM that are intrinsic to the advancement of the study of technology. Some of the more explicitly linked of these standards include:

- the inclusion of biological systems,… systems understanding [that] usually require[s] knowledge from a variety of fields especially S-M-T,… understanding of the use of resources and engages a variety of mental strategies… developed through experiences in designing, modeling, testing,
troubleshooting, observing, analyzing and investigating, Assessing and forecasting processes involve,… determining quality and costs, evaluating risks,… projecting trends and future developments and anticipating possible consequences…. The nature and evolution of technology is influenced by many factors, including the following: needs of society and individual or group desires, information base, intellectual and social climate, education of the citizens, social acceptance and compatibility, level of development of related technological components, devices and systems, level of talent and expertise available, economic capability and desire of society to support technological development and human intervention and innovation…. Science is a study of the natural world, and technology extends people’s abilities to modify that world. Science and technology are different, yet symbiotic. Technology is much more than applied science and science is quite different from applied technology. When people use technology to alter the natural world, they make an impact on science. Science is dependant upon technology to develop, test, experiment, verify and apply many of its natural laws, theories and principles. Likewise, technology is dependant upon science for its understanding of how the natural world is structured and functions (Technology for All Americans Project [TfAAP], 2000).

These statements about the nature and evolution of technology are very similar to those made in the nature of technology section of Science for All Americans (AAAS, 1989). They match so closely that they implicitly show the agreement between the two organizations that govern each of these disciplines. The standards included above are the ones which most closely link the discipline of TE to those of SE, EE, and ME. Science is brought in under biological systems, resources, strategies and more. Engineering and technology are so closely aligned that the majority of standards developed for TE, which include research and development, have merit within the field of EE. TE calls in ME formally with the incorporation of testing, analyzing, assessing, determining, evaluating and other strategies of deciphering. This establishes mathematics not only as a language of science, but also as a language of technology. Each of the three disciplines have been openly invited to not only participate but to explore the
connections and implications of themselves to TE. Given the built-in adaptability of TE, this invitation establishes this field as the most closely in line with those that might potentially be developed for STEM.

Current Trends in EE

Engineering is the profession in which knowledge of the mathematical and natural sciences gained by study, experience and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind (Engineering Accreditation Commission [EAC], 2004). The comparison of engineering and technology indicate remarkable similarities. Many references use engineering and technology synonymously (Dugger, 1993), however, engineering is not as encompassing as technology. Technology, being the study of the human-made world, (Dugger, 1993), includes purposeful and unintentional human-made products. Ideally engineering is purposeful technology that “aids society and its members with limited negative impacts on society and the environment. Since new creations are not just limited by science, math and technology factors, but also by societal influences and laws, engineering does not have an open design process” (National Academy of Engineering of the National Academies. [NAENA] (2004). Engineering is the use of creativity and logic, based in math and science, utilizing technology as a linking agent, to create contributions to the world.

In [EE], pupils can use the technical knowledge and understanding acquired in science to justify technical design decisions in design & technology. If the technological purpose for acquiring such technical knowledge and understanding is made explicit to pupils in the first place i.e. you can use what you find out to make better design decisions; such investigations become authentic and are much more likely to be taken seriously by the pupils (Barlex & Pitt, 2000). EE studies have the position of governing most of the research and development explorations that come about from combining elements of S-T and M.

Currently there is a trend to advance into the future of engineering as primarily a team-based enterprise (NAENA, 2004). With the use of technology, engineering teams can be physically placed in locations, either for professional or personal convenience, and be able to converse in real-time, at any
time, with precision and clarity to all members of a global virtual team (Freedman, 2006 & NAENA, 2004). This has impacts on the issue of creating teams of engineers to work on projects in order to create a balance of knowledge, versus expecting an individual to be able to grasp and apply such vast amounts of knowledge. For students to be successful they must learn to operate as part of a team, much as people do in society. They must “learn to evaluate needs, wants and opportunities as well as how to respond to them in the most responsible, enjoyable, supportive, feasible and effective ways. By understanding these processes, students become discriminating and informed users as well as innovators” (Barlex, 2006).

Both advances in technology and science have major impacts on engineering. Such knowledge is a constant revising factor for the applications and understanding of how things connect and combine. It is of vital importance that engineers understand the necessity of being aware of impacting advancements in other disciplines and maintain an ability to continue to comprehend and incorporate such knowledge into their specific fields (NAENA, 2004). Not only should engineers be aware of advancements and discoveries, but also they should be aware of what pursuits are being focused on in relating disciplines.

Engineers are no longer only responsible to the companies that they work for, but are receiving increasing pressure to make developments that also assist societies and people without the knowledge and/or resources to do it for them (NAENA, 2004). This brings engineering further away from the realm of what could be and further into the realm of what should be. Engineers are expected to not just be accurate, but also to produce things with limited impacts on their users, society as a whole and the environment (NAENA, 2004). As our society becomes more and more aware of and concerned with technological effects on nature and society, there is more and more concern to develop the social consciousness of the future engineer. More then ever before, engineers are required to design with safety and reliability in mind (NAENA, 2004). EE programs around the world are aware of all of these changes and are in constant reevaluation efforts to reframe their programs to produce the types of engineers needed to work in today and tomorrow’s societies. There are two major focuses of these changes, one is to educate future engineers deeper within particular disciplines and the other is to educate them with a broader spectrum in interdisciplinary practices (NAENA, 2004). The larger, more successful EE
programs are offering both and allowing students to decide what balance of breadth and depth they need to pursue in order to be best prepared for their particular concentration of engineering interests and goals (NAENA, 2004). The scope of engineering is so broad that where one engineer needs depth of a particular content knowledge another may need more of a breadth of the scope of knowledge of the field, many times engineering teams have members with varying degrees of these types of knowledge to create a balanced team.

The Accreditation Board for Engineering and Technology [ABET] standards ramped up this movement of producing a more universally aware engineer, by promoting the following abilities as being of primary importance for instilling in developing engineers.

These include abilities to; (1) apply knowledge of M, S, E, (2) design and conduct experiments as well as to analyze and interpret data, (3) design a system, component or process, (4) function on multi-disciplinary teams, (5) identify, formulate, and solve engineering problems, (6) understand of professional and ethical responsibility, (6) communicate effectively, (7) understand the impact of engineering solutions, (8) engage in life-long learning, (8) have a knowledge of contemporary issues and (9) use the techniques, skills, and modern engineering tools (EAC, 2004).

The standards above are written in a broad way to encompass the enormous scope of engineering. Science is represented in areas of application, components, formulations, impacts and skills. Technology is intrinsically involved in every standard of engineering with the arguable exception of working in multi-disciplinary teams as this is often the case in technology, but not always. Also all technologists do not necessarily use engineering tools, but they are used frequently within technology. EE is heavily reliant on ME to address the standards of application, experimentation, analysis, interpretation, formulation, communication and many of the other active parts of engineering. The other three disciplines are absolutely necessary for the advancement and comprehension of EE. Given the relationship of EE to TE, the standards of EE are also tied very closely to with those that might potentially be developed for STEM.

*Current Trends in ME*
Schawab’s (1978) four ‘commonplaces of teaching’ mathematics are the subject, the learner, the teacher, and the milieu of teaching, including the relationship of mathematics T&L, 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 interdisciplinary 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, 1990). So in teaching about society and how mathematics can transform it, it becomes apparent to students how math is applicable and naturally an interdisciplinary part of science, technology and engineering.

The current predominant epistemological trend in mathematics is very much in line with interdisciplinary and constructivist views. The philosophy of mathematics is changing, it is said to be in the midst of a ‘Kuhnian revolution (Ernest, 1994). There is a multidisciplinary ‘maverick’ tradition emerging in the philosophy of mathematics itself (Ernest 1994). Wittgenstein, Lakatos, Putnam, Wang, Davis, Hersh, Kitcher, Tymoczko, proposed that ‘the philosophy of mathematics is to account for mathematics more fully, including the practices of mathematicians, its history and applications, [its] place… in human culture,… including issues of values and education, in short, describing the human face of mathematics’ (Ernest, 1994). This concern with the social dimension of mathematics promotes a ‘desire to see a multidisciplinary account of mathematics drawing inspiration for many currents of thought, including (among many), social constructivism and the rhetoric of science (Billig, Knorr-Cetina, Latour), post-structuralism (Focault, Walkerdine), post-modernism (Derrida, Lyotard), semiotics (Peirce, Eco), social constructionist psychology (Cergen, Harre, Shotter), critical theory (Habermas, Marcuse)’ (Ernest, 1994). The barrier that once keep mathematics neatly packaged as a silo discipline is now wide open for mathematics to be incorporated universally into all fields.

The field of SE has welcomed mathematics, saying it is a process of thinking that involves building and applying abstract, logically connected networks of ideas (AAAS, 1989). These ideas often arise from the need to solve problems in science, technology, and everyday life. The study of mathematics contains numbers, symbolic relationships, shapes, uncertainty (including probability, summarizing and
sampling data) and reasoning (AAAS, 1989). It seems as though mathematics has rediscovered itself and technology and science have welcomed it into their realms of study.

These studies revolve 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. Aristotelian logic is not necessarily always the best way of deciding. (5) Mathematical objects are certain variety of social-cultural-historical objects – Hersh, et al. (Hersh, 1994).

Not only did the field of mathematics make a dramatic change in its epistemology, but it caused a similar shift in ME as well. The National Council of Teachers of Mathematics [NCTM] standards reflected this by promoting the following ME theories as being of primary importance for instilling in developing educational programs.

1. There is a concentrated effort to convey mathematics to all kinds of learners

2. An overall concept of mathematical theory, history and application is taught in addition to applied mathematics, much more then just the hard facts of math operations.

3. 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.

4. Technology is being more readily used.

5. Assessment includes projects, constructions, analysis and process work, as well as (instead of solely) the results. (NCTM, 1989)

The AAAS also reinforced this connection with their own list of related connections to ME entitles the nature of mathematics.

The primary elements included mathematics as: relying on both logic and creativity, the science of patterns and relationships, an applied science, abstractly universal, trying to discover general
patterns and relationships, the chief language of the grammar of science - giving it analyzing rules and a general contributor to engineering & technology. This section also includes an acknowledgement of computer technology having opened up whole new areas in mathematics and theoretical mathematics as exploring the possible relationships among abstractions unconstrained by the real world, but contributes to a better understanding of the world by influencing mathematical applications (AAAS, 1989).

The study of technology and engineering is not possible without the study of the natural sciences. These in turn cannot be understood in depth without a fundamental understanding of mathematics. (Dugger, 1993) In turn, a fundamental understanding of math includes its cultural application. This is where mathematics is invited into every realm imaginable and in turn invites in all other disciplines, but especially those of S-T and E.

**Common Trends**

In reality all of these fields are interdependent upon each other. Yet, in education they are still formally separated. However, the leading educational organizations affiliated with each of the STEM disciplines have come out with documents supporting their own signature pedagogies that, in order for students to obtain a life-long functional literacy, aspects of interdisciplinary STEM education are being recommended as a necessary element of formal education. The disciplines are actively engaged in this transition.

**Learning Theories & Epistemologies Supporting STEM Commonalities**

Theories promoting interdisciplinary and contextual learning have been around since the beginning of modern education. Comenius was mentioned earlier, but other proponents of supporting theories over the last four centuries include the following individuals. Froebel, (1947) who said, “Man lives in a world of objects, which influence him, and which he desires to influence; therefore he ought to know these objects in their nature, in their conditions, and in their relations with each other and with mankind.” John Stuart Mill contributed ‘the time has arrived when it is desirable and necessary in the education of the people that the principles of science (and technology) [sic] should form an important
element in the tuition of all classes of the community” (Conference, 1868) (Dakers, 2005). Maria Montessori who promoted that “the child needs to have a ‘prior interest in the whole; (Montessori, 1992) so that he or she can make sense of individual facts. The history of problem-based learning (PBL) goes back to Dewey and Rousseau’s concepts that led to Bruner’s ‘learning by discovery’ hypothesis. This claimed that such a method of instruction was more engaging and powerful with more persistent and enduring learning occurring (Shulman, 2004). PBL’s primary six features include: Engagement, understanding, performance, reflection, generativity, and commitment (Shulman, 2004). Bruner himself admitted that PBL was not the sole or the best method of instruction, but an important one that needed to find its place in curriculums (Shulman, 2004). Some educators took notice and in the 1930’s some broke from the fact-and memorization-centered approach to teaching and moved to a problem-centered approach (Harmin et al., 1976). This theory, in conjunction with more thoughts by Dewey as well as those from Piaget, Vygotsky and Bruner led to the development of constructivism (Driscoll, 2005). Constructivism, as also Piaget’s notion of equilibration or schema theory, considers meanings to be constructed actively, relating the new with ideas that are already held via a generally analogical process (Mellado, Ruiz, Bermejo and Jimenez, 2006, p. 421), [and are] formed and develop through the coordination and internalization of a person’s actions on objects in the world (Driver, 1994, p. 6). The Vygotskian project aligns with social constructivism in the sense that students learn a culture. This knowledge gives them a sense of how to understand the world, what exists within it and which elements have which hierarchy of importance, influence and place within it. They talk about contextual, meaningful learning being tied to previously understood concepts and scaffolded to a broader or deeper level of understanding either within or in connection to numerous disciplines” (Driver, Asoko, Leach, Mortimer and Scott, 1994). Other theories that align themselves with constructivist values include those labeled “constructionist, generative learning, embodied cognition, cognitive flexibility theory, postmodern and poststructural curricula and situated cognition” (Driscoll, 2005). Despite the particular label given to this pedagogical style, theories that support the tenets of ‘constructivism,’ are well documented as already being accepted by learning theorists throughout the history of modern education.
and the disciplines. All of these supporting theories have been used promoting the use of constructivist style pedagogies across the disciplines. This means that if these teaching styles are good for using in each discipline, that they can also be considered beneficial for teaching across interdisciplinary disciplines.

Constructivism is so widely used that there are thousands of books on it, which address virtually every imaginable division of teaching. ‘Strong’ constructivism is described as being; active, anticipatory, whole-bodied, form-giving, involving processes of organization, structure, construction, deconstruction & reconstruction, meanings are based on other meanings, knowledge is transitory and provisional, there is self-determination and idea communication, testing and social care (Herman, 1995). It is realistic in nature and rich with meaning and context. Yet, “no simple rules for pedagogical practice emerge from a constructivist view of learning” (Driver et al., 1994). This means that its very nature is open to various interpretations and implementations. Its very essence instills a need for including more than one discipline. Since one cannot experience life solely through the lens of a singular discipline, one cannot have reality-based instruction that does not incorporate interdisciplinary factors. Constructivism is a unique theory as its freedom from pedagogical structure allows it to be universally adaptable to all disciplines whether they are stand-alone or inter-connected with other disciplines.

With this type of learning, ‘students who learn the basic ideas and methods of inquiry can readily assimilate and classify facts. They can integrate facts into overall concepts and fundamental themes…. students develop concepts and skills, which they can use for a lifetime’ (Harmin et al., 1976). This means that despite the dominating subject, despite the content matter, the primary elements of learning is how to learn, not what to learn.

Teaching thinking across the curriculum means focusing on the attitudes, habits and intellectual skills common to all disciplines… If thinking is only taught in one or a few places, it is not likely to take root… Everyone needs thinking skills to meet the demands of career and citizenship… thus to deny meaningful instruction in thinking to students below a certain IQ or proficiency level is to deny them an essential part of their humanity” (Ruggiero, 1988).
Life-long learners are created, across a large range of ability types, who have the skills to be functionally literate.

Science teaching research has been dominated since the 1980’s by the constructivist paradigm, which has led to considerable progress in many aspects of the T&L of science (Mellado et al, 2006). What is preferred is that SE includes teaching a process of learning as well as the content of the field. This allows the learners to understand the cultural tools and conventions and how to use them. This allows them to recall previous experiences and substantiate their meaning with a deeper understanding. It also teaches them how to apply the knowledge of such concepts outside the classroom in the future (Driver et al., 1994). Constructivism has also done a service by making educators aware of the human dimension of science: its fallibility, its connection to culture and interests, the place of convention in scientific theory, the historicity of concepts, the contested nature of theories and much else (Matthews, 1997). The connections between disciplines goes far beyond content and immediate context, it gives meaning, order and reference to individuals so that a more full range of opportunities and impacts can be comprehended on all levels.

Learning theories, educational psychology and epistemologists have all offered significant evidence for the support of the individual discipline’s shifts towards developing a more formally interconnected future. They give the substance to the claims that T&L benefits from interdisciplinary approaches, especially those that utilize cooperation and thematic delivery through constructivist ideals.

The Implications of Teaching and Learning STEM with Contextual Meaning

Guiding Position Restated: STEM education is currently in the best position to give contextual meaning to teaching and learning the concepts of the four disciplines because it provides relevance not previously achieved in the traditional silo approach.

There is a symbiotic relationship between technology, science, engineering and mathematics, with technology being held as the constant variable. Also, there is a very important interdependence among these areas of study (Dugger, 1993). We now live in a world where you cannot understand science without technology, which you cannot have without engineering, which you can’t figure out without an
understanding of mathematics and science. In reality all of these fields are interdependent upon each other. Yet, in education they are still formally separated. Shulman (1993) talks of ‘pedagogical solitude,’ which he earlier referred to as teaching being conducted without an audience of peers (Shulman, 1987, pp. 11-12) (Huber & Hutchings, 2005). However, this solitude is disintegrating with significant prompting from the leading educational organizations affiliated with each of the STEM disciplines who have come out with documents declaring their beliefs that in order for students to obtain a life-long functional literacy, aspects of interdisciplinary STEM education are a necessary element of formal education. Despite the fact that signature pedagogies are unique to a field, there are differing amounts of commonalities between them. Some commonalities include; adaptive features that establish a set pattern that frees the mind to focus on the problem itself and not how to frame it, engagement, which leads to accountability, scaffolding, which creates a peer pacing guide (Shulman, 2005a). Finding the connections between the disciplines will give all the disciplines a common ‘language’ with which to teach the connections to other branches within their own.

Although each discipline will remain intact as a silo entity, the silos can regularly contain contents from the other disciplines to round out topics and concepts. In some circumstances, topical studies will call for a more full integration of disciplines where one may dominate or all may be fully integrated for a more holistic approach to T&L. This will allow for previously disconnected disciplines to inter-relate as they do in reality so that students will be able to learn the applications and relationships of otherwise rote knowledge. In professional education, learning for practice is deeper then learning for knowledge and understanding alone. Professionals do not merely practice but do so with skill, theoretical grounding, integrity and ethics. Professional educators are expected to develop pedagogies and values that provide a judgment framework and an awareness of consequences (Shulman, 2005). ‘Talented people find ingenious solutions to problems in learning every academic term, and traditionally most of that work is lost (Huber & Hutchings, 2005). Borrowing methods from other fields may enrich the process and make lessons learned from the work both deeper and more broadly significant” (Huber & Hutchings, 2005).
The key “innovators” in industry work within incentive structures that strongly motivate them to find and use research knowledge. The innovators in STEM education (teaching faculty) face a totally different situation. Their primary motivators are to generate research, not to improve teaching (i.e., to innovate in STEM education, whether drawing upon research or other knowledge resources). The “dual roles” of faculty has dire consequences for STEM innovation, given the priority placed on the other role – research. (Porter, 2006) However, the idea that it is impossible to teach people to think, which has been advanced again and again throughout this century, 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). But thinking can be taught as is being discovered by the scholars of T&L. “The scholarship of T&L may look different in different disciplines. To be sure, many pedagogical issues and topics cut across fields (Huber & Hutchings, 2005). Practices and insights can be borrowed from all kinds of communities, and have been for as long as T&L have been recognized. Even when all these researchers, philosophers, theorists and standards role into one current system, as of 1991, approximately 50% of students can look at tenth grade biology as the last science course they will ever take (in the USA) (DeBoer, 1991). Since 1955, most secondary schools usually only require one or two years of science coursework (Hegglelson, et.al. p. 37) (DeBoer, 1991). With an integration of science elements into technology, engineering and mathematics courses, it would be very hard to avoid receiving some instruction in science throughout a student’s entire educational experience. STEM education could lead to No-Subject-Left-Behind.

STEM education paves the way for an even more holistic educational approach that would formally recognize and incorporate the imperative disciplines of the arts and liberal sciences, especially languages and the social sciences. The hope is that as teachers and programs break through the limitations of silo-based instruction to initiate cross-curricular studies, the result will be the development of more functionally literate, life-long learners who are highly employable and responsible citizens.
References


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Addendum A.

G. Yakman
STEM Pedagogy Rationale Paper Proposal
EDCI 5774: STEM Educational Pedagogy
September 28, 2006

Paper Title:
The Pedagogy Pyramid: Analyzing the primary disciplines for the creation of a balanced STEM education signature pedagogy.

Proposed Question to Answer:
Which (or how does one select) specific pedagogical elements, from the individual disciplines, are best for the creation of a STEM education signature pedagogy with the most complete yet flexible attributes?

Rationale Statement:
An analysis of signature and other commonly used pedagogies, among the individual disciplines, will be conducted to indicate some primary commonalities that are applicable for use with interdisciplinary studies. The focus of this paper is to create a rationale for proposing some primary pedagogical commonalities that would benefit the creation of a signature pedagogy for the field of STEM education.