PREPARING MATH DEFICIENT UNIVERSITY STUDENTS FOR STEM ACHIEVEMENT AND SUSTAINABLE LEARNING

By

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Abstract

The purpose of the investigation was to explore what to do with university students who possess both a desire and ability to matriculate into technical skills but who present in need of math remediation and/or development and who typically lack effective problem solving skills. The decision for remediation or development is based on one of 3 math placement criteria: (1) score below 21 on ACT math subtest; (2) score below 520 on SAT math subtest; or (3) Compass math placement.

At Youngstown State University, a course, ENTC 1500 was created for students who seek to matriculate into engineering technology. The course emphasizes hands on labs that simulate how engineers attack and solve problems, problem solving employing the same 6 step problem solving methodology practicing engineers use on novel problems. ENTC 1500 is typically taken concurrent with intermediate algebra (remedial), an intermediate/college algebra course (developmental) or a basic trigonometry class (developmental). Once students have completed intermediate algebra, trigonometry and ENTC 1500 they can move into their chosen major (Civil and Construction, Electrical or Mechanical Engineering Technology) and take pre-calculus and an introductory engineering technology class with integrated lab, ENTC 1505 for degree credit.

The study applied an Individual Participant Data (also termed primary) meta-analysis. This investigation considered n = 116 ENTC 1500 students exposed to what is termed *New Treatment* and compared them with n = 273 *No Treatment* students who placed directly into pre-calculus (and ENTC 1505). The students were grouped by ENTC

1505 cohorts from Spring 2009 through Fall 2012 (seven cohorts). Quantitative analyses employed SPSS and Comprehensive Meta-Analysis (CMA) using mixed effects analysis. The *New Treatment* discussed has been found to work well for six to 24 students in a class typically setting at tables rather than student desks.

For five target classes spanning roughly two years into an engineering technology degree, the *New Treatment* students perform as well as or outperform the *No Treatment* students in each of the five target courses individually and outperform the *No Treatment* students over time (for all five classes combined).

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Dr. Beebe also taught five of the classes that aided in my progression: Basic Research Design, Human Resources, Seminar in Administrative Theory, Professional Skills Development (nearly as good as my ENTC 1500 Technical Skills Development) and the Proposal Class. I have known Dr. Ram Kasuganti for a number of years; his background in both engineering and management contributed a frame of reference that realigned this effort. Dr. Mary Lou DiPillo's vision of applied math instruction within the parochial schools and administrative experience within higher education focused the writing onto an executive path.

Dedication

This textbook is dedicated to eight great teachers in my life:

Mother, Agnes K. George, an ovarian cancer survivor who taught me the value of courage against long odds.

Grandfather, John Koleda, a Polish immigrant who taught me all things are possible to those who possess humor, faith and an indomitable spirit.

High school teacher, William Pickins who taught me that mathematics possesses a beauty and elegance.

University professor, Frank Ellis who taught me patience by virtue of an insight he fostered to spark this once struggling physics student.

University president, Howard Jones who taught me the lesson that truly great leaders help others reach their potential.

Electrical project engineer, Albert Sebok who taught me there was no better job than that of a project engineer.

Engineering vice president, John H. Porter who taught me that effective leadership is a matter of respect and trust.

Attorney James Lieber who taught me that thorough research is fundamental, softly spoken words persuasive and elegant prose powerful.

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CHAPTER 1

"Come, Watson, come! The game is afoot."

'The Abbey Grange', *The Return of Sherlock Holmes* (1904) (Rees, 1997, p. 214).

Introduction

At both national and state levels, an emphasis has emerged on Science Technology Engineering and Mathematics (STEM). At its heart is a demand for a more technically trained workforce. Paradoxically, the foundation for a practical college level solution in the first three fields rests with reaching a population who increasingly display disinterest and poor performance in abstract mathematics. Students enter college environments at a variety of ages, maturity levels, skill sets and knowledge. The purpose of the current investigation is to explore what can be done for students who possess both a desire and ability to matriculate into technical fields but who present in need of math remediation and/or development and typically lack effective problem solving skills.

Beyond the concern of bringing more students into STEM is the issue of retaining them once they are there. Seymour and Hewitt (1997) performed a study involving seven universities finding that 44.1% of STEM majors switched over to non-STEM majors before graduation. In particular, they noted that students perceived introductory STEM courses as a major barrier owing to their level of difficulty, stress on competition and impersonal large lecture format.

One promising approach is underway at the University of Cincinnati. Retention of primarily biology students has been enhanced for students with low math placement scores by way of a course (SM 101) introduced in fall 2008. Unfortunately, when successful SM 101 students took their follow-up introductory biology course, they fared no better than comparable students who did not take the course (Koenig, Schen, Edwards, & Bao, 2012).

Problem Statement

Few longitudinal studies exist that explore the subject of the current investigation; those that do are primarily retrospective in nature. True contemporary achievement studies are rare in that such investigations are difficult to fund; difficult to conduct. Beyond achievement, this study will endeavor to determine whether the learning achieved by way of a developmental class singly or in concert with other developmental classes and/or activities is sustainable learning.

This investigation will center around a course in Technical Skills Development, Engineering Technology (ENTC) 1500, which was developed at Youngstown State University in 2001 (as a remedial class) but extensively revamped (as a developmental class) in fall 2008. Since that time, 303 students signed up for the *New Treatment* version of ENTC 1500 (fall 2008 through spring 2012). Of these, nine students never showed up for class, four withdrew for financial reasons, one was suspended and six withdrew for medical reasons. Of the remaining 283, some 213 passed (A, B or C), for a 75% success rate. The proposed study will compare 116 of these 213 who opted into engineering technology and their success rates on initial attempt in seven follow-up classes. The seven courses were selected for one of two reasons:

(1) Ready comparison with a control group of engineering technology students who were deemed not in need of ENTC 1500 due to their math

(cut score) placement. Coursework selected stressed math related preparation and performance (ENTC 1505, Math 1570 & Math 2670);

(2) Courses that had been identified as major obstacles in the first 2 years of the program for engineering technology students regardless of math cut scores (Math 1513, MET 1515, & Phys. 1501).

It should be possible to demonstrate correlations between student behaviors and success within ENTC 1500. It should also be possible to indicate promising practices which are now part of both ENTC 1500 and ENTC 1505 (e.g., hands on learning, skills application, problem solving methodology, collaboration in small groups) as one means of promoting success among self-selected students of engineering technology at Youngstown State University. Additional effects of achievement in specific follow-up courses and variables (e.g., measure of initial math ability, SES, preferred student method of getting things done, ACT scores) should prove informative.

Acronyms and Key Terms

- Accreditation Board for Engineering and Technology (ABET);
- Engineering Accreditation Commission (EAC);
- Artificial Intelligence (AI);
- Myers Briggs Type Indicator (MBTI);
- Problem Based Learning (PBL), and
- Team Based Learning (TBL).

Key terms are included in Appendix I. These include definitions for those above as well as Active learning, Achievement, Applications Engineer, Cognitive, Cognitive enclosure, Cognitive neuroscience, Conative, Constructive learning, Contextual learning, Convergent thinking, Cooperative learning, Demonstration, Developmental coursework, Design, Design Engineer, Design skills, Divergent thinking, Effect size, Extrinsic motivation, Formative assessment, Intrinsic motivation, Kolbe A, Meta-analysis, Remedial coursework, Self-directed learning, Skill, Socio Economic Status, Success, Summative assessment, Sustainability and Visual Analysis.

CHAPTER 2

Literature Review

“Data! Data! Data!” he cried impatiently. “I can’t make bricks without clay.”

Sherlock Holmes: ‘The Adventure of the Copper Beeches’ (//sherlockholmesquotes.com).

Introduction

This section examines existing literature associated with promoting adult student achievement and sustainable learning. The overall mission was to develop a framework for STEM Program success in higher education and craft a set of research questions relating to the central ENTC 1500 intervention at the core of the study. Four objectives were judged necessary to achieve this mission.

The literature review begins with a discussion of why understanding human learning can be a daunting task. For such an undertaking, it is necessary to construct a supportive scaffold of overarching transcendent principles. The *first objective*, therefore, was to fit together complementary conceptual philosophical and research models on how the human brain operates in order to develop a framework. Ultimately, the primary pieces selected:

1. Classical (e.g., Aristotle, Plato, Jung) interactive elements of the mind: cognition, affect and conation;
2. Human evolutionary brain structure (the 1970s concept of a triune brain);
3. Charles S. Peirce (1839-1914) epistemology of pragmatism with underlying ontological foundation;

4. Bottom up long-term potentiation (LTP) memory model fully delineated and documented by Gary Lynch's research team (1973-2007), and
5. Top down memory-prediction framework of intelligence developed by John Hawkins (2004).

The *second objective* was to delve deeply into adult learning and the role of higher education, consistent with the joined framework constructed. To achieve this objective, four primary pieces were selected from the fields of educational philosophy, teaching/training, cognitive neuroscience and teaching/education; specifically:

1. John Tagg's philosophy on role, challenges and remedies for higher education (1995-present);
2. Sports lessons as defining personal success and learning effects of training (John Wooden & Tim Gallwey 1970s);
3. Usha Goswami's principles of learning (2008) based on a cognitive neuroscience (scientific method) approach, and
4. Arrowsmith-Young's application of neuroscience to adult students with severe neurological issues at the Arrowsmith School in Toronto (2012).

The *third objective* was to uncover basic tools and measures for identifying, quantifying and understanding the most productive influences on STEM adult education. This third objective flowed naturally from John Tagg's recommendations. Two major pieces came into play. The literature review suggested that the S (logistic) curve provides a useful tool whenever learning achievement is examined, not as a snapshot, but longitudinally over time. Second, John Hattie's 2009 synthesis of 138 influences on student achievement provided a means for matching the spirit of the ENTC 1500 intervention against Hattie's "hinge point" effect size criteria of which influences should be emulated in the classroom.

From the 138 influences synthesized, 67 were above the hinge point. From among the 67, 16 were selected to inform the direction of the study which follows.

The *fourth* and final *objective* was two-fold: find studies (if any) that matched the potential ENTC 1500 intervention study and fill in information that fell into the gaps among the three previous objectives. Two studies were found that were structurally close to this dissertation. The 2008-2012 study at the University of Cincinnati was cited in the Introduction (Koenig, Schen, Edwards, & Bao, 2012). The second study, a developmental math impact study by Susan Lesik (2007), very much parallels the dissertation study and will assist with construction of the research questions. A discussion of national goals for STEM achievement, implications derived from the Lesik study and research question statements conclude the literature review section.

Toward Understanding Sustainable Human Learning

The annual Society for Neuroscience (SFN) conference was held in Atlanta in October, 2006. A special three-day convocation on the subject of long-term potentiation (LTP) honoring Tim Bliss preceded the five day annual conference. Tim Bliss coauthored the initial discovery work on LTP along with Terje Lomo in 1973. A 2006 synopsis of the state of neuroscience in general and the convocation and conference in particular follows.

> Our actual knowledge of what is going on within the brain when memories are made is shocking in its absence. The lack of broad theory in which to fit the individual bits and pieces that different scientists were describing is striking. By some counts more than one thousand different kinds of proteins are present at a single synapse [and 40,000 in each neuron]. There were during the three-

> day LTP conference fifty thirty-minute talks, almost all of them devoted to discussion of different, particular molecules. Little was offered in the way of a theory as to how the brain actually works or how memory is encoded. The five days of the broader neuroscience meeting that followed were much the same. And almost every talk contained at its core some bit of hand-waving, some magic that inexplicably accounted for whatever was being examined. (McDermott, 2010, p. 213)

Murray Gell-Mann received the 1969 Nobel Prize in Physics for his discovery of quarks, the fundamental constituents of neutrons and protons. Obviously a highly trained specialist in physics, he felt this should not preclude concern for the unity of human culture, for understanding "transcendent, overarching principles that cover many different kinds of subjects" (Moyers, 1990, p.188). As founder of the Santa Fe Institute, he set a

> principal mission . . . to study issues that transcend specialized subjects . . . in particular in the study of complex adaptive systems . . . [including] the evolution of . . . individual learning and thinking . . . because learning, adaptation, and evolution are all very similar phenomena. (Moyers, 1990, p.188)

Gell-Mann concluded that physics would be a much tougher undertaking if particles could think. Learning, adaptation and evolution are on a higher level of complexity. Similarly, Lynch concluded that a theory of everything may be appropriate for physics but a theory of a lot is as much as can be hoped for in biology. The Lynch and Hawkins memory (learning) models will fill this "explains a lot but not everything" role for this study.

Bottom Up: Synaptic Plasticity and Lynch's Memory Model

In the late 1700s, scientists worked out what would come to be called Cell Theory. It proposed that all life was made up of individual cells. It was not until several decades later that a Spanish anatomist, Santiago Cajal, was able to develop a novel staining technique that demonstrated conclusively that individual brain cells; (i.e., neurons) were the building blocks of the brain. He used a tree analogy to identify the three main components of a neuron. "[T]he trunk represents the cell body, the [extensively branched] axon its roots and the dendrites [Greek for tree] its branches" (McDermott, 2010, p. 21). Spacing (i.e., the gap or synapse) between neurons is approximately 20 nanometers (20 billionths of a meter or 1/2000 the width of a human hair (McDermott, 2010).

The importance of developing new tools and techniques is also critical in science because direction is not necessarily progress. Sometimes the tools can dictate direction as in the cliché: If you have only a hammer, every problem looks like a nail.

Cajal correctly inferred that the electric current that flows through a neuron always moves from dendrites through cell body to the axon, then on to dendrites of other neurons. In addition, he correctly speculated that the connections between neurons could be strengthened by use. Cajal claimed that he was searching not simply for cellular connections; he was hunting for "the butterflies of the soul" (McDermott, 2010, p. 23).

Modern cell theory states that cells communicate by exchanging proteins with one another and the spaces between them. When passing to a distant location, the bloodstream is often utilized in which case such long distance proteins are termed hormones. In humans, each neuron contains approximately 40,000 proteins (McDermott, 2010).

At the cellular level, Eric Kandel, in his detailed study of marine sea snail neurons in the 1960s and early 1970s, discovered that upon five instances of firing, actual structural changes occurred creating a long-term memory. In addition, long term memory in sea snails, as in humans; require repeated training interspersed with rest periods (Kandel, 2006). Perhaps Kandel's greatest contribution to neuroscience was to move the science from an investigation of behavior to an investigation of molecules (McDermott, 2010).

> In 2000, Eric Kandel won the Nobel Prize for demonstrating synaptic plasticity—that is, the strengthening of the connections between neurons as a result of exposure to stimulation, which resulted in learning and the formation of long-term memory. This was Hebb's rule, a concept introduced in 1949 by Canadian psychologist Donald Hebb, in action. Simply put, the rule is neurons that fire together wire together. The more often they fire together, the stronger their connection. (Arrowsmith-Young, 2012)

Gary Lynch, working with a research team at the University of California Irvine over a 35 year development period (1973-2007), uncovered a complex memory encoding process based on the Bliss-Lomo concept of a long-term potentiation (LTP) effect. Lynch's process model followed a serpentine path from interactions at the level of individual neurons past encoding of individual memories leading eventually to shaping memory into mathematically definable patterns that defined learning rules at the synaptic level (McDermott, 2010).

Lynch identified three stages of LTP: *induction*, *expression* and *consolidation*. Explaining the three stages was equivalent to answering three fundamental questions: "How did the change occur? What was the actual change? Why did it last?" (McDermott, 2010, p. 58). Following this sequence, the following nine step process was painstakingly laid out:

1. *Induction phase begins*: Theta (5 Hertz) bursts open channels into the neuron (opens the double door of two brain receptors which release neurotransmitters and Brain-Derived Neurotrophic Factor (BDNF);
2. Ion (Calcium Ca^{+}) influx sets off a chemical cascade that activates disassembly of the cell cytoskeleton;
3. Reassembly of the cell (actin polymerization);
4. *Expression phase begins*: Brain cells (neurons) quickly change shape and networks of such neurons with altered shapes create a modified dendritic spine;
5. Integrins lock in dendritic spine shape. Integrins are the same material that cause blood clotting and stabilize a wound;
6. Shape change makes room for more receptors at synapse;
7. Greater number of receptors strengthens likelihood of synaptic communication;
8. Memory occurs instantaneously but can be dislodged and lost if not locked into place. Sharp waves that occur during sleep and in wakeful rest act as an erasure mechanism for new experiences, and

9. *Consolidation*: Cortactin protein and calcium-calmodulin sensitive kinase enzyme lock memory into place (McDermott, 2010).

Long-Term Potentiation (LTP) is a dual modulated homeostatic system responsive to either too much inhibition or too little incitement. BDNF and integrins on one side of the scale are balanced by excess adenosine and sharp waves on the other (McDermott, 2010). The complexity of forming memories fits with the analogy coined by Oliver Wendell Holmes circa 1920: "Memory is a net: one that finds it full of fish when he takes it from the brook, but a dozen miles of water have run through it without sticking" (McDermott, 2010, p. i).

Top Down: Peirce's Pragmatism and Hawkins' Predictive-Memory Framework

Plato and Aristotle spoke to three human interactive elements of the mind: the *cognitive*, the *affective* and the *conative*. *Cognition* provides the requisite understanding of cause and effect; *affect* supplies the passion and emotion necessary to motivate an undertaking and *conation* the instinctive modes of operation to drive the necessary actions. Per their construction, all three elements are necessary to cause a decisive nonrandom individual action (Kolbe, 2009).

In the 1970s, a hierarchy of three main strata of brain "types" was established. The innermost most primitive layer of the then termed triune brain was named the *reptilian R-complex* due to its correspondence to lizard and reptile full brains. It was conjectured that in humans, archetypal patterns and shadowy representations, as suggested by speculations of Carl Jung and Plato's allegory of the cave, would be appropriate modern brain emanations (Restak, 1979).

Whether by action of the *reptilian R-complex* in isolation or by way of usurpation and enhancement by higher strata, a correspondence with the element of *conation* can be made.

Extending the relationship, Carl Jung's theory of human development, can be bulleted into five individual predispositions:

- There exist persistent patterns (or types) of behavior that influence an individual's interaction with the environment;
- A single pattern dominates for a given individual;
- Behavioral responses can be used to measure dominance of the patterns;
- There exist behavior overlays that may be represented as a continuum between polar positions, and
- In a specific context, such overlays may determine how individuals employ cognitive or affective responses (Kolbe, 2004).

The second layer, the *limbic system*, surrounds the reptilian R-complex. It forms a cap (limbus) around the brainstem and is often referred to as the old mammalian system. "[It] introduced emotion as a unifying . . . factor in animal and human behavior (Restak, 1979, p. 66). Here is a direct structural analog of the element of *affect*.

The third layer, the neo-cortex (also termed the new mammalian layer or simply the cortex), is a thin pinkish grey, squishy sheet of neural tissue (two mm thick) that in humans envelops most of the limbic system. Jeff Hawkins' 2004 memory-prediction system is based primarily on the homogeneous structure and hierarchical function of the neo-cortex. It is a top down hierarchical model looking at feed-back and feed-forward from the highest layer of human brain tissue and forwarding of truly novel ideas to an older heterogeneous structure, the hippocampus (Hawkins, 2004).

The human neo-cortex contains roughly 10 to 30 billion neurons that "contain almost all your memories, knowledge, skills, and accumulated life experience" (Hawkins, 2004, p. 43). Each neuron has dozens of dendrites, each dendrite thousands of synapses. Estimates of the total number of synapses range from 100 trillion to many quadrillion providing immense storage capabilities (McDermott, 2010).

The neo-cortex can be likened to a six layer napkin with a depth of roughly six business or playing cards. Unlike the tissue in the lower layers, the neo-cortex is remarkably uniform. Vernon Mountcastle, a neuroscientist at Johns Hopkins in 1978, concluded that all six regions of the neo-cortex perform the same algorithmic function whether the sense is sight, hearing, touch or motor control (Hawkins, 2004).

Circa 2005, David Linden, neuroscientist at Johns Hopkins University in Baltimore updated the triune brain model when he compared the human brain to a three-scoop ice-cream cone. You get the equivalent of a frog's cognitive ability on the bottom (layer one), a dog's in the middle (layer two) and the latest in Homo sapiens on top (layer three). By mass, this third layer represents 80% of the human brain. While a human brain is dramatically larger than that of a frog or dog, the need for backward compatibility forces retention of many of the same limitations. For example, the speed of neural communication, 27 meters per second, is the same for frogs, dogs and humans. This speed is fast (a hundred yard dash in three seconds) though not lightning fast (McDermott, 2010).

The olfactory cortex, which a dog possesses, may well be the prototype for the fully developed neo-cortex in humans. Dogs sniff at a rather precise rhythmic rate of one sniff each 200 milliseconds: 1/0.2 sec = 5 Hertz. The human brain operates at different times at different discrete rhythms, the result of neurons firing electrical signals called action potentials. The gamma rate is 70 Hertz (70 spikes per second) while the theta rhythm rate is a leisurely five Hz. It is the theta rhythm that invokes LTP and, as we will see, memory creation (McDermott, 2010).

The neo-cortex usurped most of the motor control in humans that exists in the cerebellum of most mammals and may well have enlisted the hippocampus from the limbic system for purposes of temporary storage of new and novel memories. Regardless of what is held in the hippocampus, “you will permanently remember something . . . only if you experience it over and over, either in reality or by thinking of it” (Hawkins, 2004, p. 171). Long term memories must eventually reside in the neo-cortex whether or not they coexist in the hippocampus (McDermott, 2010). Somewhere within the boundaries of the neo-cortex then resides *cognition*.

Charles S. Peirce (1839-1914) physicist, philosopher, mathematician, logician, born in Cambridge, Massachusetts, educated at Harvard, is generally credited as founder of pragmatism (Angeles, 1992). His stiff scholarly writing approach was eclipsed by the colloquial style of his close friend, psychologist and philosopher, William James (1842-1910), and his legacy obscured by philosopher/educator, John Dewey (1859-1952) (Rohmann, 1999). All three philosophers were critical of rationalism choosing instead to embrace empirical (sensory perception) inquiry and the pragmatic notion of knowledge derived from experience, experimental methods and practical direct activities (Angeles, 1992). Table 1 contrasts Post-positivism (most strongly associated with science today), Constructivism (currently, most strongly associated with education) and the Pragmatic worldviews.

Table 1. Comparison of Post-positivism, Pragmatism & Constructivism (Creswell & Plano Clark, 2011)

Element	Post-positivism	Pragmatism	Constructivism
Knowledge claim	Cause & effect	Consequences	Understanding
Analysis goal	Reduce variables	Problem centered	Disclose multiple participant meanings
How?	Empirical observations	Method secondary to problem significance	Social & historical constructions
Strengths/orientation	Theory verification	Oriented to "what works"	Theory generation
Ontology (nature of reality)	Singular and objective reality	Singular and multiple objective realities	Multiple and subjective realities
Epistemological stance	Distance & impartiality	Practicality	Closeness
Method	Deductive	Mixed	Inductive

Peirce developed an ontological foundation underpinning his epistemology by creating a triad of three universal aspects that are omnipresent for every real thing or event. Although one aspect may clearly predominate to a real observer at any point in time, all 3 aspects must be present in every real thing. He labeled these categories: *Firstness*, *Secondness* and *Thirdness*.

Firstness is a category of being that is experienced with a minimum of cognitive processing. Typically, it is most evident as an immediate quality or feeling when things/events are initially sensed, that is, experienced with a minimum of cognitive processing. To attempt to comprehend, vocalize with clarity or express this feeling mathematically is impossible (McCarthy, 2005).

All sensory input, excluding smell, arrives at the brain in the joint form of spatial and temporal patterns. One without the other is insufficient and confusing. Hearing involves (spatial) position of the cochlea receptor cells as well as timing between sounds (temporal). Vision involves temporal jumping of the eye at a rate of three times per second as well as the obvious spatial patterns. The brain allows us to perceive the continuously changing images as stable patterns. Touch (feeling) an object to identify it requires more than one spot touch sensation; one must gain a requisite temporal component as well as a spatial aspect. The only way to perceive an auditory pattern (e.g., a melody) or a tactile object (e.g., a pen) is by observing a flow of input over time (Hawkins, 2004).

Secondness is a dynamic interaction characterized by the dialectic of action and reaction, of effort and resistance. On a personal level, when we push on the outer world, the world pushes back; we make an effort and observe a resistance. This resistance can be overcome by sufficient exertion appropriately directed. While there is generally less resistance when applied to our inner world of thought, it remains present; otherwise we would never be aware of a change in thought (McCarthy, 2005).

As information from each (and every) sense moves up through its relevant six layers of neo-cortex, each level develops “names” for the sequences it knows and passes these sequence “names” on to the next higher region in the hierarchy. Besides feed-forward connections there are feed-back connections. While what is actually happening (observed patterns) flows upward, what you expect to happen (predictions) flows downward. It is the push and pull of what you perceive and what you expect that fills in reality. When feed-forward perception is lacking, as the case for the eye’s blind spot, the feed-back fills in the void (Hawkins, 2004).

Thirdness is the aspect of any real thing/event that is representational (and meaningful). Each thing/event is a sign, the meaning of which can potentially be read (or mis-read). Even ideas, though psychical things, are real things/events. Since the interactions of human beings with other real entities/events are not under our sole control, ontologically, there is parity of all real things, including ourselves (McCarthy, 2005).

As one feeds-forward up the hierarchy for any of the senses, one moves from spatially specific to spatially invariant, from fast changing to slow changing and from features and details to objects. The brain forms invariant representations. For example, a friend can appear in countless positions, lighting, etc., yet you still recognize her. The invariant face representation of your friend's countenance is enfolded down the hierarchy to verify that, yes, that's her (Hawkins, 2004).

True beliefs owe their existence to "real objects", i.e., beliefs about meanings that are real. Peirce wrote: "The cognitions which thus reach us by . . . inductions and hypotheses . . . are of two kinds, the true and the untrue, or cognitions whose objects are real and those whose objects are unreal" (McCarthy, 2005, p. 163). Progress occurs gradually as nature springs surprises, those observations that fail to match the expectation of the observer, are compared with events experienced that did match. In such a state, a true belief takes the place of a false belief and the surprise event invokes learning. It follows that in each true learning experience, there is a surprise (McCarthy, 2005).

If an unexpected event (pattern) arrives in the cortical hierarchy, this unexpected pattern is immediately passed up to the next higher level. The higher the unexpected pattern needs to go, the more levels get involved in resolving the discrepancy. The more novel the event, the higher the unexpected pattern needs to go with the highest level likely to be the hippocampus. When a higher level thinks it understands the unexpected event, it generates a new prediction that cascades down the hierarchy. Confusion occurs while the cortex fails to find a higher level memory that matches the input; the "aha!" moment occurs when a prediction unfolds from the top of the hierarchy by passing sequences to the bottom that fit the input (Hawkins, 2004). According to Peirce's vernacular you have obtained a real (true) belief.

Peirce concluded that "[t]here is nothing, then to prevent our knowing outward things as they really are, and it is most likely that we do thus know them in numberless cases, although we can never be absolutely certain of doing so in any special case" (McCarthy, 2005, p. 170). Learning becomes more likely when actions are deliberately taken to put one's existing beliefs to the test. When existing beliefs pass the test by not leading to a state of surprise, their meanings are likely stable, reliable and useful; that is more likely to be valuable since they have proven to be a safe basis for prediction and hence more likely to be true beliefs (McCarthy, 2005).

Prediction is at the heart of Hawkins' predictive-memory system:

> The human cortex is particularly large and therefore has a massive memory capacity. It is constantly predicting what you will see, hear, and feel; mostly in ways you are unconscious of. These predictions are our thoughts, and when combined with sensory input, they are our perceptions. I call this view of the brain the *memory-prediction framework* of intelligence. . . . Prediction, not behavior [as promoted

> by Alan Turing] is the proof of intelligence. (Hawkins, 2004, pp. 104-105)

For any task an individual might undertake, Charles Spearman, in 1904, proposed two separate contributions. The first, *g*, a singular general factor, constitutes an ability to do many things well. The second, *s*, specific factors, include individual skills, knowledge and aptitudes that apply to a very specific activity. For any particular task, the two factors combine to determine the overall level of performance (Duncan, 2010).

In the 1960s, psychologist Raymond Cattell introduced a distinction between "fluid" and "crystallized" intelligence. Fluid intelligence concerns current ability to solve novel problems. Tests to measure fluid intelligence strive to minimize dependence on specific education and maximize generalization across multiple cultures. Cattell's Culture Fair and Raven's Matrices are two such measures. Crystallized intelligence, on the other hand, refers to acquired knowledge and is typically culture specific. Examples include tests of vocabulary or arithmetic (Duncan, 2010).

Fluid intelligence, like ability to form new memories, declines with age while any relationship between crystallized intelligence and age seems dependent on other factors. The clearest relationship pattern is between ability to form new memories and age; ability to form new memories declines linearly with age after the age of 20 (McDermott, 2010). This appears analogous to the decline in farsightedness after age 40.

The work of John Duncan suggests that these two concepts may well be one and the same; that is, *g* may in fact be another name for *"fluid" intelligence* while *s* may be synonymous with *"crystallized" intelligence*. Duncan coined the term multiple demand system to refer to discrete sections of neo-cortex where system operation correlated with test results off Cattell's Culture Fair and Raven's Matrices. Brain scans revealed a brain circuit came "online for *almost any kind* of demanding cognitive activity" while this general circuit was "joined by other brain areas specific for the particular task" (Duncan, 2010, p. 164).

The multiple demand circuit components consist of a small portion of prefrontal lobe in conjunction with a smaller fragment of parietal lobe. Duncan confirmed Russian neuro-psychologist, Aleksandr Luria's contention that proper frontal lobe activity was essential for constructing organized sequences necessary for goal directed activities (Duncan, 2010).

Duncan's body of work suggests that as many as one in six English adults who trained in the 1980s to become London bus drivers appeared to have some multiple demand system issues and by his inferential extension *g* and fluid intelligence issues. His most recent research, though preliminary, suggests the student learning effect of creating bulleted lists is superior to repeating "the rules" of a mental exercise. This effect was most pronounced for the subgroup identified by Cattell's Culture Fair or Raven's Matrices as having multiple demand system issues (Duncan, 2010).

The field of Artificial Intelligence (AI) was founded as an "area of computer science that attempts to deconstruct the processes underlying intelligence and then program them into a computer, so that it can learn and think for itself in the same way as a human being" (Parsons, 2009, p. 74). We have already noted that feed-back as well as feed-forward are key features of the neo-cortex. In addition, Jeff Hawkins developed a hundred-step rule which appears to invalidate the notion that the human brain can or should be likened to a computer.

> Hawkins points out a fallacy in this [classical brain as computer] reasoning, which he calls the hundred-step rule. He gives this example: When a human is shown a picture and asked to press a button if a cat is in the picture, it takes about a half second or less. … [N]eurons are much slower than a computer, and in that half second, information entering the brain can traverse only a chain of one hundred neurons. You can come up with the answer with only one hundred steps. A digital computer would take billions of steps to come up with the answer. (Gazzaniga, 2009, pp. 366-367)

Hawkins concluded that the neo-cortex doesn't compute answers to problems; it retrieves the answers from memory. The entire neo-cortex is not a computer at all but rather a sophisticated memory system. But unlike computer memory, the neo-cortex stores *sequences of patterns*. It recalls the patterns auto-associatively (a partial pattern recalls a complete pattern). The patterns are of an invariant form (one recognizes a friend from different angles and distances) and the six hierarchical layers of the neo-cortex are in constant communication (up and down) (Hawkins, 2004).

In practice, when we work to commit something to memory, the more areas that can be recruited to support learning and retention, the more likely we will remember. Learning and memory arise as neurons connect to and communicate with other neurons. New synapses form when repetition reinforces an association creating a memory as conceptualized in Hebb's rule (Arrowsmith-Young, 2012, p. 179).

Compatible though not designed to converge at a common junction, the combination of Hawkins' memory-prediction system together with Lynch's LTP memory model explains "a lot" about the human memory process function, as well as consequences when the operation is compromised. Such an understanding of memory provides a glimpse into how humans think and learn. Both models emphasize that memories are highly clustered and categorized. Both correspond with Immanuel Kant's assertion that one type of aesthetic pleasure derives from a unification of sensory inputs that occur subconsciously by virtue of the sense of completion it induces in the viewer. Lynch's neural correlate "is that the brain . . . generates a feeling of satisfaction when new inputs are made to align with old inputs already clustered and categorized" (McDermott, 2010, p.101). This would appear to be the polar opposite of cognitive dissonance.

Lynch goes on to speculate that the human need to fit new events into prior categories provides "an insight into the power of narrative on the human imagination. Narrative is a form of categorization, taking a nearly random set of experiences and shaping [reducing] them into coherence" (McDermott, 2010, pp. 101-102).

Such normal human behavior runs counter to the baseball hitter who needs to live in the moment. A high tight fastball tends to lock in memory. A pitcher can now throw a breaking ball away that will start on the same path but break dramatically away at the end. Intellectually, the experienced hitter expects this follow-up pitch. However, if unable to erase the memory of the prior event, the likelihood is that the batter will flinch involuntarily, swing weakly and miss (McDermott, 2010).

Before digging into basic learning principles and how they might harmonize with higher education supported by this joined framework, let's lay groundwork by examining the role of higher education and the simpler concept and consequences of training.

Dispelling the Fog of Learning—John Tagg

In 1995, John Tagg and his colleague Robert Bar noted a paradigm shift in higher education:

> In its briefest form, the paradigm that has governed our colleges is this: A college is an institution that exists *to provide instruction*. Subtly but profoundly we are shifting to a new paradigm: A college is an institution that exists to *produce learning.* (Barr & Tagg, 1995, p. 13)

Table 2 indicates the implications of adopting this shift in the operation of undergraduate education.

Table 2. *New Learning Paradigm vs. Old Teaching Paradigm* (Fink, 2003)

	Old Teaching Paradigm	New Learning Paradigm
Mission and purpose	Improve quality of instruction	Improve quality of learning
Criteria for success	Focus on quality of entering students	Focus on quality of exiting students
Teaching and learning structures	Cover the necessary material	Seek specific learning results
Learning theory	Learning is cumulative and linear	Learning is an interaction of frameworks
Productivity and funding	Define productivity as cost per hour of instruction per student	Define productivity as cost per unit of learning per student
Nature of faculty role	Faculty are primarily lecturers	Faculty are primarily designers of learning methods & environments

More recently John Tagg (2010a) characterized the quest to produce undergraduate higher education learning as occurring in a figurative fog. Three related problems are responsible for generating this fog:

- Lack of information: We lack much information we require if learning is our reason for existence (e.g., student goals aside from getting a good grade, typical isolation of teachers from colleagues obscuring the work of the one from many, etc.);
- Unreliable information: It's not that we receive insufficient information but that we don't trust much of it. Stephen Few (2009) laments that in a data-rich world, information only becomes valuable when it is understood; yet the ability to make sense of it is not intuitive. This faculty requires a skill set employing visual representations (graphs) of quantitative information to piece facts together into a picture of the whole, and
- Distorted information: Credit hours, grades and their combination for a series of courses (the transcript) are what counts in education but in focusing on grade achievement are we neglecting more important yet elusive to quantify factors; individual student learning and success?

Tagg recommends pursuit of the Scholarship of Teaching and Learning (SoTL) "to cast a light on what is important and relevant to student learning . . . [in order to] disperse the fog and make the learning process more visible" (Tagg, 2010a, p. 4). Within this context he recommends:

- "[Tie] specific research projects to a larger body of research that can anchor our new understanding" (Tagg, 2010a, p. 5);
- Based on the work of Hutchings and Shulman (1999) "classroom researchers [need] to 'go meta' [in order to advance] practice beyond [the individual classroom]" (Tagg, 2010a, p.5), and
- "What if the lesson they [students] learned in their first semester was not that every class must be approached [as] What does *this* teacher want?—but that each class builds toward a common goal, that they are connected in ways . . . that are vivid and meaningful and lead someplace that students want to go?" (Tagg, 2010a, p. 6).

Student Success, Achievement and the Training Effect

So where do students want to go? How can we define success for an individual? In the world of sports, UCLA college basketball coach, John Wooden, stressed the higher value of success over winning. Early in his high school coaching career, he defined a standard of personal success based on his classroom (English) and basketball court observations of children and concern with unrealistic (achievement) standards put upon them by parents: "Success is the peace of mind which is a direct result of the self-satisfaction in knowing that you made the effort to become the best of which you are capable" (Nater & Galimore, 2006, p. 25).

Sports is replete with the notion that long term sustainable achievement is related to fundamentals often associated with absolutes, precise attention to details, respect for tradition and, above all, an emphasis on practice and execution (Lau & Glossbrenner, 1980; Maraniss, 1999; Wooden & Jamison, 2005; Schembechler & Bacon, 2006). In baseball, golf and tennis, the swing sports, there is a long time fascination with grooving a swing:

> [E]verytime you swing your racket in a certain way, you increase the probabilities that you will swing that way again. In this way patterns, called grooves, build up which have a predisposition to repeat themselves. Golfers use the same term. It is as if the nervous system were like a record disk. Every time an action is performed, a slight impression is made in the microscopic cells of the brain, just as a leaf blowing over a fine-grained beach of sand will leave its faint trace. When the same action is repeated, the groove is made slightly deeper. After many similar actions there is a more recognizable groove into which the needle of behavior seems to fall automatically. Then the behavior can be termed grooved. (Gallwey, 1974, p. 78)

The sports coach most passionate about the combination of research, motivation and pedagogy was the aforementioned John Wooden. His pedagogy back in the 1970s emphasized grounding in fundamentals and mastery of the larger concept of how each small detail fit into the big picture: the strategy of the entire play. He drove his players to be automatic in fundamentals and concepts but not to turn into robots. Wooden claimed it took more than a hundred repetitions to make an operation automatic. He wanted his players to devise their own unique solutions to the constantly changing problems their opponents provided. In his words, Wooden wanted "to be as surprised as our opponent at what my team came up with when confronted with an unexpected challenge" (Nater &

Galimore, 2006, p. 90). In similar fashion, in the 1960s, Green Bay football coach, Vince Lombardi introduced the innovation to “run to daylight” (Maraniss, 1999) and in the 1980s Michigan football coach, Bo Schembechler had a similar desire to prepare his players for “sudden change” (Schembechler & Bacon, 2006).

Hawkins’ memory-prediction framework model suggests that with repeated training, the neo-cortex should relearn sequences in lower hierarchical levels. A detectable change in reaction times should also be noted because inputs need not travel as far up the hierarchy in order to be recognized (Hawkins, 2004).

Learning Principles from Cognitive Neuroscience

> Cognitive neuroscience [a sub-field within neuroscience] takes psychological theories about the mind (e.g., that short-term and long-term memory are distinct systems) or symbolic descriptions of mental processes (e.g., that we think using images versus ‘inner speech’) and explores them by measuring electro-chemical activity in the brain. Interpretations of neural activity are constrained by using experimental paradigms drawn from cognitive psychology. (Goswami, 2008, p. 382)

At birth, considerable brain development has already occurred. Neural structures have formed but will become increasingly specialized as the infant and young child experiences stimulation from the environment. Human evolution set up connections (typically in the sensory system) to reflect expectations by the brain to receive such stimulations. Connections not used frequently are aggressively pruned.

> At the age of three, a toddler's brain is roughly the same size as an adult's but with nearly twice as many synapses. The child develops, keeping the synapses being actively used and pruning away those not being used. For example, an infant can discriminate speech sounds from all languages, not just those that exist in his native tongue. The brain restructures the auditory networks to become tuned to the sounds regularly heard and loses the ability to discriminate sounds that are not part of that infant's auditory world. This rewiring, which occurs naturally and automatically, increases our brain's efficiency while applying one critical principle: use it or lose it. (Arrowsmith-Young, 2012, p. 201)

The following basic principles of learning have emerged from cognitive science:

- Learning is incremental and experience based: "The growth of new fibre connections in the brain always occurs in response to new inputs" (Goswami, 2008, p. 388);
- Learning is multi-sensory: The implication is that "if children are taught new information using a variety of their senses, learning will be stronger (that is, learning will be represented across a greater network of neurons connecting a greater number of different neural structures, and accessible via a greater number of modalities)" (Goswami, 2008, p.389). This principle tends to negate the concept that children can be said to have different learning styles;

- The brain in learning extracts structure from input: "[O]ne goal of education is to help all individuals to extract the higher-order structure (or 'principles' or 'rules') that underpin a given body of knowledge. It is generally felt that a combination of 'discovery led' and directly transmitted knowledge provides the best way of doing this but there [is no consensus] over the optimal balance" (Goswami, 2008, p. 391);
- Learning is social: "The social nature of human learning means that learning with others is usually more effective than learning alone and that language and communication are central to this social process" (Goswami, 2008, p. 392);
- Learning in terms of cognition (thinking and reasoning) is integrated with emotions in the brain: "[Neuroeconomics] as a discipline has learned that human behavior cannot be explained solely in rational cognitive terms . . . economic models incorporating emotional measures such as regret appear to be more efficient at modeling human behavior. . . . Cumulative emotional experience must also play a role in the efficiency of learning" (Goswami, 2008, p. 393), and

- Learning shows life-long plasticity and compensation: "Greater synaptic density is associated with more learning. . . . [Following a stroke] connections can reform . . . these compensatory

> mechanisms . . . show that plasticity continues into late adult life" (Goswami, 2008, p. 394).
>
> When tackling brain processing problems, however, as with so much else, the devil is in the details. One must have an intimate understanding of the pace at which the brain changes, how to "dose" the exercises, and which brain function to target. The latter is important because a simple problem, e.g., a reading problem, can actually be caused by a weakness in any number of different brain areas, and only one of these need be weak for a person to have a reading problem. . . . One woman began applying neuroplastic principles first to herself [1977] and then to students [1995] . . . when Barbara Arrowsmith-Young and the team at her lab school began applying neuroplastic principles to learning problems. Barbara's own story—which I recounted . . . in my book, *The Brain That Changes Itself* (2007) . . . is truly heroic, on par with the achievements of Helen Keller. . . . I can only thank my lucky stars that I live in the city [Toronto] where this school developed, and that I can refer the children I know, when appropriate to [the] Arrowsmith [school]. (Norman Doidge Foreword in Arrowsmith-Young, 2012, pp. xiv, xvi, xvii)

The Arrowsmith School performs a "cognitive assessment . . . [to identify] which cognitive areas are underperforming and contributing to an individual's learning difficulties. The test results serve as the basis for developing an individualized program of cognitive exercises for each student" (Arrowsmith-Young, 2012, p. 217). A partial listing of 19 prominent cognitive deficits, a characteristic student quote and description follows in Table 3:

Table 3. *Arrowsmith-Young Cognitive Deficits*

#	Cognitive deficit	Characteristic student quote	Description
1	Motor Symbol Sequencing	"Please don't erase that blackboard yet."	This capacity is involved in process of learning motor plans necessary to produce a set of symbols (e.g., alphabet or numbers). Deficit means eyes can't track properly; handwriting typically messy, irregular and not automatic; spelling erratic, speech rambling. Story telling leaves large chunks of critical information out.
2	Symbol Relations	"I just don't get it."	Involved in understanding relationships between two or more ideas or concepts. Students typically can learn math procedures but not why they are doing them. Prepositions (in, out, with, without) are hard to understand, letters may be reversed and reading an analog clock difficult.
3	Memory for Information or Instructions	"I have a mind like a sieve."	Capacity flawed re: remembering chunks of info. Can be mistaken for shyness since student holds back; does not participate in conversations. Extensive effort required to retain information.
4	Predicative Speech	"Words don't always come out in the right order."	Capacity flawed for converting thought into organized word sequences. Student speaks and writes in short sentences, maintains a list of memorized short phrases. Inability to mentally rehearse (internal speech) interpreted as rudeness
5	Broca's Speech Pron.	"People say I mumble."	Student mispronounces works or avoids words he/she knows because of uncertainty in pronunciation. Since it's difficult to talk and think at same time; train of thought often lost. If severe; speech usually flat and monotone with lack of rhythm and intonation.
6	Auditory Speech Discrimination	"Sorry. Could you repeat that?"	Capacity is lacking to discriminate between similar sounding speech sounds.
7	Symbolic Thinking	"Planning was never my strong suit."	Student has difficulty developing personal strategies (e.g., for studying). Organization, planning and establishing goals are formidable.
8	Symbol Recognition	"I was never a great reader."	Capacity to recognize and remember a word or symbol requires extreme effort. Learning to read and spell is a laborious process.
9	Lexical Memory	"I'm not good remembering the names of things."	Capacity for remembering individual words and names of things--days of the week, colors and people's names is compromised.

Table 3 (cont.) *Arrowsmith-Young Cognitive Deficits*

#	Cognitive deficit	Characteristic student quote	Description
10	Kinesthetic Perception	"I am such a klutz."	Capacity to perceive where one or both sides of the body are in space. Bumping into objects with affected side of body, going outside lines if problem exists in writing hand are common. Driving car or operating power tools can be significant risk.
11	Primary Motor	"My reaction time is a bit slow."	Deficit interferes with speed, strength & control of muscle movements nearly always confined to one body side. Interacts with kinesthetic perception.
12	Kinesthetic Speech	"I slur my words sometimes."	Specifically there is a lack of awareness of position of lips and tongue.
13	Artifactual Thinking	"I'm just not good at reading people."	Capacity to interpret emotions, read nonverbal curs (e.g., facial expressions mind body language). Result--a failure to understand other and yourself.
14	Narrow Visual Span	"My eyes hurt when I read."	Capacity limits number of symbols or objects a student can see in a single visual focus. With this deficit, student must make 3 to 10 times normal eye fixations to read a line of print.
15	Object recognition	"Have we met?"	Capacity for recognizing and remembering details of visual objects including faces. Student takes longer to recognize and locate objects and this fuzziness typically creates social problems.
16	Spatial Reasoning	"I am forever getting lost."	Capacity to imagine a series of maneuver through space prior to executing them. Student typically forgets where objects are left, materials are stacked in piles within sight because anything put away (e.g., in filing cabinet) will likely be unlinked to a mental map of where it might be.
17	Mechanical Reasoning	"I'm not handy."	Difficulty imagining how machines operate, parts interact and tools operate.
18	Abstract Reasoning	"I couldn't program the VCR to save my life."	Deficit involves a problem with carrying out a nonverbal sequence of steps. Computer programmer and baker are likely poor career matches.
19	Supplementary Motor Quantification	"I'm not a numbers person."	Capacity to do math in your head. Extreme difficulty for students with this deficit to calculate change, learn to add or multiply.

The S (Logistic) Curve as a Learning Achievement Tool

In the process of study, a learner is confronted with decisions relating to how best to allocate time to a variety of items. The learner must monitor the extent to which individual items have been mastered and then control subsequent time allocations. This monitoring and control constitutes the framework of metacognition and results in study strategies. There are two key aspects necessary to develop an optimal time allocation study strategy: the shape of the learning curve and the goals or objectives of the learner (Son & Sethi, 2006).

Consider a learning curve of competence vs. study time allocated is considered, there are two possibilities based on the constraint that for any given task, the learning curve must eventually plateau. The first is a learning curve with diminishing returns where exponential, hyperbolic, square root or power functions have commonly been applied in laboratory situations.

A simplified count based exponential learning model can be constructed. If $5^1 = 5$ is the threshold of long term memory per Kandel and a conservative value of $5^3 = 125$ repetitions is associated with ingrained habit of the type sought by Wooden then $5^2 = 25$ repetitions is likely associated with a long term memory unlikely to be easily pruned over time. Extrapolating; $5^4 = 625$ repetitions could be associated with a memory "belief" so deeply held as to be unshakable. An analogy in statistics would be the danger of committing a Type I error; a false belief that a genuine effect was caused by an intervention based on a *p* test with a large sample size (i.e., $n = 625$) (Field, 2009).

An analogy in social psychology is the construct of cognitive dissonance (Tavres & Aronson, 2007).

The criticism of snapshot models and studies that employ them is that they generally constitute a short time scale and so the experiment's learning curve might merely be capturing the upper portion of an S shaped curve (see Figure 1) which more accurately describes learning over a longer time frame (Son & Sethi, 2006). Then too, count based models do not account for critical practice factors like pace, level of intensity, duration, the practicality of teacher correction/redirection and the need for rest and reflection (Gallimore, Ermeling, & Nater, 2012).

In fact, careful long term studies in the learning of complex skills provide empirical evidence of such an S shaped characteristic in the fields of language acquisition, sequence learning and motor learning (Son & Sethi, 2006).

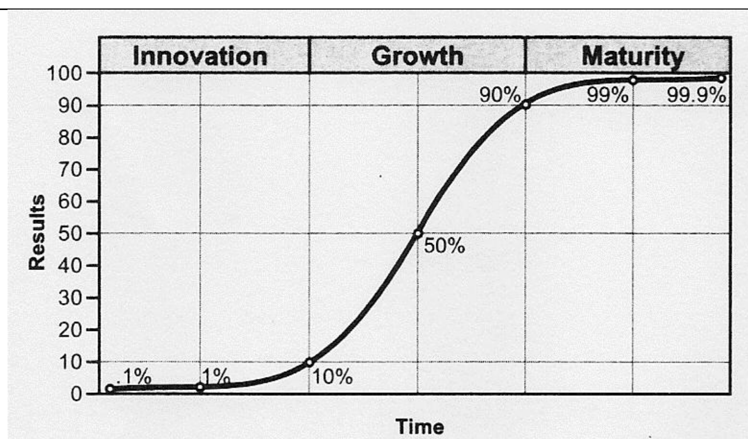

Figure 1. *The S Curve (Dent, 1993, p. 101)*

A surprising aspect of the S (logistic) curve is that it takes an identical amount of time to go from ground zero to 10% (Innovation Phase) as to go from 10% to 90% (Growth Phase). Then, in order to achieve that final 10% (Maturity Phase) another equal time increment is required. Resembling a wave, the S curve accumulates into a normal distribution. Establishment of startup companies, introduction of new products and technologies, exercise programs and change of various sorts have been effectively modeled as progressing along the path of S curves (Dent, 1993).

Achievement is generally considered a combination of (innate) talent plus preparation. As psychologists hone in on the careers of those recognized by peers as having attained the greatest achievement in a given field, less significance is found for the role innate talent plays than the role of preparation. Excellence at performing a complex task requires a critical threshold of practice and what researchers have settled upon is a time commitment of 10,000 hours to attain mastery (Gladwell, 2008).

Imagine a 14 year old boy, Andy who meets his boyhood hero, Rick Idol, a 20 year old world class guitar player. Rock tells Andy that he began playing when he, Rock was 14 and has spent 32 hours a week, week in and week out practicing. This would put Rock at 10,000 hours of practice time when they met. One year later, Andy, age 15, has followed the prescription and is now at 1% of Rock's proficiency with the guitar. Even at age 16 per the S Curve, he will have attained only 10% proficiency. Most would not persevere but luckily Andy is stubborn and his learning curve takes off: 50% at age 17, 90% at age 18 and then the inevitable leveling off: 99% at age 19 and 99.9% at age 20. The moral to Andy's story matches the lessons of building construction; change (e.g., learning) is not linear, it proceeds slowly at first (prepare the foundation) before rapidly accelerating (put up the superstructure).

John Hattie's Synthesis re: Student Achievement in Adult STEM Education

John Hattie (2009), noted measurement and research design specialist concluded that teachers typically attain annual student achievement growth effects of between $d = 0.20$ and $d = 0.40$. Effect sizes themselves follow a normal distribution. He suggests that achievement gains above this "average" effect size imply a guideline—a reference or hinge point ($d = 0.40$). Why not just go with what works? According to Hattie:

> [a]lmost everything works. Ninety percent of all effect sizes in education are positive. Of the ten percent that are negative, about half are "expected" (e.g., effects of disruptive students); thus about 95 percent of all things we do have a positive influence on achievement. When teachers claim that they are having a positive effect on achievement or when a policy improves achievement this is almost a trivial claim: virtually everything works. One only needs a pulse and we can improve achievement. (Hattie, 2009, pp. 15-16)

Of equal import is the notion of sustainability. On this note, Hattie began his 15 year quest to synthesize 800 meta-analyses on student achievement based on roughly 50,000 studies and millions of students. From this analysis of analyses, it is possible to filter some 38 student achievement factors with effect sizes above 0.40 ($d \geq 0.40$) that appear to apply to Post Secondary STEM education (Hattie, 2009).

Of the 38 student achievement factors above the hinge point, seven are items over which an individual educator has limited control. These include: prior achievement, self-reported grades, self-concept, reduction of anxiety, Socio Economic Status (SES), school size and self-verbalization and self-questioning. Since SES occurs so often with such powerful effects, it appears propitious to include an SES factor in this study to understand its role. By anticipating a strong SES effect, it is hoped that some potential methods of mitigating negative effects of low SES can be unearthed. Mitigation is not equivalent to solution.

The remaining 31 student achievement factors above the hinge point offer post-secondary educators' optional practices that indicate potential significant improvements under educator/institutional control. These include: student motivation, concentration/ engagement, teacher-student relationships, professional development, teacher clarity, creativity programs, feedback, formative evaluation of programs, spaced vs. massed practice, meta-cognitive strategies, teaching strategies, homework, teacher expectations, writing programs, mathematics programs, science programs, goals to enhance achievement, advanced (behavioral) organizers, concept mapping, mastery learning, questioning (for feedback), peer tutoring, learning styles, cooperative learning and interactive video.

Ten of the 31 controllable factors above are integrated into the ENTC 1500 design: student motivation, concentration/engagement, teacher student relationships, feedback, creativity program, spaced vs. massed practice, teaching strategies (in terms of problem solving teaching), homework, teacher expectations and cooperative learning. In addition, five factors: the impact of meta-cognitive strategies (in the form of study skills), writing programs, mathematics programs, science programs and learning styles will be considered as interaction effects. Table 4 summarizes the 16 influence factors chosen for further discussion and prospective analysis.

Table 4. *Summary of 16 influences with visible effect on student learning*

Item	Description	Effect size	Standard error
I	Student Motivation	*d* = 0.48	medium
	Gender is moderator (more powerful effect for F)		
	Subject is moderator (more powerful effect for natural than social sciences)		
II	Concentration/Engagement	*d* = 0.48	low
	Effective time in science classes produces an even more powerful effect (*d* = 1.09)		
III	Teacher-student Relationships	*d* = 0.72	low
IV	Feedback	*d* = 0.48	low
V	Creativity Programs	*d* = 0.65	high
VI	Spaced vs. Massed Practice	*d* = 0.71	NA
VII	Problem Solving Teaching	*d* = 0.61	medium
VIII	Homework (high school level)	*d* = 0.64	low
	Age is a moderator; as age ↑ d ↑		
IX	Teacher Expectations	*d* = 0.43	high
X	Cooperative Learning	*d* = 0.41	medium
	Cooperative learning more effective than individualistic methods (*d* = 0.59)		
	Cooperative learning more effective than competitive learning (*d* = 0.54)		
	Age is a moderator; as age ↑ d ↑ (Johnson & Johnson, 1987)		
XI	Socio Economic Status (SES)	*d* = 0.57	low
XII	Study Skills	*d* = 0.59	high
XIII	Writing Programs	*d* = 0.44	medium
	Work together to plan, draft, revise and edit (*d* = 0.75)		
	Set clear & specific goals of what writing should accomplish (*d* = 0.70)		
XIV	Mathematics Programs	*d* = 0.45	medium
	H.S. Algebra Direct Instruction (*d* = 0.55)		
	H.S. Algebra Problem Solving (*d* = 0.52)		
	H.S. Algebra Technology Aided (*d* = 0.07),		
	Communication & Study Skills (*d* = 0.07)		
	Feedback to students (*d* = 0.71), Peer assisted learning (*d* = 0.65), Direct Instruction (*d* = 0.65), Real world apps (*d* = – 0.04) (Baker, 2002)		
XV	Science Programs	*d* = 0.40	low
XVI	Learning Styles	*d* = 0.41	low

Key Factors (10) Internal to ENTC 1500

Student Motivation

> The brain is a social organ innately designed to learn through shared experience. Throughout the life span, we all need others who show interest in us, help us feel safe, and encourage our understanding of the world around us. Brains grow best in this context of interactive discovery and through cocreation of stories that shape and support memories of what is being learned. (Cozolino & Sprokay, 2006, p. 11)

Research literature suggests benefits accruing from techniques designed to enhance intrinsic interest and motivation as opposed to extrinsic rewards. Cordova and Lepper (1989) were able to show differences in the quality of intellectual performance and enjoyment of the two inducement types among children. Rewards led children to use guesswork and unimaginative rote strategies; enhancement of intrinsic interest led children to adopt more complex and efficient problem solving strategies resulting in superior performance. The extrinsic reward group rated their performance and ability more negatively. While the enhanced intrinsic interest group expressed more ambitious preferences for future tasks, the extrinsic reward group expressed interest in easier problems (Ross & Nisbett, 1991).

Students who have a sense of control over their learning; who take on personal responsibility for life events, like learning, are likely to enjoy greater academic achievement (Hattie, 2009).

Concentration/Engagement

> When students are engaged, they are related to the tasks they are involved with in a different way than when they are strategically or ritually compliant. Among other things, the relationship between these students and their work is generally unconditional. They are committed to the task, and the commitment is not contingent on the presence of rewards that are extrinsic to the work or the threat of punishment or negative sanctions. (Schlechty, 2011, p. 23)

Philip Schlechty (2011) has long promoted the importance of student engagement. In order to engage students, Schlechty argues for the model of teachers as designers vs. teachers as performers. While the analogy of guide on the side vs. sage on the stage has a poetic ring, it also connotes too passive a role.

Persistence is also related to concentration and engagement. McClelland et al., (2012) asked parents of 430 preschoolers to rate their children's ability to pay attention, follow directions and complete tasks. The children were assessed at age seven and again at age 21 on reading and math abilities. Those children rated higher by their parents at age four had nearly 50% greater chances of receiving a bachelor's degree by age 25 (McClelland et al., 2012). The symbiotic relationship among achievement, effort and engagement appears to be key to achievement in schools.

Teacher-student Relationships

> From a neurobiological perspective, the role of the mentor/educator in adult brain development may be likened to the role of a primary nurturer in a child's brain development. Both offer a safe haven, emotional attunement, and a scaffold to support the learning process. This aspect of the adult educator's task is directly related to the fact that the brain is a social organ and learns best in the context of a trusting relationship. Such a relationship is the developmental "holding environment" . . . in which adult learning experiences can be optimized. (Cozolino & Sprokay, 2006, p. 15)

Highest effects were related to six sub-factors per study by Cornelius-White, (2007):

- Non-directivity (student initiated & regulated activities);
- Empathy;
- Warmth;
- Encouraging higher order thinking;
- Encouraging learning, and
- Adapting to differences.

Feedback

> [F]eedback is information about how we are doing in our efforts to reach a goal. I hit a tennis ball with the goal of keeping it in the court, and I see where it lands—in or out. I tell a joke with the goal of making people laugh, and I observe the audience's reaction—they

> laugh loudly or barely snicker. I teach a lesson with the goal of engaging students, and I see that some students have their eyes riveted on me while others are nodding off. . . . Effective feedback requires that a person has a goal, takes action to achieve the goal, and receives goal-related information about his or her actions. (Wiggins, 2012, pp. 11-13)

Feedback is among the most powerful influences on student achievement especially if it is feedback from student to teacher.

> When teachers seek, or at least are open to, feedback from students as to what students know, what they understand, where they make errors, when they have misconceptions, when they are not engaged—then teaching and learning can be synchronized and powerful. Feedback to teachers helps make learning visible. (Hattie, 2009, p. 173)

Feedback should address three questions:

1. Where am I going (learning intentions, goals and achievement criteria)?
2. How am I doing (self-assessment and self-evaluation)?
3. Where to next (progression to new goals)?

Feedback from teachers to students must build on effective instruction. Providing this feedback is not about giving rewards which undermine intrinsic motivation (ref: **Student Motivation**) but providing information about the task at hand (Hattie, 2009).

"[T]he best feedback isn't a score or grade; it's clear, specific guidance on how to improve" (Goodwin & Miller, 2012, p. 83).

Creativity Programs

Programs that enhance thinking and creative processing affects curricular achievement, the quantifiable subject of this dissertation (*d* = 0.65) but per a study by Higgins, Hall, Baumfield, and Moseley (2005) had even stronger effects on cognitive outcomes (*d* = 0.62) and affective outcomes (*d* = 1.44). The most effective creativity programs relative to curricular achievement have a high level of structuring (*d* = 0.73) and questioning (*d* = 0.70) (Hattie, 2009).

Spaced vs. Massed Practice

> One of Wooden's philosophies was to set a strict limit on the length of practice—no time was added if drills didn't go well or his players' efforts fell short of expectations. Bias [Kettering, Ohio high school basketball coach] followed this idea, focusing on making practices intense, demanding, and precisely two hours long. (Gallimore, Ermeling, & Nater, 2012, p. 45)

It is the frequency of opportunities rather than time on task that improves learning. Students often need three to four exposures, usually over several days, before a reasonable probability of learning occurs (Hattie, 2009; Nuthall, 2005). The effectiveness and length of spacing are related to complexity and challenge of task; relatively simple tasks require brief rest periods, complex tasks, longer rest periods (typically 24 hours or more) (Hattie, 2009; Donovan & Radosevich, 1998).

Problem Solving Teaching (A Teaching Strategy)

Over 300 years ago, Rene Descartes proposed guidelines for problem solving. The first step in most problem solving methodologies is to understand the problem, next to apply a plan of solution (break the problem into simpler relatively independent parts, solve a sequence of smaller problems isolating single actions from repetitive cases) and then once a proposed solution is obtained, examine it to ensure it is complete and correct (Shortt & Wilson, 1979).

At its heart, problem-solving teaching is based on the power of teaching the heuristic (empirical using rules of thumb) method of approaching problems. A format of problem statements supported by diagrams, figures or sketches relate to better solution performance (Hattie, 2009).

A well-known though seldom delineated engineering methodology is employed in ENTC 1500:

1. Given & Find: Break the problem into what you know and what is unknown;
2. Sketch/Table: Provide a visual picture of what the problem is about;
3. Equation(s): Write down any relevant equation or equations;
4. Plug/Chug: Plug into equation(s) with units and then carry through calculation, and
5. Units/Reality: Check that units are consistent and “answers” realistic.

Homework

The effect size of homework on student achievement, synthesized by John Hattie, stands in a wide range from *(d* = 0.15 to 0.64) with a low standard error. Cooper (1989) argued that the effects of homework were twice as large for high school as for junior high and twice as large for junior high as for elementary students. Trautwein et al., (2002) favored short, frequent homework closely monitored by the teacher. There exist incredible differences in achievement effect sizes between elementary (*d* = 0.15), why bother, and high school students (*d* = 0.64). This difference was theorized as related to the more advanced skills of study involved in high school. Effects were particularly large when the purpose of homework was practice (Hattie, 2009; Trautwein et al., 2002).

Teacher Expectations

> [S]uccessful learning may be seen as a "safe emergency"—a state of high attention but without the debilitating anxiety. If the response is a teacher's supportive caring, encouragement, and enthusiasm balanced with an *appropriate level of challenge* [italics added], learning is enhanced. (Cozolino & Sprokay, 2006, p. 14)

Students recognize different treatment in various classrooms based on expectations held by individual teachers (Weinstein, 2002). When teachers hold low expectations, they tend to do so for all students in the class (Rubie-Davies, 2007).

A retrospective look at teacher expectations and self-fulfilling prophesies was performed by Jussim and Harber in 2005. They concluded that teacher expectations clearly influence students. The Pygmalian study conducted by Rosenthal and Jacobson in

1968 would likely not be approved by an internal review board today. Teachers' false expectations became true over a two year study period as related to IQ gains of supposed "late bloomers". While the late bloomers gained 12 IQ points, it is important to note that the control group gained eight IQ points so that the dark side of teacher expectations actively harming students was not clearly demonstrated. So while ". . . the across-the board IQ increases could be described as 'dramatic,' the differences between the gains of the late bloomers and the controls were not so dramatic" (Jussim & Harber, 2005, p. 134).

The 2005 retrospective concludes that:

- Self-fulfilling prophesies tend to dissipate rather than accumulate over time;
- Self-fulfilling prophesies may selectively occur among stigmatized student social group populations;
- It is unclear that self-fulfilling prophesies affect intelligence;
- It is unclear that self-fulfilling prophesies in general do more harm than good, and
- Teacher expectations are more likely to predict student outcomes because these expectations are accurate than because they are self-fulfilling.

Cooperative Learning

> The message is clear: What students learn is greatly influenced by how they learn, and many students learn best through active, collaborative, small-group work inside and outside the classroom. . . . [One] rationale for implementing group goals is that, if students value the success of

> the group, they will encourage and help one another to achieve, in contrast to competitive learning environments. . . . [I]f new information is to be retained it must be related to information already in memory. Therefore, learners must engage in some sort of cognitive restructuring, or elaboration of the material. One of the most effective means of elaboration is explaining the material to someone else. (Springer, Stanne & Donovan, 1999, pp. 22, 24- 25)

Two studies on group learning each pointed toward gains in deep learning; building concepts and long term strategies. The first, a cooperative small group Problem Based Learning experiment performed with fifty 7th grade science students for 30 class hours indicated improved academic achievement over traditional teaching. More intriguing was the qualitative conclusion that the treatment group assimilated concepts like vectors better and gained deeper understanding than the control group (Akinoglu & Tandogan, 2007).

An unusual second study tracked 10 years of student evaluations of a small group (three to five) team based problem solving, experiential learning model in the United Kingdom (Anderson & Lennox, 2009). This model "embraces the principles of 'interprofessionality' defined as the development of cohesive practice between professionals". The authors claim that "[i]nter- professional learning in inner city areas where people experience socio-economic disadvantage is particularly important" (Anderson & Lennox, 2009, p. 570).

Impact of Related (Interactive) Factors External to ENTC 1500

Socio Economic Status (SES). Sociologist, Annette Laureau, conducted a painstaking 10 year qualitative case based study of 5th graders from which she distilled two dominant parenting styles. These styles which she named *concerted cultivation* and *natural growth* are highly correlated with parental SES (Table 5). A result of these cultural differences is parents of low SES and their children perceive school language and cultural norms as foreign and beyond personal control (Lareau, 2003).

> Rather than seeing society as a collection of individuals, I [Annette Lareau] stressed the importance of individuals' social structural location in shaping their daily lives. Following a well-established European tradition, I rejected analyses that see differences in American families as best interpreted as a matter of fine gradations. Instead, I see as more valuable a *categorical* analysis, wherein families are grouped into social categories such as poor, working class, and middle class. . . . Class position influences critical aspects of family life: time use, language use, and kin ties. . . . . When children and parents move outside the home into the world of social institutions, they find that these cultural practices are not given equal value. There are signs that middle-class children benefit, in ways that are invisible to them and to their parents, from the degree of similarity between the cultural repertoires in the home and those standards adopted by institutions. (Lareau, 2003, pp. 236- 237)

Table 5. *Lareau's Parenting Styles (Excepts from [Lareau, 2013, p. 31])*

Factor	Style 1: Concerted Cultivation	Style 2: Natural Growth
Essence of the Style	Parent actively fosters and assesses child's talents, opinions and skills.	Parent cares for child and allows child to grow.
Organization of Daily Life	Multiple child leisure activities orchestrated by adults.	"Hanging out" particularly with kin.
Language use	Reasoning/directives: Child contests adult statements Extended negotiations between parents and child	Directives: Rare questioning or challenging of adults General acceptance by child of directives.
Interventions in Institutions	Criticism and interventions on behalf of child. Train child to take on role promoting own self interests.	Dependence on institutions. Sense of powerlessness. Conflict between child rearing at home and school.
Consequence	Emerging sense of entitlement by child	Emerging sense of constraint by child.

The Program for International Student Assessment (PISA) periodically tests 15 year old students from 50 countries in reading, math and scientific literacy. Thirty industrial countries including the U.S. make up the Organization for Economic Cooperation and Development (OECD). According to statistical research, what lowers mean scores for all countries are the so called "tails" of low SES students. U.S. privileged students' (those from high SES households) results on PISA are comparable to students from any country. Claims in the U.S. media that size of U.S. population and heterogeneity cause weak U.S. results are unsupported by research. In 2009, Perry noted successful strategies for mitigating low SES based on OECD research include:

1. Comprehensive education systems are more effective than differentiated systems.

This is a plus for the United States. However, U.S. policies of tracking, ability grouping and an overemphasis on reading, writing and arithmetic at expense of physical education and the arts are negatives;

2. Schools and society need to make strong efforts to overcome the influence of low SES;
3. Only countries that implemented welfare policies to reduce poverty showed improved access for low SES students;
4. Privatization, academic selectivity and school choice generally reduce equity and have a negative effect on test scores, and
5. Countries with top mean scores on the exams took steps to raise respect for the teaching profession (Perry, 2009).

> Whether a person attends a postsecondary school (and the type of school he or she attends) has a major impact on individual development, occupational status, and wealth. . . . Previous research indicates that socioeconomic status is the best predictor of academic attainment, and that low SES forecasts low attainment. (Lee, Daniels, Pulg, Newgent & Nam, 2008, pp. 307, 309)

Study Skills (A Meta-cognitive Strategy)

> [S]elf-regulation is a systematic process involving the setting of personal goals and the channeling of one's behaviour towards their achievement. Self-regulation involves *cognitive*, *motivational*, *affective* and *behavioral* components that enable individuals to adjust their actions and/or their goals in order to achieve desired results in changing environmental circumstances. . . Classroom interventions . . .

> emphasize the importance of helping students to develop a positive orientation to learning and a belief that they are capable of succeeding if they work hard and use appropriate strategies. (Moseley et. al., 2004, p. 8)

Study skills interventions can take place in one of three realms—cognitive, meta-cognitive or affective. Cognitive interventions focus on developing task skills, e.g., note taking and summarizing. Meta-cognitive interventions focus on where, when and how to use strategies. While study skills alone can have an effect on surface level information, it is necessary to combine study skills with content in order to have an effect on deeper levels of understanding (Hattie, 2009). This complexity may account for the paradox that effects of study skills programs appear to be low for those most often targeted; students who are struggling at the college level (Hattie, 2009).

Writing Programs

> Being an effective technical writer is becoming increasingly important . . . If you cannot communicate what you know to those who need to know it, then what you know will not count for much. In engineering and science, being able to put your ideas into a form that others can use easily and effectively is the key to success …. (Finkelstein, 2005, p. xix)

> The contemporary human brain embodies millions of years of evolutionary adaptation, with old structures being conserved and modified while new structures emerge, expand, and network. . . .

> Given the brain's evolution is intertwined with both increasing social complexity and the emergence of language and symbolic thought, coconstruction of narratives has evolved to serve as an external organizing element of neural coherence and cohesion. . . . [S]tories serve as ways of enhancing memory through linked associations. . . . [E]ngag[ing] adults in journaling and group discussion . . . is a powerful antidote to anxiety. (Cozolino & Sprokay, 2006, pp. 16-17)

Various strategies were examined for planning, revising and editing compositions. Of significance to the topic of this dissertation were two: (a) work together to plan, draft, revise and edit, and (b) set clear and specific goals for what writing should accomplish. The advice based on best practices: Work together in an organized fashion and set clear goals, especially as to the purpose of each piece of writing (Hattie, 2009; Graham & Perin, 2007).

Mathematics Programs

> Mathematics provides the essential framework for and is the basic language of all the technologies. With this basic understanding of mathematics, you will be able to quickly understand your chosen field of study and then be able to independently pursue your own lifelong education. Without this basic understanding, you will likely struggle and often feel frustrated not only in your mathematics and support sciences courses but also in your technical courses. (Ewen, Gary, & Trefzger, 2001, pp. iv-v)

Relative to achievement effect on high school algebra, direct instruction and problem-solving were powerful teaching strategies. Technology aided and communication and study skills approaches were disappointing. Focus, per Haas (2005), should be on desired learning outcomes, an emphasis on pacing, curriculum and enhanced learning should be sought for all students (Hattie, 2009; Haas, 2005). A math study by Baker et al., (2002) showed the following strong achievement effects: (a) feedback to students, (b) peer assisted learning, and (c) direct instruction. On the other hand, emphasis on real world applications proved fruitless (Hattie, 2009; Baker et al., 2002).

Science Programs

> One of the foundations of science is that effects have causes and don't simply occur willy-nilly. Whatever happens, we can look backward in time to find what caused it. We can also predict the future to some extent, based on insight acquired from the past and on knowledge of the present. And where predictability is limited, we can understand those limitations. What distinguishes the physical sciences and mathematics from other fields is that there are often absolute answers, free from inconsistency, contraindication, or paradox . . . perhaps the most magical aspect of our universe is that it is not magic; that it is orderly, structured, and understandable. (Bloomfield, 2010, p. xiv)

Rubin (1996) distinguished between two distinct forms of lab experiences. He found that lab type one aimed to question, explain and encourage thinking at a higher level using a variety of sources to discover answers. Lab type two verified what had previously been presented. Type one lab experiences showed an achievement advantage (*d* = 0.57) over lab type two.

Schroeder et al. (2007) examined effects of various science teaching strategies on student achievement. Effective science classrooms employed: (a) enhanced content strategies (e.g., topics related to previous experience, student interest engaged) (*d* = 1.48), and (b) collaborative learning strategies (*d* = 0.67); (3) inquiry strategies (*d* = 0.65); (4) manipulation strategies (*d* = 0.51); (5) instructional technology strategies (*d* = 0.48). Their conclusion:

> [I]f students are placed in an environment in which they can actively connect the instruction to their interests and present understanding and have an opportunity to experience collaborative scientific inquiry under the guidance of an effective teacher, achievement will be accelerated. (Hattie, 2009, p. 148; Schroeder et al., 2007, p. 1452)

Learning Styles. A detailed literature search was performed by Selby Markham (2004). Approximately 70 sources were cited primarily from peer reviewed journals with an emphasis on 1998 to 2004 studies (roughly 45). He surveyed seven learning style instruments:

1. Kolb Learning Styles Inventory (Kolb LSI) (1987)
2. Felder-Solomon Inventory of Learning Styles (Felder ILS) (1988)
3. Canfield Learning Styles Inventory (Canfield LSI) (≈1990)
4. Honey and Mumford's Learning Styles Questionnaire (≈1990)

5. Dunn Learning Styles Inventory (Dunn LSI) (2000)
6. Perceptual Learning Style Preference Questionnaire (2001)
7. Vermunt Inventory of Learning Styles (2003)

Selby's conclusion was that none of the seven learning styles' instruments had shown practical usage in educational improvement. On the other hand, he suggested some value to the Myers Briggs Type Indicator (MBTI), a personality instrument sometimes associated with learning styles.

The effect size of matching learning styles to students on student achievement synthesized by John Hattie stands at ($d = 0.41$) with a low standard error. After extensive analysis of the phenomenon of learning styles (despite the large effect size), Hattie (2009) concluded that a better approach (and explanation as to effect cause) is to pursue learning strategies rather than attempt to employ the learning styles' model(s). "Learning strategies, yes; enjoying learning, yes; learning styles, no" (Hattie, 2009, p. 197).

Does the fault lie with the concept of learning styles or with the paradigm of how people learn that existed prior to the circa 2000 acceptance in mainstream neuroscience of the neuro-plastic brain capable of rewiring? Based on the constraint of a hardwired-machine model of the brain (Arrowsmith-Young, 2012), the adaptive concept embodied in learning style models was that learners fit into one of three distinct groups: auditory, visual or kinesthetic learners. Could it be that the underlying learning style models had merit, but, since it was based on a false hardwire rather than a plastic brain, was the model too simple? An Einstein quote is apropos "Everything should be made as simple as possible, but not simpler" (//rescomp.stnadord.edu/~cheshire/EinsteinQuotes.html).

Looking back from the perspective of 2007 to the instrument he co-developed in 1988, Richard Felder shared these perspectives:

> The theory and philosophy behind the development and use of the Index of Learning Styles is firmly in the fluid trait category. It was developed based on the belief that the principal value of a learning styles model is to provide guidance to instructors on developing and using a balanced teaching approach. Once a model has been chosen to serve as a basis for instructional design, the instructor's goal should be to make sure that instruction sometimes addresses each learning style preference defined by the model. The appropriate balance between opposite preferences depends on the course subject and on the background and experience of the students taking the course, but there must be a balance.
>
> In our view, learning style assessments should not be used to label individual students for the purposes of prescribing their curriculum or career choices or to draw inferences about their potential ability to succeed at any endeavor. A student's learning style may provide clues about strengths and areas that might call for additional concentration, but no more than that. Students with any learning style preference have the potential to succeed at any endeavor; the fact that a student prefers, say, visual presentation of information implies nothing about his or her ability to process

> verbal information, or for that matter his or her ability to process visual information. (Litzinger, Lee, Wise & Felder, 2007)

Delayed Gratification, Multitasking and the Conative Connection. In 1972, psychologist Walter Mishel conducted what is now known as the Stanford Marshmallow Test. Four to six year old children were given a marshmallow and told they could eat it now or wait 15 minutes when they would receive a second marshmallow. Responses were recorded in terms of length of time the children could delay gratification. A follow-up in 1988 revealed that the now young adults who delayed gratification were significantly more competent than those unable to do so. One significant correlation was with higher Scholastic Aptitude Test (SAT) scores. It is now conjectured that what was actually being measured was the functioning of the prefrontal cortex, in particular, symbolic thinking (Arrowsmith-Young, 2012).

Multitasking, in particular texting, may well be the contemporary Marshmallow Test for older students. On average, 13 to 18 year olds use more than six types of media simultaneously during off school time. The sheer pervasiveness of technology and social media combined with a fear of missing out on something important leads students to pay continuous partial attention to everything with a resultant difficulty concentrating deeply on anything.

> It's fine to walk and chew gum at the same time, but when a person tries to do two things at the same time that each require a choice, there's a brief "bottleneck" in the prefrontal cortex—the decision making part of the brain—that delays the second task, he [Steven G.

> Yantis, Chair of the psychological and brain sciences department at Johns Hopkins] said. In most situations, that delay is only milliseconds long. Yet the newer the task, the more dynamic the environment, and the more intense the distraction, the longer it will take the brain to react. In the case of an adolescent driver, Mr. Yantis said he found that texting could slow reaction time by a full second . . . In a landmark 2009 study . . . Stanford University researchers compared the attention-switching abilities of people who said they multitasked often with those of people who did so rarely. It found that the frequent multi-taskers were more easily distracted and performed worse on memory and attention tests than those who preferred to do one thing at a time. (Sparks, 2012, p. 2)

Why do siblings from identical backgrounds find that their own unique modes of action help them get things done? Stated another way, why do so many individuals find emulating actions of brothers or sisters work against their grain? Kathy Kolbe developed an action model and battery of tests that provide an interesting contrast with the cognitive model and battery of personnel tests developed by her father, Eric Wonderlic.

Kathy Kolbe's Conative Index (KCI), not to be confused with Kolb's Learning Styles Inventory, holds promise. There are several sources that indicate positive benefits for usage of the KCI in forming groups as well as limited support for this model in understanding student educational success (Lingard & Berry, 2002; Lingard, Timmerman, & Berry, 2005; Kolbe, Young, & Gerdes, 2008).

Consider the following analogy. Imagine a flask filled with 20 milliliters (mL) of liquid and four graduated cylinders marked in increments of 1 mL and scaled from 1 through 10 mL. The task is to fill each of the cylinders to a whole number of mL to total up to the original 20 mL. An additional constraint is that none of the cylinders can be left empty and none can be filled beyond 9 mL.

Now imagine that the graduated cylinders represent four separate instinctive modes of action and liquid units replaced by energy units available for action. To the levels, attach a characterization (one to three resistant, four to six accommodating, and seven to nine insistent) to portray an individual's available energy to act in each mode of operation. An example of one such configuration, innate and stable over time, is shown in Figure 2. Note: 8+ 5 + 3 + 4 = 20:

1. FF—Fact Finder mode, instinctive need to gather information;
2. FT—Follow Thru mode, instinctive need to store and retrieve information;
3. QS—Quick Start mode, instinctive need to tackle the unknown, and
4. IM—Implementor (sic) mode, instinctive need to deal with tangible physical entities (Kolbe, 2004).

Simply because someone has a low level in a given action mode does not mean they are incapable of operating in that vein, only that their energy in that mode is limited. However, a long term effect of trying to fit into a job that necessitates large regular expenditures from a mode where one has a low energy level is exhaustion as one works against their natural grain (Kolbe, 2004).

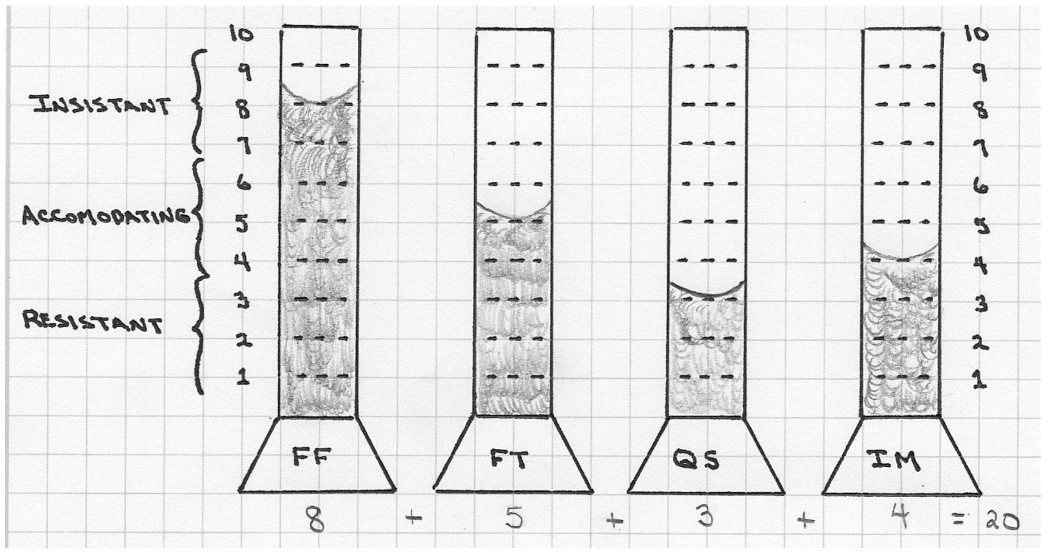

Figure 2. *Kolbe Action Modes*

High levels in Fact Finder mode are common among teachers in English, history, mathematics and natural science since the need to gather data is highly associated with successful test taking. The ability to store and retrieve information (Follow Thru) is also prized, so deficits among a group of such teachers in Implementor (*sic*) and Quick Start are common. One unanticipated consequence of the recent de-emphasis on art, music and the industrial arts lies in the loss of many individuals with high level of Implementor (*sic*) energy. Yet one of the best documented uses for Kolbe is in assembling work teams where diversity of mode characteristics is a strong indicator of successful group activity.

The Remarkable Lesik Longitudinal Study on developmental math. A longitudinal study of 1,276 first-time, full-time college freshmen who entered a four year state university in the northeast between 2000 and 2002 tracked them over three years. From this group, a reduced sample (*n* = 212) was selected; students within five points either side of a math cutoff score. Those below the cutoff score received an intermediate algebra (developmental) treatment while those above the cut score proceeded immediately to college level coursework. The study was able to show by use of regression discontinuity that the particular developmental intervention at this college was effective in helping students persist; that is stay enrolled in school (Lesik, 2007).

It is the establishment of a true causal relationship between the developmental treatment and student retention that separates this study from studies that preceded it. A multitude of other studies have developed regression models that show correlation between remediation or developmental courses and risks of dropping out of college. This study employed a regression discontinuity design that indicated a *causal relationship*. As such, this study design stands on a par with experimental group studies (Lesik, 2007).

Toward a Framework for STEM Program Achievement

Practices and Processes. The National Academies (NAS, NAE, IM, NRC) 2012 report, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas,* has major implications for defining the foundation of STEM education. This report frames STEM as "an assemblage of practices and processes that transcend disciplinary lines . . . from which knowledge and learning of a particular kind emerges . . . [and] is shared [across disciplines]" (Moon & Singer, 2012, p. 32). The report turns the conversation from a content-specific focus on disciplines within STEM to an epistemological question: How do scientists, technologists, engineers and mathematicians achieve their ends; i.e., come to knowledge and insights? (Moon & Singer, 2012).

Practices are those frequently used by STEM professionals in the field, namely model-building, developing alternative explanations, critical evaluation, investigation and/or design, deductive and inductive reasoning and multiple scientific methods. This is in contrast to the concept of a single set of fixed deductive steps; (i.e., the scientific method) (National Academies, 2012).

Cross cutting concepts are those that slice across disciplines, i.e., pattern recognition, comparisons, relationship of cause (input) and effect (output) and predictions (based on counting, tabulating & graphing), scale (e.g., nano through terra), proportion (direct and inverse), quantity (e.g., base & derived quantities, measurement units, scalars & vectors), system models (e.g., stability and change) and energy (i.e., transfer and conservation) (National Academies, 2012).

Core ideas stress the importance of interactions. These ideas include matter and their interactions, motion and forces and their interactions, waves, Earth systems and natural resources, the universe and Earth's place in it, structure and processes, life interactions (e.g., ecosystems), heredity and biological evolution (National Academies, 2012).

Retention and Persistence. The literature paints traditional engineering students as atypical STEM students. For example, a study of first year GPA as a measure of success at the highly selective University of Michigan College of Engineering (fall 2004 & fall 2005 first time, full time freshmen) indicated that excellent quantitative preparation in math and science trumped overall high school achievement. The study found this conclusion to be well supported by previous studies. Both SAT and ACT quantitative scores were good predictors of future achievement. This is not the case for other STEM students; overall academic achievement dominated (Veenstra, Dey, & Herrin, 2008). An internal Youngstown State University (YSU) case study (George, 2011) on success rates in Math 1513 (pre-calculus) for roughly 1400 students over five years synchronizes with this notion. In particular, achievement rates of those looking to matriculate into engineering (as well as chemistry) suggest a different population than those desiring majors in fields like engineering technology, biology and information technology.

A four year Persistence In Engineering (PIE) study looked at 160 students at four U.S. universities. Attrition was 19 with 107 Persisters (P) and 34 NonPersisters (NP) for a potential success rate of 67%. The instrument developed from this study was dovetailed with a survey conducted on 900 traditional engineering students at the same four U.S. universities. Angst was expressed over the negative effect of low Socio Economic Status. Regardless of this factor, a clear disturbing trend was that both Persisters and NonPersisters steadily became disengaged with engineering over time (Donaldson, Lichtenstein, & Sheppard, 2008; Eris, et al., 2010). In summary, getting students into engineering, particularly those from low SES backgrounds constitutes one core issue; keeping them interested is another.

A cross sectional study by Cabrera, Colbeck, and Terenzini (2001) undertaken on 1,258 undergraduate engineering students in 1998 uncovered significant factors for self-reported group skills development: (a) collaborative learning, (b) negative association with SAT score, and (c) instructor interaction and feedback. For self-reported problem solving skills, the significant performance indicators were: (a) instructor interaction and feedback, (b) collaborative learning, and (c) clarity and organization. Readily admitting to the complexity involved, the authors recommended "[s]tructuring classroom activities to promote gains in occupational awareness, problem solving, and group skills" (Cabrera, Colbeck, & Terenzini, 2001, p. 350).

Lesik (2007) made four specific recommendations for future studies that suggest one approach for framing an ENTC 1500 study:

1. Examine ENTC 1500 as causal to retention;
2. Examine ENTC 1500 and interaction of developmental mathematics (e.g., college algebra and trigonometry) vs. ENTC 1505 direct entry (utilize cutoff scores) as causal to retention;
3. Examine in detail what specific aspects of ENTC 1500 and follow-up classes contribute to student retention, and
4. Examine causal effect that ENTC 1500 and other developmental classes have on degree completion.

The proposed investigation will attempt to emulate Lesik's recommendations for future research as it pursues the structure that follows. The contrast among Engineering

Technology students between those below and above relevant cut scores is indicated in the flow chart contained in Figure 3.

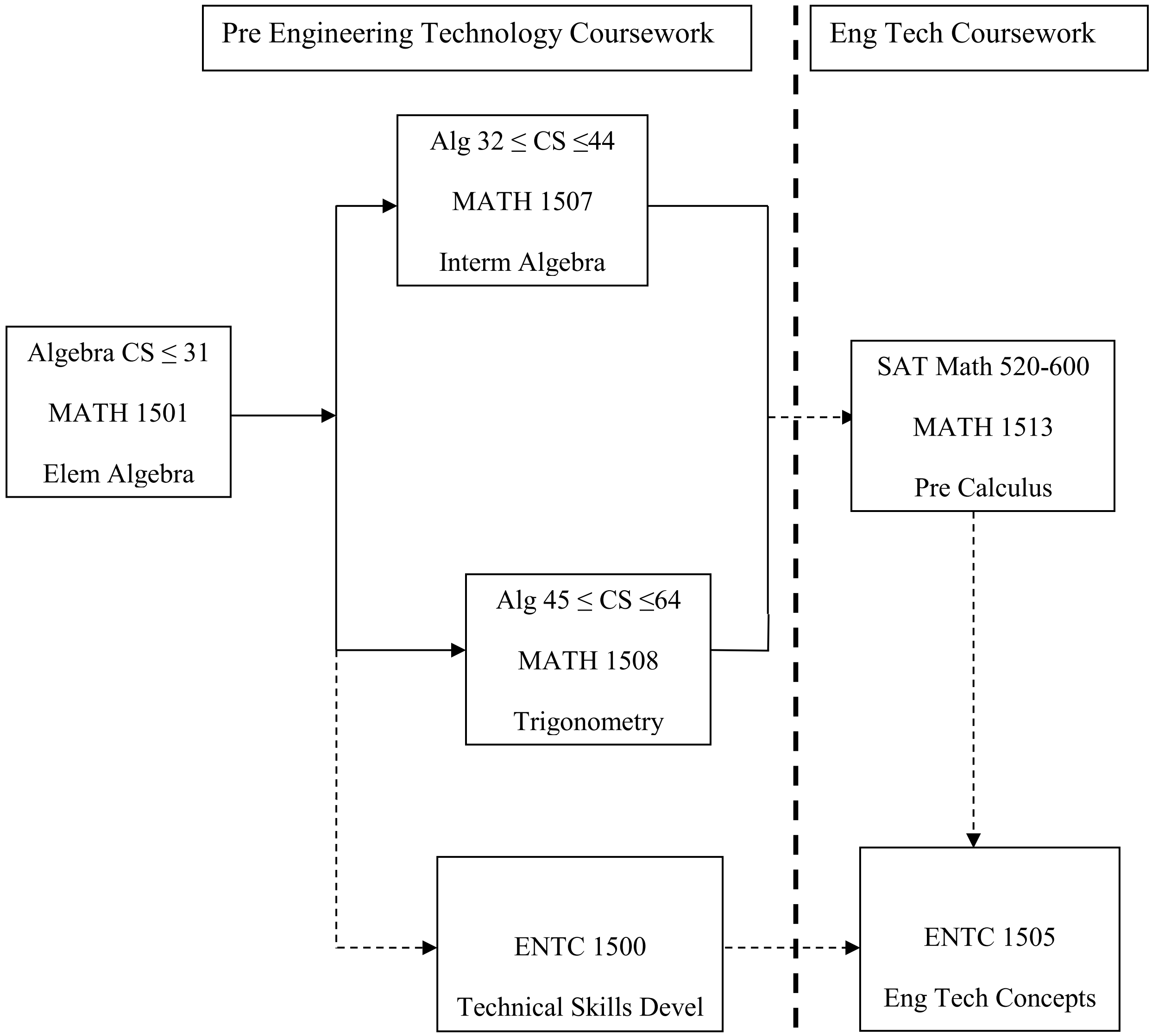

Figure 3. *Flow Chart of Math classes for Engineering Technology Students*

Research Questions:

1. Compare Engineering Technology students who successfully completed the *New Treatment* version of ENTC 1500 in 7 follow-up classes with their counterparts (*No Treatment* students) who placed directly into MATH 1513 and ENTC 1505 owing to higher ACT (or equivalent) math test scores;
2. Examine ENTC 1500 *New Treatment* as causal to retention (and eventual student achievement);
3. Examine ENTC 1500 *New Treatment* and interaction of developmental mathematics (e.g., Math 1508, trigonometry) as causal to retention (and eventual student achievement);
4. Examine in detail (qualitatively) what specific aspects of ENTC 1500 *New Treatment* and follow-up classes contribute to student retention (and eventual student achievement), and
5. Examine potential causal effect that ENTC 1500 *New Treatment* and other developmental classes have on degree completion.

Chapter 3

Methodology

"You know my methods, Watson, – apply them."

Sherlock Holmes: 'The Crooked Man' (Rees, 1997, p. 213).

Introduction

The traditional regression discontinuity (RD) approach employed by Lesik was rejected due to a lack of statistical power. Instead, this study takes the form of an *individual participant data* (IPD) or primary meta- analysis. The advantages of IPD meta-analysis over literature based meta-analysis are multifold:

1. Ability to perform consistent data checking;
2. Availability of a complete and up to date dataset on which to base analyses;
3. Ability to perform a wide array of statistical analyses on every study;
4. Ability to examine effects of participant-level covariates;
5. Flexibility: Methods can be applied that analyze each study separately and then effect sizes can be combined using standard meta-analysis techniques and/or methods can analyze all data at once;
6. Based on access to raw data the meta-analysis can adjust for the same covariates in every study, and
7. Information may be borrowed from one study to another (Borenstein, Hedges, Higgins & Rothstein, 2009).

Design of the Study

For 4 of the 5 research questions posed at the end of the **Literature Review**, analysis will be done quantitatively by comparing results of relevant comparison groups. Research question (4) will require a qualitative approach.

Historical Overview

Youngstown State University has traditionally operated as an open access university; approximate enrollment of 12,800 undergraduate students (fall 2011). Current plans call for conversion to an urban research university. The roots of the Engineering School dated back to 1924 while the School of Engineering Technology started operation as part of a technical and community college outreach, College of Applied Science and Technology (CAST) in 1968. The Electric Utility Technology, Power Plant option began in 2004 as a partnership with FirstEnergy Corporation. This program is housed in the School of Engineering Technology which confers a 2 year Associate in Technical Studies (ATS) degree upon successful completion. Both Engineering and Engineering Technology Schools are part of a College of STEM (Science Technology Engineering and Mathematics) formed in 2007.

ABET, the Accreditation Board for Engineering and Technology, Inc. provides national accreditation of engineering programs through EAC (Engineering Accreditation Commission) of ABET and national accreditation of engineering technology programs through ETAC (Engineering Technology Accreditation Commission) of ABET. YSU confers Bachelors of Engineering (BE) degrees in the fields of Civil Engineering, Chemical Engineering, Electrical Engineering, Mechanical Engineering and Industrial

Engineering each of which is EAC ABET accredited. YSU also confers 2 year Associate in Applied Science (AAS) and (plus) 2 year Bachelor of Science in Applied Science (BSAS) ETAC of ABET accredited degrees in Electrical, Civil and Mechanical Engineering Technology.

In 1998, it was recognized that a high failure rate was occurring in an entry level class, STECH 1505 (now ENTC 1505) which oriented aspiring technicians and application engineers to expectations and methodologies of respective engineering technology professions. Approximately one in three students was unsuccessful on initial attempt. The group at greatest risk was those lacking in basic mathematics; especially introductory algebra skills (Kurtanich, 1998).

Math placement cut score levels were raised and these "high risk" students were required to enroll in an elementary algebra class (MATH 1501). However, despite mathematics remediation, the results were disappointing. In January 2002, a two-pronged approach was launched. On the math end, MATH 1501 was standardized and computer lab component added.

On the engineering technology front, a new course, Technical Skills Development [School of TECHnology (STECH) 1500; now ENgineering TeChnology (ENTC) 1500] was created in spring 2002 as an intervention to address inadequate mathematical and problem solving backgrounds of students wishing to pursue either engineering or engineering technology studies. The success of this course from 2002 through 2006 is documented in an earlier study (George & Burden, 2007). In this timeframe, students generally concurrently took STECH 1500 and the remedial introductory algebra class, MATH 1501. In fall 2004, a second major group of students, all those seeking to become power plant operators began to take the class as well.

The next phase of ENTC 1500 from 2006 through 2008 witnessed a significant drop in course passage rates (64% to 34%). Discussions with primary instructor revealed that the initial mission shifted from providing applied uses for mathematics to teaching mathematics itself and from limited hands on student laboratory involvement to student observation and reporting of instructor demonstrations. A redesign, introduced in 2008 emphasized team based, cooperative learning aspects with a major emphasis on hands on small group (typically size 2) labs. In 2008, the *Fidelity Failure Treatment* and *New Treatment* versions were run simultaneously before the *Fidelity Failure* approach was abandoned in spring 2010.

In 2007, the College of Engineering and Engineering Technology became part of a larger STEM college and the math prerequisite for a follow-up engineering technology concepts class (ENTC 1505) was raised from a concurrent intermediate algebra course (Math 1504) to a concurrent pre-calculus course (Math 1513). Post 2007, the ATS power plant students entering ENTC 1500 typically have completed the introductory algebra remediation and those seeking matriculation into engineering technology normally are taking intermediate algebra either concurrently or subsequently. Hence, the nature of ENTC 1500 shifted from remedial to developmental.

The timeline (Figure 4) which follows indicates key events which have impacted the design and evolution of the ENTC 1500 class.

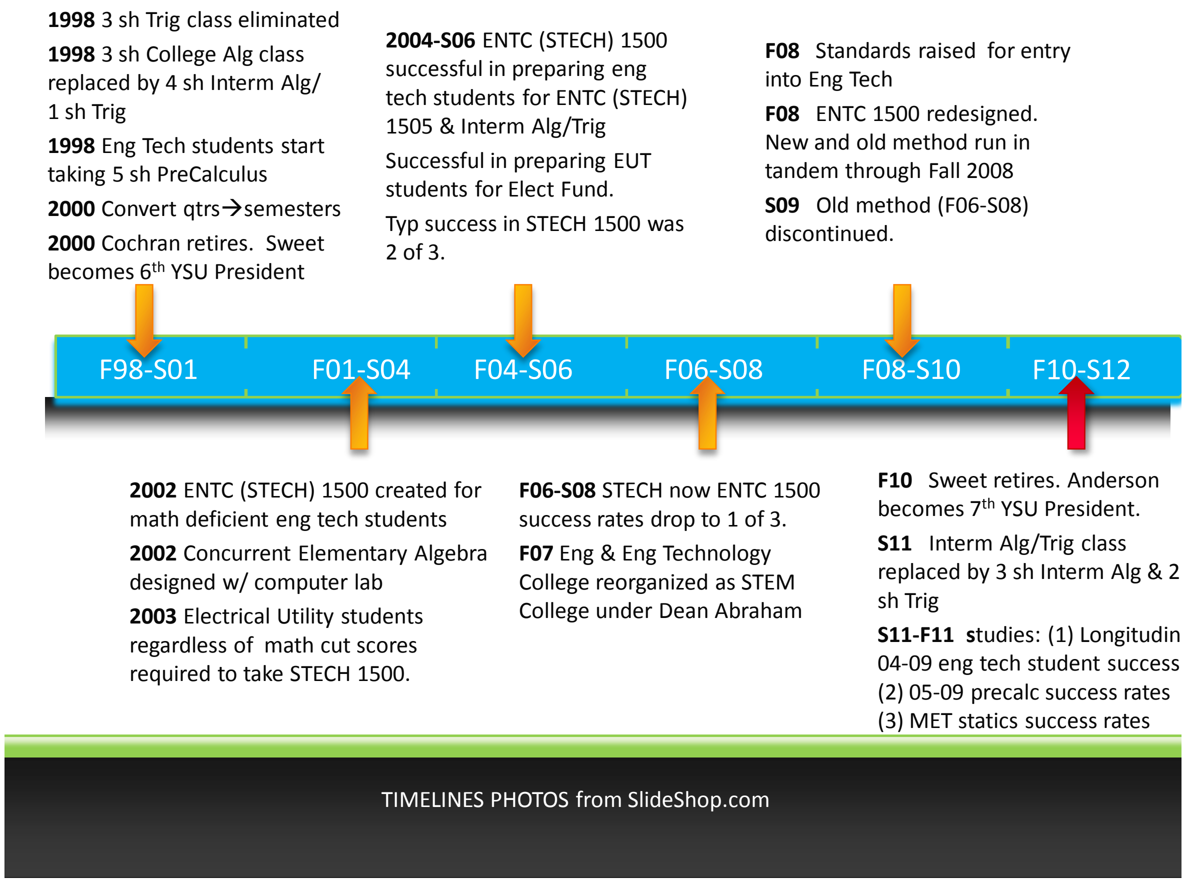

Figure 4. *Timeline 1998-2012*

In the period spring 2011 through fall 2011, three internal action research studies were undertaken. The first was concluded March 31, 2011 on cohorts of engineering technology students who began in ENTC (STECH) 1505 between fall 2004 and fall 2005. This study indicated three significant problem courses resulting in substantial dropout, untimely holds or transfer of students out of engineering technology. The courses were ENTC (STECH) 1505 itself, the associated ENTC 1505 lab, the math pre-calculus course, Math 1513 and the mechanical engineering technology mechanics (statics) course, MET 1515.

The concerns with ENTC 1505 have been resolved, issues with MET 1515 alleviated though not solved and problems with Math 1513 unaddressed. One issue not identified but recognized recently is a problem for engineering technology students with their physics mechanics course (Phys 1501). In addition to these core 5 follow-up classes; the Applied Calculus sequence, Math 1570 and Math 2670 were added. The grades from all seven of these follow-up courses will act as dependent variable measures of learning and its sustainability over time.

The Course, ENTC 1500

ENTC 1500. *Technical Skills Development*. A course designed to develop the technical, analytical and problem solving skills of students planning to enter an engineering or technical course of study. Three (3) hours of lecture and three (3) hours lab per week. Grading is A, B, C, NC. Prereq. or concurrent: MATH 1501

Course Goals:

1. Training: How do I develop a <u>dependable problem solving approach</u>? ←6 Step Method

2. Training: How can I ethically <u>max scores on technical exams</u>? ← Above + "understanding units" + "no blanks"

3. Training: How can I use Excel as an analysis tool? ← Ref 6)

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4. Education: How to develop an <u>effective personal learning strategy</u>? ←epls = f(*1*-pract time {10K hr rule}, *2*-reps {Rule of 5}, *3*-**<u>A</u>**ction →**<u>R</u>** e f l e c t →**<u>A</u>**ction, *4*-hw, *5*-attendance)

5. Education: How can I "make sense of mathematics"? ←Applications (contextual learning) & visualization [see 6])

6. Education: How can I spot trends & analyze data to produce effective technical (lab) reports? ← Data: 1) **G**ather, 2) **A**rrange (tabulate), 3) **M**anipulate (assemble/disassemble), 4) **G**raph (visualize), 5) **A**nalyze (to understand relationships), 6) **M**ake good decisions.

Course Grade determined as follows:

5 Prelim Exams, 5 Labs (1 double) (100 pts each)	= 50 %	(1000 pts)
Drop lowest of 10 Exam/Lab Scores		
HW, Excel, Other Assign's (200 pts)	= 10 %	(200 pts)
Comprehensive Final (500 pts)	= 25 %	(500 pts)
Median Preliminary Exam (100 pts)	= 5 %	(100pts)
Median Lab (100 pts)	= 5 %	(100pts)
Better of Median Prelim Exam & Median Lab (100)	= 5 %	(100pts)
Total	=100 %	(2000 pts)

For additional details see **Appendix A**.

Participants (Fall 2008 through Spring 2012)

Some 303 students signed up for the *New Treatment* version of ENTC 1500 (fall 2008 through spring 2012). Of these nine students never showed up for class, 4 withdrew for financial reasons, 1 was suspended and 6 withdrew for medical reasons. Of the remaining 283; 213 passed (A, B, or C) for a 75% success rate. The proposed study will focus on 116 of these 213; those who opted into engineering technology and their achievement rates on initial attempt in seven follow-up classes (as well as three prior, concurrent or subsequent courses).

Some 273 students placed directly into Math 1513 and ENTC 1505 by virtue of an ACT Math score above 22 (SAT Math above 520 or equivalent math placement test). This group of 273 termed *No Treatment* will be the primary comparison group for the 116 students successful in ENTC 1500 who moved on into engineering technology.

The 3rd major population of ENTC students consists of 97 power plant students who were successful in ENTC 1500. Some 70 students constitute the remainder of the database: either those who ultimately pursued a major different from engineering technology or power plant or those unsuccessful in ENTC 1500. Figure 5 displays these populations visually.

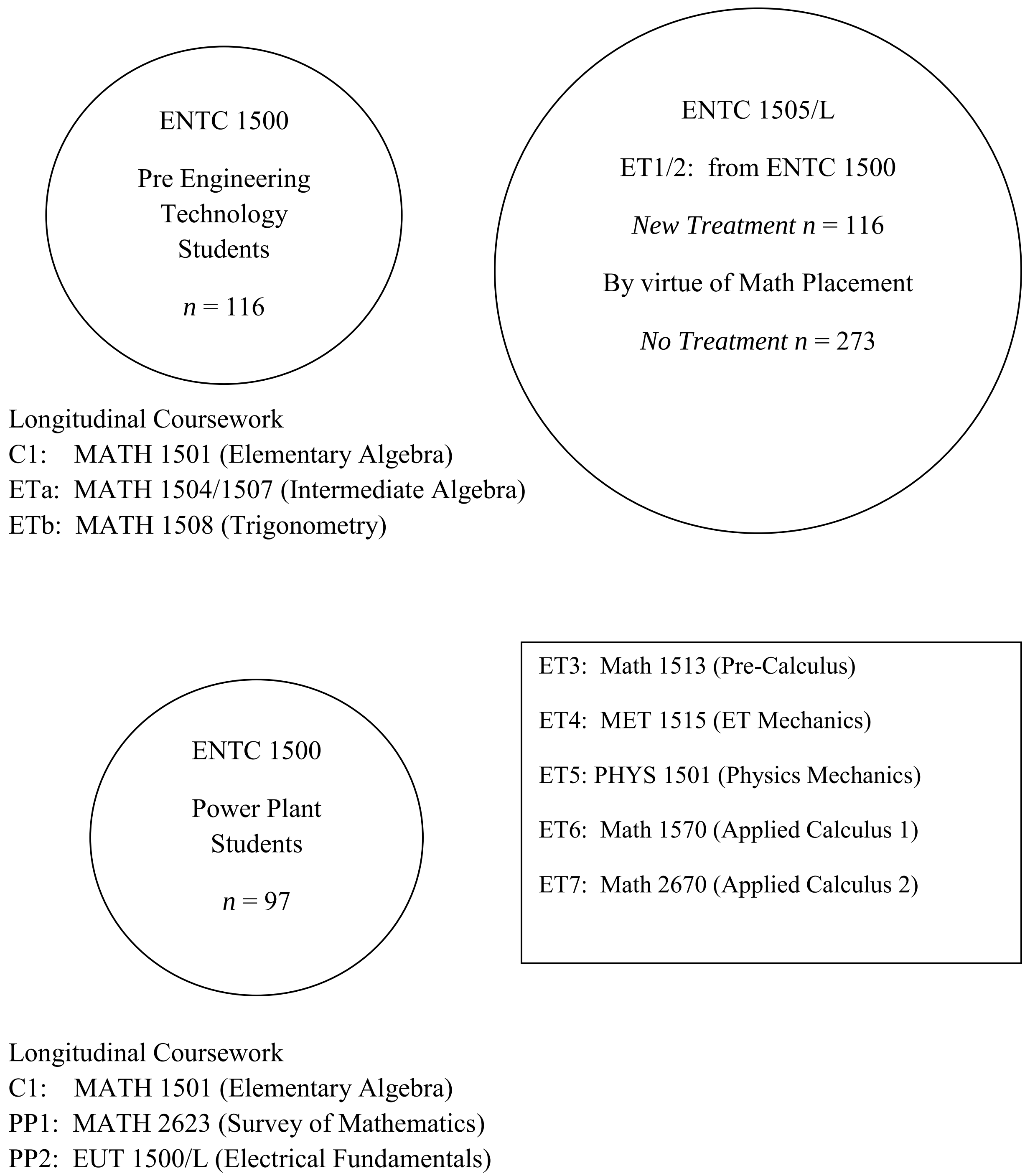

Figure 5. *ENTC Populations*

Smaller populations of ENTC 1500 students include those who received a *Classic Treatment* (*n* = 63) based on the original 2001 course design, a *Fidelity Failure Treatment* (*n* = 14) and an *Intend for New Treatment* (*n* = 26) who signed up but chose not to participate in the treatment.

The entire database then consists of 561 students who took ENTC 1500 and/or ENTC 1505 in the period from fall 2008 through spring 2012.

Instrumentation and Procedure

Instruments used include the standard ACT math, ACT reading and ACT composition tests as well as overall high school GPA obtained from institutional research. In addition, a first week in class survey of ENTC 1500 students (Appendix B) provided a simplified Kolbe self-evaluation of instinctive (conative) preference, a self-evaluation of learning style preference (visual, auditory or kinesthetic), typical employment hours per week, type of employment, high school attended and years since high school graduation.

For each ENTC 1500 student, a median formative ENTC 1500 test score, median formative ENTC 1500 lab score and summative ENTC 1500 final exam score, class attendance, performance on homework over first half of term and final grade percentage were compiled. All preceding scores were based on a 0 to 100% scale. A cohort of 27 students took an end of term survey fall term 2011 (Appendix C) intended to (a) contrast/compare ENTC 1500 with a mathematics course, (b) provide an open ended student listing of ENTC 1500 positives, negatives and complementarity with mathematics class(es), and (c) record student perspectives on achievement of ENTC 1500 course objectives.

Student transcripts were utilized to provide course grades for the relevant populations in the following math courses: Math 1501, Math 2623, Math 1504, Math 1507, Math 1508, Math 1513, Math 1570, and Math 2670; engineering technology courses: ENTC 1505/L and MET 1515; physics course: Phys 1501; electrical utilities course: EUT 1500/L.

Following successful completion of requirements for candidacy August 2012 and approval from Internal Review Board, information was requested from institutional research and financial aid to obtain the following information on the 561 students noted above. This data include: gender, age (when taking relevant course), flag if veteran, race, measure of SES, measure of scholarship or financial aid assistance, flag if student took reading and study skills prior or concurrent with relevant ENTC course, high school attended & year graduated, Student Progress visit type (eight categories) and number of visits to Student Progress prior to or concurrent with relevant ENTC course.

Substantial relationships between the ACT/SAT and college academic performance GPA were demonstrated with an $r = 0.39$ in a meta-analysis performed by Robbins et al., 2004. Within the same study, the relation between college and past (high school GPA) was also significant, $r = 0.45$. The results of a path analysis of academic performance worked better when ACT/SAT scores were used to operationalize prior ability than high school GPA. The conclusion was that high school GPA related more closely with self-efficacy while ACT/SAT had a stronger connection to general cognitive ability (Brown et. al, 2008).

The Kolbe A instrument based on the 4 constructs (Fact Finder, Follow Thru, Quick Start, and Implementor [*sic*]) began with an item analysis of 200 questions. Based on criterion group analysis and correlation studies using cognitive (e.g., Wonderlic Personnel Test) and affective (e.g., MBTI) 150 of the original 200 questions were eliminated. The 50 remaining items were given to 200 subjects who were asked to complete the index in such a way to best present themselves in a socially desirable manner. Items (6) which fit into a socially desirable response set were eliminated. This left 44 items in the pool of possible questions. The final version (in 2004) consisted of 36 items (Kolbe, 2004).

Dr. Robert Keim conducted a study on bias and the Kolbe instrument in 1990 wherein he examined 4030 Kolbe results. Analyses of variance with each of the four conative modes as dependent variables and independent variables of race, gender and age indicated (in 65 of 68 analyses) that at the .05 level of significance the differences in Kolbe scores could not be attributed to race, gender or age. Based on Chi square testing of the 3 suspect cases, Dr. Keim concluded that at the $\alpha = 0.05$ level, the Kolbe was not biased by gender, age or race (Kolbe, 2004).

A comparison of individuals born in the U.S. and natives of other countries (10,124 U.S. origin and 1,182 non-U.S. origin) indicates that country of origin does not influence distribution of Kolbe results (see Table 6).

Table 6. *Kolbe distributions U.S. origin vs. non-U.S. origin*

Action Mode	% Initiate		% Accommodate		% Resist	
	U.S. origin	Non-U.S.	U.S. origin	Non-U.S.	U.S. origin	Non-U.S.
FF	39.29	40.61	51.1	50	9.61	9.39
FT	20.89	26.4	55.81	52.37	23.3	21.24
QS	36.08	32.66	35.4	34.35	28.52	32.99
IM	6.87	6.6	49.03	48.39	44.09	45.01
Total	25.79	26.57	47.83	46.28	26.38	27.16

Procedural Details

To recap, during the first week of class, all ENTC 1500 students (fall 2008 through spring 2012) filled out a survey (Appendix B). Also at the end of fall 2011, 27 students filled out a survey on ENTC 1500 (Appendix C). For students who took ENTC 1500 grades were obtained from transcripts for the following courses as applicable: Math 1501, Math 1504, Math 1507, Math 1508, and Math 2623 (PPT only).

Each of the courses above could have been taken previous, concurrent or subsequent to ENTC 1500 depending on the individual course. Relevant flags were constructed to allow specificity in subsequent analysis. For example a student could take Math 1508 concurrent or subsequent to ENTC 1500. In similar fashion, the 5 subsequent courses which were specific to the engineering technology longitudinal study (Math 1513, ENTC 1505 and Lab, MET 1515, Phys 1501, Math 1570, and Math 2670) and the subsequent course Electrical Fundamentals and Lab (EUT 1500/L) taken by the Power Plant students were updated term by term.

Off of the file received in March 2012 (see **Instrumentation and Procedure**) updates for the Math 1513, ENTC 1505 and Lab, MET 1515, Phys 1501, Math 1570 and

Math 2670 were added to the data base from transcripts of 278 students who placed directly into Math 1513 and ENTC 1505 by virtue of an ACT Math score above 22 (SAT math above 520 or equivalent math placement test).

Fixed Effect versus Mixed (Random) Effects Model

In fixed effect analysis, the assumption is that the true effect size is the same in all studies and the summary effect will be the same in all studies. In a mixed effects analysis, the assumption is that the true effect size varies from one study to the next and the studies in our analysis represent a random sample of effect sizes so that the summary effect is an estimate of the mean of these separate effects.

For the case of k one-group studies, standard deviation σ and sample size n, the fixed effect model standard error of the summary result is given by:

$$SE_M = \sqrt{\frac{\sigma^2}{k \cdot n}} \qquad (3.1)$$

where with a large enough sample size the standard error will approach zero.

The mixed effects model standard error of the summary result is given by:

$$\mathrm{SE_M} = \sqrt{\frac{\sigma^2}{k \cdot n} + \frac{\tau^2}{k}} \qquad (3.2)$$

where the first term under the radical is identical to the fixed effect model and again with a large enough sample size will approach zero. The second term reflects the reality that the between studies variance will only approach zero as the number of studies approaches infinity (Borenstein, Hedges, Higgins, & Rothstein, 2009).

There is good reason to believe that all studies included in the dissertation analysis are functionally identical which would suggest use of a fixed effect model rather than a mixed effects model. However, the *goal* of this investigation is not to compute the common effect size for the identified population but rather *to generalize to other populations*. Therefore, the fixed model is rejected in favor of the mixed methods model.

A problem with choosing a mixed methods model is that if the number of studies is small (as it is in this investigation), the estimate of the variance between studies (τ^2) will have poor precision. The best option in this case per Borenstein et al. (2009) calls for estimating τ^2 based on data from outside of the current set of studies (a Bayesian approach). However, such an approach is complex and seldom pursued in practice.

Ultimately, the Comprehensive Meta Analysis (CMA) program was selected to analyze the cohorts of ENTC 1505 students; particularly because this program weighs sample sizes of each cohort group. Note the small sample sizes of *New Treatment* students in fall 2008 and spring 2009.

Limitations of Methodology

The analysis is likely to have good ecological validity not only in the field of engineering technology but in other STEM related practitioner fields as well (e.g., biology, information technology) but probably not in more science and research focused bachelor degree fields (e.g., chemistry, computer science, engineering, physics and mathematics). These more abstract research (vs. applications) fields tend to attract a different population of students. It would be interesting to know if conclusions reached could be applied to other practitioner fields (e.g., nursing, business, fine and performing arts and teacher education). Obviously this study will not accomplish that. However, even confined to the narrow field of engineering technology, the very ecological validity strength of teaching and learning in a realistic higher education context implies a sacrifice of internal validity when compared to a controlled laboratory study.

There is likely to be a fairly high confidence level in generalizing results to other engineering technology urban and suburban settings though perhaps not to populations with a high concentration of bilingual students.

Chapter 4

Analysis of Data

"Is there any other point to which you would wish to draw my attention?" "To the curious incident of the dog in the night-time." "The dog did nothing in the night-time." "That was the curious incident," remarked Sherlock Holmes.

'Silver Blaze' in *The Memoirs of Sherlock Holmes* (1894) (Rees, 1997, 213, 214).

Introduction

This section begins with a presentation of concerns which arose as to retention of ENTC 1500 students in the fall 2006 through spring 2008 period. Next basic group demographics are laid out. Students are broken into four separate test groups with the students receiving the *New Treatment* as the treatment group and the other 3 as *Control* Groups. Ultimately, based on term by term clustering of students, it became apparent that the most meaningful analysis would be between the two largest groups, *New Treatment* and the large group of students who did not by virtue of math placement require any treatment, the *No Treatment* group. An interesting and unexpected pattern emerges with the *New Treatment* group which will be highlighted at the end of this Chapter and discussed in depth in Chapter 5.

The Issue of Retention and Identification of ENTC 1500 Treatments

The primary method of teaching ENTC 1500 in academic years 2006 and 2007 departed from the classic method (*Classic Treatment*) developed at its inception in 2001. In part, this was a response to changes in the college itself. In 2007, the STEM College was formed. This would lead to higher math requirements for entry into engineering technology in 2008. The style adopted was very much in keeping with the old teaching paradigm indicated back in Table 2 with an acceptance of a lecture role for faculty and a focus of concern on the quality of entering rather than exiting students. An increased emphasis on teaching math skills and de-emphasis on labs (replaced by demonstrations) were notable. This method of teaching will be referred to as *Fidelity Failure* to contrast with the *Classic Treatment* primarily aimed at; but not exclusive to electrical utility students.

The *Fidelity Failure* method was ultimately applied to 275 ENTC 1500 students from fall 2006 through fall 2008 with 93 passing the course (33.8%). Between fall 2006 and fall 2008, the *Classic Treatment* was applied to 150 ENTC 1500 students with 90 passing the course (58.8%). The same metric applied to the 319 ENTC 1500 students who would be exposed to the *New Treatment* from fall 2008 through spring 2012 resulted in 225 students passing the course (70.5%).

Table 7. *Teaching Method and Achievement in ENTC 1500 (C or above)*

Method	Terms	Start Class	Achieved C or Above	% C or Above
Fidelity Failure	Fall 06–Fall 08	275	93	33.8%
Classic Treat	Fall 06–Fall 08	150	90	58.8%
New Treatment	Fall 08–Spr 12	319	225	70.5%

Included in the *New Treatment* group of 319 are 30 students who signed up for the class multiple times and 26 students who either never showed up for a single class or did not submit a major piece of classwork. The group of 26 who fit within the extreme of

Non Attendance F (NAF) students will be separated out into a fifth grouping, *Intend to Treat* (see Table 11). For sake of applies to apples comparison with *Fidelity* Failure and *Classic Treatment*, the 70.5% *New Treatment* pass rate will be used. A more accurate measure of achievement in ENTC 1500 for *New Treatment* would be 225/263 = 85.6%.

University and STEM College Demographics

The university has long relied on the tri-county population (Mahoning, Trumbull and Columbiana) for a high percentage of her enrollments. A similar pattern holds for the College of STEM. Table 8 illustrates this pattern for the 2008 through 2012 period.

Table 8. *Tri-county undergraduate enrollments at YSU (2008 through 2012)* (YSU Institutional Research, 9/7/2012)

Entity	Mahoning	Trumbull	Columbiana	Total
University	50.1% - 53.5%	22.9% - 23.9%	5.14% - 6.09%	79.1% - 81.7%
STEM College	44.8% - 47.3%	23.0% - 25.0%	8.20% - 9.02%	76.9% - 79.0%

When feeder high schools are examined roughly one-third of new students arrive at the university and the STEM College from just nine feeder secondary schools; with seven of the top nine identical. G.E.D. recipients are considered one of these feeder schools. This relationship is indicated in Table 9.

Table 9. *Feeder High schools > 2.9% of undergraduate entry students for 2008 - 2012* (YSU Institutional Research, 9/7/2012)

	University	STEM College
Boardman	6.67% - 7.29%	6.35 - 7.59%
G.E.D. recipients	4.91% - 6.78%	2.14% - 5.72%
Austintown Fitch	5.08% - 6.65%	4.67% - 7.17%
Canfield	2.35% - 3.59%	2.30% - 4.61%
Poland Seminary	2.95% - 3.55%	2.53% - 4.09%
Hubbard	2.59 - 3.29%	2.66% - 3.36%
Struthers	2.48% - 3.31%	2.72% - 3.07%
Chaney	2.06% - 3.15%	N/A
East	1.00% - 3.11%	N/A
Liberty	N/A	2.12 - 3.31%
Cardinal Mooney	N/A	1.43 - 2.92%
Total	32.4% - 36.7%	32.4% - 37.3%

Gender is slightly higher for females across the university but much higher for males in the STEM College. See Table 10.

Table 10. *Undergraduate enrollments at YSU (2008 through 2012) by Gender* (YSU Institutional Research, 9/7/2012)

Entity	Male	Female
University	46.2% - 47.6%	52.4% - 53.8%
STEM College	72.3% - 73.3%	26.7% - 27.7%

Table 11 indicates total undergraduate enrollments for university, STEM College and 4 year engineering technology (2+2) programs for fall 2008 through fall 2012. Note the large percentage enrollment drops for the university fall 2011 (– 3.8%) and fall 2012 (– 5.3%) and an even more dramatic percentage drop for engineering technology fall 2011 (– 7.2%) and fall 2012 (– 7.8%).

Table 11. *Undergrad Enrollments* (YSU Institutional Research, 9/7/12; 12/2/11)

14th Day Enrollments	Fall 2008	Fall 2009	Fall 2010	Fall 2011	Fall 2012
University Total	12,412	13,377	13,902	13,369	12,656
% Increase (vs. Prev. Yr.)		7.8%	3.9%	– 3.8%	– 5.3%
STEM College Total	2,337	2,594	2,679	2,671	2,649
% Increase (vs. Prev. Yr.)		11.0%	3.2%	– 0.3%	– 0.8%
Eng Tech (CCET, EET, MET)	222	239	249	231	213
% Increase (vs. Prev. Yr.)		7.6%	4.2%	– 7.2%	– 7.8%

Group Demographics for the Study

Gender across the five treatment groups was analyzed. The pattern reveals an across the board predominance of male students (89%, 84%, 100%, 98% and 95%), as indicated in Table 12.

Table 12. *Treatment vs. Gender*

Gender		No Treat	Intend Treat	Fidelity Fail	Classic Treat	New Treat
0	Male	177	26	14	63	249
1	Female	21	5	0	1	14

An examination of race distribution indicates a predominance of white students, as seen in Table 13. The largest percentage of minority students (black and Hispanic) began in the *New Treatment* or *Classic Treatment* groups (roughly 19%) while the *No Treatment* group was around 8.5%. On the other hand, black students were the most likely to end up no shows or nonparticipants and consequently placed in the *Intend to Treat* group (roughly 35%).

Table 13. *Treatment vs. Race*

Race		No Treat	Intend to Treat	Fidelity Fail	Classic Treat	New Treat
1	Amer Indian/Alaskan Native	2	0	0	0	1
2	Asian	0	0	0	0	1
3	Black	12	9	1	11	38
4	Hispanic	4	1	0	0	8
5	Multiracial	1	0	0	0	1
6	White	169	16	13	48	195

Students who registered as veterans were examined and revealed to lie between 5 and 10% across the five treatment groups as indicated in Table 14.

Table 14. *Treatment vs. Veteran Registration*

Veteran Registration		No Treat	Intend to Treat	Fidelity Fail	Classic Treat	New Treat
0	Not registered as Veteran	187	24	14	58	244
1	Registered as Veteran	11	2	0	6	19

In order to track progress of students from ENTC 1500 into subsequent courses; counts of students by term fall 2008 through spring 2012 Table 15 was constructed.

Table 15. *Treatment vs. Term Entry into ENTC 1500*

Entry Term		No Treat	Intend to Treat	Fidelity Fail	Classic Treat	New Treat
1	Fall 2008	0	7	13	23	38
2	Spring 2009	0	3	1	8	21
3	Fall 2009	0	5	0	28	40
4	Spring 2010	0	3	0	0	33
5	Fall 2010	0	3	0	4	45
6	Spring 2011	0	4	0	0	25
7	Fall 2011	0	1	0	0	36
8	Spring 2012	0	0	0	0	25

For direct comparison between the *No Treatment* and *New Treatment* groups, the aggregates of data were organized by term of entry into ENTC 1505. This data are presented in Table 16. Note: the *New Treatment* small sample sizes for spring 2009 and fall 2009 (n = 3 and n = 2 respectively).

Table 16. *Treatment vs. Term Entry into ENTC 1505*

	Entry Term	No Treat	Intend to Treat	Fidelity Fail	Classic Treat	New Treat
1	Fall 2008	26	0	0	0	0
2	Spring 2009	17	0	6	0	3
3	Fall 2009	41	0	0	1	2
4	Spring 2010	24	0	0	4	14
5	Fall 2010	31	0	0	1	13
6	Spring 2011	11	0	0	1	10
7	Fall 2011	25	0	0	1	14
8	Spring 2012	17	0	0	0	13
9	Fall 2012	NA	0	0	0	10

Table 17 indicates student involvement in Reading and Study Skills (R&SS 1510 A, B or C). The number of students is small; particularly since fall 2009.

Table 17. *Treatment vs. Entry into Reading & Study Skills*

	Entry Term	No Treat	Intend to Treat	Fidelity Fail	Classic Treat	New Treat
1	Fall 2008	8	3	1	2	11
2	Spring 2009	4	2	0	4	4
3	Fall 2009	5	3	1	2	12
4	Spring 2010	1	1	0	1	8
5	Fall 2010	1	2	0	0	7
6	Spring 2011	3	0	0	1	2
7	Fall 2011	1	0	0	0	5
8	Spring 2012	0	0	0	0	1

The majority of students receiving intervention services by way of R&SS 1510 per Table 16 above were in the *New Treatment* group as would be expected. As indicated in Table 18, 88% of those students successfully completed the R&SS class.

Table 18. *Treatment vs. Reading & Study Skills Grade*

Entry Term		No Treat	Intend to Treat	Fidelity Fail	Classic Treat	New Treat
0	No Credit	2	5	0	0	6
2	C	1	2	0	3	9
3	B	4	1	0	2	14
4	A	16	3	2	5	21

Table 19 provides a display of student constituencies who graduated from traditional high schools indicating a high proportion of nontraditional, rural/agricultural students in the *New Treatment* group vs. a nontraditional, urban and PA school concentration in the *No Treatment* group.

Table 19. *Treatment vs. Traditional H.S.*

Traditional HS (Ext Ohio 2007 Cluster Codes 1 to 7)				No Treat	Intend Treat	Fidelity Fail	Classic Treat	New Treat
State	Code	Setting	Poverty/Income Des					
OH	0	Nontraditional	Table 19 (1 to 9)	25	8	4	7	40
OH	1	Rural/agric	High poverty, low median income	14	2	1	6	37
OH	2	Above + small pop	Low poverty, low to mod med income	22	3	4	6	18
OH	3	Rural/small town	Mod to high median income	4	0	0	0	8
OH	4	Urban	Low median income, high poverty	44	6	0	18	68
OH	5	Urban	Very high poverty	11	2	1	6	18
OH	6	Urban/Sub	High median income	23	3	1	7	24
OH	7	Urban/Sub	Very high med income, low poverty	2	1	0	1	0
PA	8	Any	PA Schools	31	0	2	9	21
Natl	9	Any	National (non OH & non PA)	1	0	0	0	2
Intl	10	Any	International	0	0	0	0	0

Table 20 takes a similar look to Table 19 at those who matriculated by way of alternatives to traditional high schools indicating that within the nontraditional alternatives; the GED, private religious schools and STEM schools (Girard and Fitch) had the greatest number impact. Reference the previous Table 9 for the impact of Fitch on STEM enrollments. Meanwhile, within the *No Treatment* group the nontraditional route is less often the case though when it is; the home school, private religious schools and STEM schools are most prominent.

Table 20. *Treatment vs. Nontraditional H.S.*

Nontraditional HS			No Treat	Intend Treat	Fidelity Fail	Classic Treat	New Treat
Code	Setting	Description					
0	Traditional	Codes 1 thru 10 Table 18	152	16	9	53	196
1	Nontraditional	Alternate School	0	0	0	0	0
2	Nontraditional	Cyber School	1	0	0	0	0
3	Nontraditional	GED	3	4	0	2	10
4	Nontraditional	Home School	5	0	0	0	1
5	Nontraditional	JVS (Career/Tech)	0	0	0	1	0
6	Nontraditional	Private (nonreligious charter)	0	2	0	0	4
7	Nontraditional	Private (religious)	7	1	1	3	10
8	Nontraditional	STEM (Girard & Austintown Fitch)	9	1	3	1	14
9	Nontraditional	YEC (Youngstown Early College)	0	1	0	0	1

The average age of students when enrolled in ENTC 1500 was analyzed across the five treatment groups (note: $n = 0$ for the *No Treatment* group). Analyses revealed similarities between the *Intend to Treat*, *Fidelity Failure*, *Classic Treatment* and *New Treatment* group means with consistently lower standard deviations in the *Classic Treatment* and *New Treatment* groups than in the *Intend to Treat* and *Fidelity Failure* groups. The level of skewness fell outside of the acceptable range for the *Intend to Treat* group alone (±2.0) while kurtosis was within an acceptable range for all four groups (±5.0) (Tabachnik & Fidel, 2009). These results are presented in Table 21.

Table 21. *Age when enrolled in ENTC 1500*

Group Treatment	Frequency	Mean	S.D.	Skew	Kurtosis
0 = No Treatment	0	NA	NA	NA	NA
1 = Intend to Treat	26	22.88	8.760	2.214	3.959
2 = Fidelity Failure	14	23.64	9.787	1.843	2.161
3 = Classic Treatment	63	23.70	6.331	0.894	− 0.339
4 = New Treatment	263	23.79	7.266	1.622	2.162

The age when students from the five treatment groups were enrolled in the engineering technology accredited course, ENTC 1505 was analyzed. There was a roughly one year mean difference between the *No Treatment* (M = 23.31) and *New Treatment* (M = 24.64) groups. The means of the *Fidelity Failure* and *Classic Treatment* groups more closely mirrored the *No Treatment* group (M = 23.83 and 23.38, respectively).

None of the *Intend to Treat* students moved on to ENTC 1505. Standard deviations for the *No Treatment* and *New Treatment* groups were similar while the *Classic Treatment* group was more and the *Fidelity Failure* group less precise. Both skewness and kurtosis fell outside acceptable ranges (±2.0 and ±5.0 respectively) (Tabachnik & Fidel, 2009) for the *Fidelity Failure* group; likely mitigated by the low sample size (n = 6). Skewness also fell outside the acceptable range (±2.0) (Tabachnik & Fidel, 2009) for the *No Treatment* group. These results are presented in Table 22.

Table 22. *Age when enrolled in ENTC 1505*

Group Treatment	Frequency	Mean	S.D.	Skew	Kurtosis
0 = No Treatment	192	23.31	8.109	2.256	− 0.931
1 = Intend to Treat	0	NA	NA	NA	NA
2 = Fidelity Failure	6	23.83	11.890	2.404	5.819
3 = Classic Treatment	8	23.38	6.046	0.483	− 1.992
4 = New Treatment	69	24.64	7.774	1.670	2.048

The average Effective Family Contribution (EFC) was analyzed as an indicator of socioeconomic status, across the five treatment groups. Analyses revealed similarities between the *No Treatment*, *Fidelity Failure* and *Classic Treatment* group means and standard deviations with consistently lower group means in the *Intend to Treat* and *New Treatment* groups. All levels of skewness and kurtosis were within acceptable ranges (±2.0 and ±5.0 respectively) (Tabachnik & Fidel, 2009). These results are presented in Table 23.

Table 23. *EFC Categories (6) {Financial Aid measure of SES}*

Group Treatment	Frequency	Mean	S.D.	Skew	Kurtosis
0 = No Treatment	161	2.26	1.701	– 0.014	– 1.322
1 = Intend to Treat	23	1.70	1.717	0.461	– 1.287
2 = Fidelity Failure	14	2.71	1.637	– 0.200	– 0.443
3 = Classic Treatment	48	2.56	1.809	– 0.117	– 1.409
4 = New Treatment	228	1.79	1.745	– 0.400	– 1.293

ACT math scores across the five treatment groups were analyzed. ACT math scores as expected were highest for the *No Treatment* group (M = 21.32). They were lowest for the *Fidelity Failure* group (M = 16.70); however, scores were roughly equivalent for the other three treatment groups (M between 17.89 and 18.34 for the *Intend to Treat*, *Classic Treatment* and *New Treatment* groups. Standard deviations for the *Intend* to *Treat* and *New Treatment* groups were similar (*SD* = 2.447 and 2.858 respectively) while the *Fidelity Failure* group was less spread (*SD* = 1.494) and both *Classic Treatment* and *No Treatment* groups more spread (*SD* = 3.611 and 4.010 respectively). Both skew and kurtosis were within acceptable ranges (±2.0 and ±5.0 respectively) (Tabachnik & Fidel, 2009) for all five treatment groups. These results are presented in Table 24.

Table 24. *ACT Math*

Group Treatment	Frequency	Mean	S.D.	Skew	Kurtosis
0 = No Treatment	144	21.32	4.010	– 0.156	– 0.405
1 = Intend to Treat	19	17.89	2.447	1.051	0.819
2 = Fidelity Failure	10	16.70	1.494	0.140	– 1.622
3 = Classic Treatment	40	18.20	3.611	0.693	0.283
4 = New Treatment	181	18.34	2.858	0.497	0.192

High school grade point averages (GPA) across the five treatment groups were analyzed. GPA as expected was highest for the *No Treatment* group (*M* = 2.98). They were roughly equivalent for the other four treatment groups (*M* = 2.39 for *Intend* to *Treat*, *M* = 2.64 for *Fidelity Failure*, *M* = 2.46 for *Classic Treatment* and *M* = 2.61 for *New Treatment*). Standard deviations for the *No Treatment* (SD = 0.648), *Fidelity Failure* (SD = 0.512) and *New Treatment* (SD = 0.618) groups were similar. The *Classic Treatment* was wider (*SD* = 0.776) while the *Intend to Treat* group was less spread (*SD* = 0.397). Skewness was within an acceptable ranges (±2.0) (Tabachnik & Fidel, 2009) for all five treatment groups; kurtosis fell in the acceptable range (±5.0) (Tabachnik & Fidel, 2009) for 4 of the 5 treatment groups but not so for the *No Treatment* group. These results are presented in Table 25.

Table 25. *High School GPA*

Group Treatment	Frequency	Mean	S.D.	Skew	Kurtosis
0 = No Treatment	132	2.98	0.648	– 1.614	5.737
1 = Intend to Treat	17	2.39	0.397	1.051	0.819
2 = Fidelity Failure	10	2.64	0.512	0.773	– 1.464
3 = Classic Treatment	49	2.46	0.776	– 1.305	0.283
4 = New Treatment	200	2.61	0.618	– 0.566	1.033

If a student places into Math 1501 then the class can be taken concurrently with ENTC 1500 but as a general rule advisers will wait until the student has passed Math 1501 before placing them in ENTC 1500. The following four classes can be taken concurrently or subsequently to ENTC 1500— Math 1504, Math 1507, Math 1508, and Math 2623 (power plant students). Grades in these classes per group treatment are shown in Appendix G, Tables G1 through G13. Classes taken subsequent to ENTC 1500 include Math 1513, ENTC 1505, ENTC 1505L (all three taken concurrently), then MET 1515, Physics 1501, Math 1570 and Math 2670, typically in that sequence. Grades in these seven classes per group treatment appear in Appendix G, Table G14 through G21.

Analysis of Relevant Groups

Engineering technology students were grouped together according to the term when they took ENTC 1505 since this course signifies acceptance into the program and provides a consistent timeframe with which to do subsequent student comparisons. The earliest term the *New Treatment* group hit ENTC 1505 was spring 2009. The latest term of comparison was spring 2012. The overall makeup of these ENTC 1505 cohort groups is detailed in Table 26. Again, note the low sample sizes of New Treatment students in spring 2009 and fall 2009 (n =3 and n = 2 respectively.

Table 26. *The Makeup of the ENTC 1505 Cohorts*

Entry Term		No Treat	Fidelity Fail	Classic Treat	New Treat	% New Treat
1	Fall 2008	26	0	0	0	0.0%
2	Spring 2009	17	6	0	3	11.5%
3	Fall 2009	41	0	1	2	4.5%
4	Spring 2010	24	0	4	14	33.3%
5	Fall 2010	31	0	1	13	28.9%
6	Spring 2011	11	0	1	10	45.5%
7	Fall 2011	25	0	1	14	35.0%
8	Spring 2012	17	0	0	13	43.3%
9	Fall 2012	20	0	0	10	33.3%
10	Spring 2013	10	0	0	12	54.5%

Trends in ENTC 1505 Enrollment

If Table 26 is collapsed into individual academic years 2008 through 2012 then Table 27 and Figure 6 indicate the overall trend in ENTC 1505 enrollment over time. As is clear from Figure 6, the % of students who are populating ENTC 1505 classes shows a steady rise in *New Treatment* students projected to reach 50% of the ENTC 1505 cohort population in 2014.

Table 27. *Trend in ENTC 1505 enrollment*

Entry Year		No Treat	Fidelity Fail	Classic Treat	New Treat	% New Treat
1	2008	43	6	0	3	5.7%
2	2009	65	0	5	16	18.6%
3	2010	42	0	2	23	34.3%
4	2011	42	0	1	27	38.6%
5	2012	30	0	0	22	42.3%

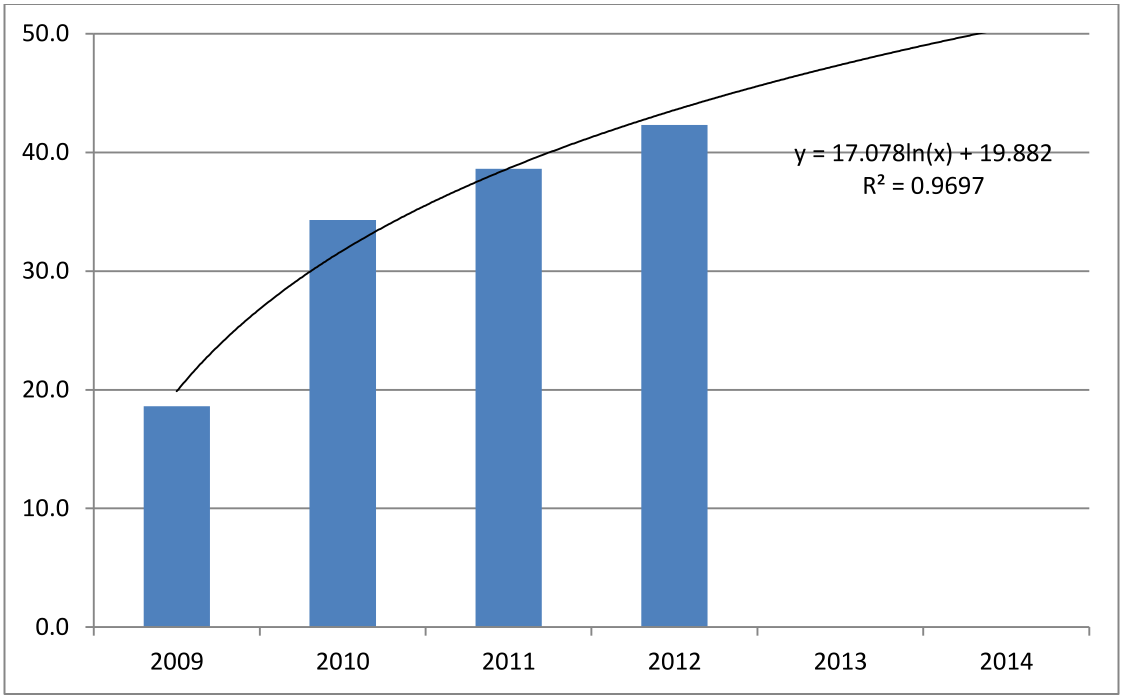

Figure 6. *New Treatment students in ENTC 1505 by Academic Year*

Initially, Groups 0 through 3, *No Treatment*, *Intend to Treat*, *Fidelity Failure* and *Classic Treatment* were aggregated into one *Control* group for comparison with Group 4, *New Treatment*. Comprehensive Meta Analysis (CMA) was employed to analyze the data. Table 28 presents the data using a Mixed Effects Analysis.

Table 28. *Student Term in ENTC 1505 [Mixed Effects Analysis]*

Treatment Groups	Number Effect Size Measures (Studies)	Between Group Effects (Q)	Mean Effect Size (Pt Est)
		0.209	
Control (0 to 3)	54		2.529
New Treatment	22		2.305**

** Significant ($p < 0.01$)

As indicated by Table 28 above, no differences were found in mean effect size for students in ENTC 1505 for the *New Treatment* group relative to the aggregated *Control* group across all course work ($p > 0.05$).

Secondarily, analysis was conducted after breaking out the *No Treatment*, *Intend to Treat*, *Fidelity Failure* and *Classic Treatment* subgroups in an attempt to better understand student performance at a lower aggregate level. The mixed effects analysis suggests that when all four groups are compared to *New Treatment* students, significant differences were present, ($p < 0.01$). These results are presented in Table 29.

Table 29. *Student Term in ENTC 1505 [Mixed Effects Analysis]*

Treatment Groups	Number Effect Size Measures (Studies)	Between Group Effects (Q)	Mean Effect Size (Pt Est)
		36,052**	
Control (No Treatment)	16		2.076**
Intend to Treat	5		0.002
Fidelity Failure	16		3.971**
Classic Treatment	17		3.276**
New Treatment	22		2.526**

** Significant ($p < 0.01$)

The extreme Mean effect size of the *Intend to Treat* group relative to the other groups led to the suspicion that the *Intend to Treat* group might be having an extreme influence on the aggregated *Control* group. Upon dropping the five studies constituting the *Intend to Treat*, a new mixed effects analysis suggests that indeed significant differences do exist at this aggregate level of analysis. Specifically, Table 30 indicates a change in Mean Effect size of the Control group from 2.529 (Table 28) to 2.790.

Table 30. *Student Term in ENTC 1505 [Mixed Effects Analysis]*

Treatment Groups	Number Effect Size Measures (Studies)	Between Group Effects (Q)	Mean Effect Size (Pt Est)
		1.694	
Control (0, 2, 3)	49		2.790**
New Treatment	22		2.306**

** Significant ($p < 0.01$)

As indicated by Table 30 above, no differences were found in mean effect size for students in ENTC 1505 for the *New Treatment* group relative to the aggregated *Control* group across all course work ($p > 0.05$).

Removal of the *Intend to Treat* group has a robust effect on mean effect size and between group effects if Tables 29 and Table 31 are compared.

Table 31. *Student Term in ENTC 1505 [Mixed Effects Analysis]*

Treatment Groups	Number Effect Size Measures (Studies)	Between Group Effects (Q)	Mean Effect Size (Pt Est)
		12.769*	
No Treatment	16		2.626**
Fidelity Failure	16		3.024**
Classic Treatment	17		2.897**
New Treatment	22		2.318**

* Significant ($p < 0.05$), ** Significant ($p < 0.01$)

As revealed by Table 31 above, while significant differences remain ($p < 0.05$) these mean effect size differences now seem to spring from differences between the *New Treatment* and *Fidelity Failure* groups.

Finally, a head to head comparison looks at the *No Treatment* group against the *New Treatment* group. Over the three year time period (spring 2009 through spring 2012), the two groups were compared. Table 32 presents these results.

Table 32. *Student Term in ENTC 1505 [Mixed Effects Analysis]*

Treatment Groups	Number Effect Size Measures (Studies)	Between Group Effects (Q)	Mean Effect Size (Pt Est)
		2.251	
No Treatment	16		2.624**
New Treatment	22		2.319**

** Significant ($p < 0.01$)

As indicated by Table 31 above, no differences were found in mean effect size for students in ENTC 1505 for the *New Treatment* group relative to the *No Treatment* group across all course work ($p > 0.05$).

Head to Head: No Treatment vs. New Treatment over time

Did differences between *No Treatment* and *New Treatment* vary over time? Specifically, for the 7 ENTC 1505 cohort semesters from spring 2009 till spring 2012 was there any change evidenced in how students achieved from semester to semester?

For each semester, data were pulled from SPSS into CMA to create seven groups of studies that suggest a positive trajectory for *New Treatment* students over time. Table 33, mixed effects analysis shows this numerically over time.

Table 33. *Student Term in ENTC 1505 [Mixed Effects Analysis]*

Semester	Number Effect Size Measures (Studies)	Between Group Effects (Q)	Mean Effect Size (Pt Est)
		21.233	
Spring 2009	4		–0.660*
Fall 2009	3		–0.935*
Spring 2010	7		0.190
Fall 2010	6		0.202
Spring 2011	6		0.706**
Fall 2011	5		–0.198
Spring 2012	4		0.235

* Significant ($p < 0.05$), ** Significant ($p < 0.01$)

Positive values indicate that *New Treatment* impact was positive relative to *New Treatment* while negative values suggest better outcomes for the *No Treatment* (control) group. A reference back to Table 16 points out that the number of *New Treatment* students among spring 2009 and fall 2009 ENTC 1505 cohorts was extremely low ($n = 3$ and $n = 2$ respectively) whereas number of students in succeeding semesters has been consistently in double digits.

Figure 7 identifies the overall time trend graphically. A noticeable upward trend is evidenced from the two earliest ENTC 1505 cohorts (spring 2009 and fall 2009) with the notable exception of fall 2011. The appearance is a slight upward movement from spring 2010 to fall 2010 followed by a major upward spike in spring 2011 then an even more dramatic plummeting in fall 2011 and finally in spring 2012 a return to a level somewhat higher than the levels of spring 2010 and fall 2010. The actual step from spring 2010 through fall 2010 and into spring 2012 is a smooth linear improvement if the spring 2011 and fall 2011 excursions are ignored, Figure 8.

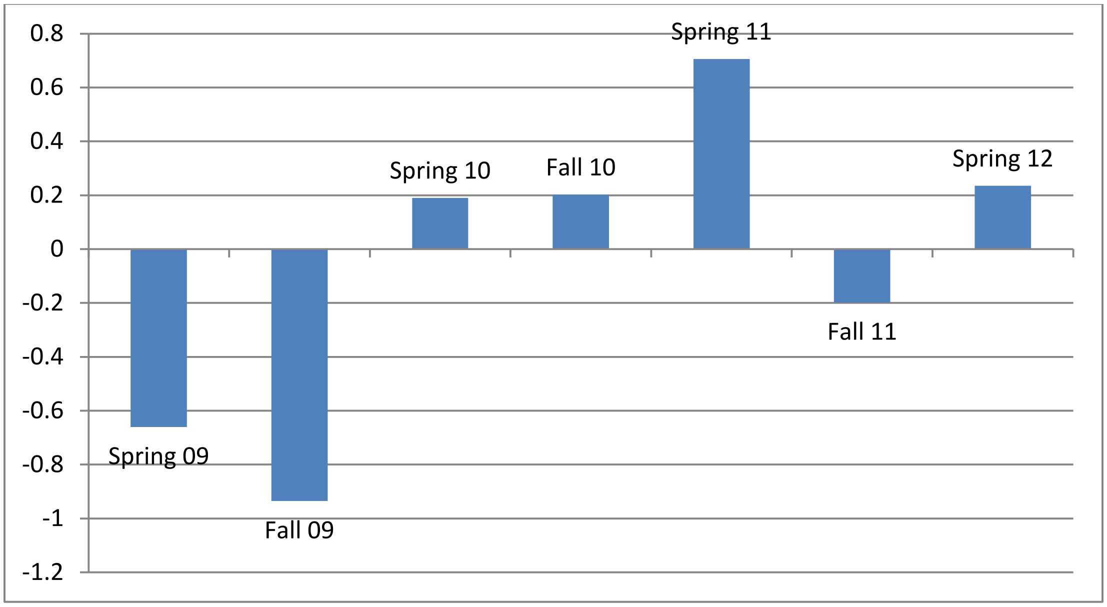

Figure 7. *Effect Size by ENTC 1505 Semester Cohort (New vs. No Treatment)*

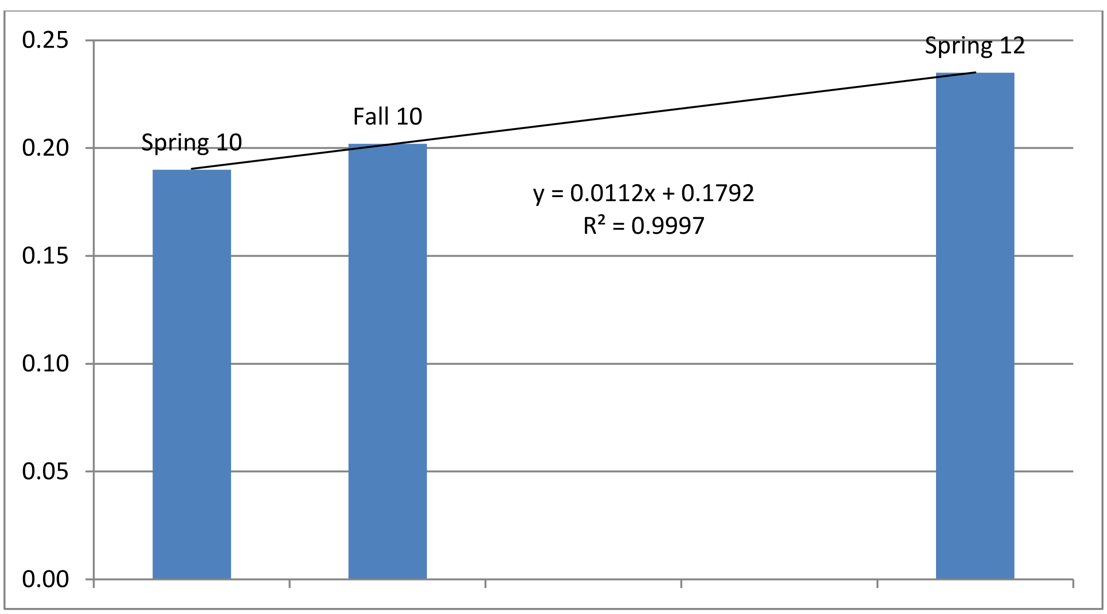

Figure 8. *Figure 7 with spring 2011 and fall 2011 excursions removed*

Head to Head: No Treatment vs. New Treatment by Target Course

Did the differences between *No Treatment* and *New Treatment* vary over follow-up courses? Specifically, for the seven ENTC 1505 cohort semesters between spring 2009 and spring 2012 were there any changes in how students achieved among the target courses.

For the seven semesters, data were pulled from SPSS into CMA to create seven groups of studies that evoke variation of performance for *New Treatment* vs. *No Treatment* students for each of the target courses over time. Table 34 shows the mixed effects analysis numerically.

Table 34. *Student Term in ENTC 1505 [Mixed Effects Analysis]*

Course (Ranked order)	Number Effect Size Measures (Studies)	Within Group Effects (Q)	Mean Effect Size (Pt Est)
		0.976	
ENTC 1505	7		– 0.002
ENTC 1505L	5		0.238
Math 1513	7		0.111
MET 1515	5		0.172
Math 1570	5		0.076
Phys 1501	4		– 0.022
Math 2670	2		– 0.139

Figure 9 shows the effect detailed in Table 31 graphically. ENTC 1505 and Physics 1501 appear to be a wash, ENTC 1505L, Math 1513, MET 1515 and Math 1570 more positive for *New Treatment* over *No Treatment* and Math 2670 a negative. The Math 2670 negative is mitigated by the small number of effect size measures ($n = 2$).

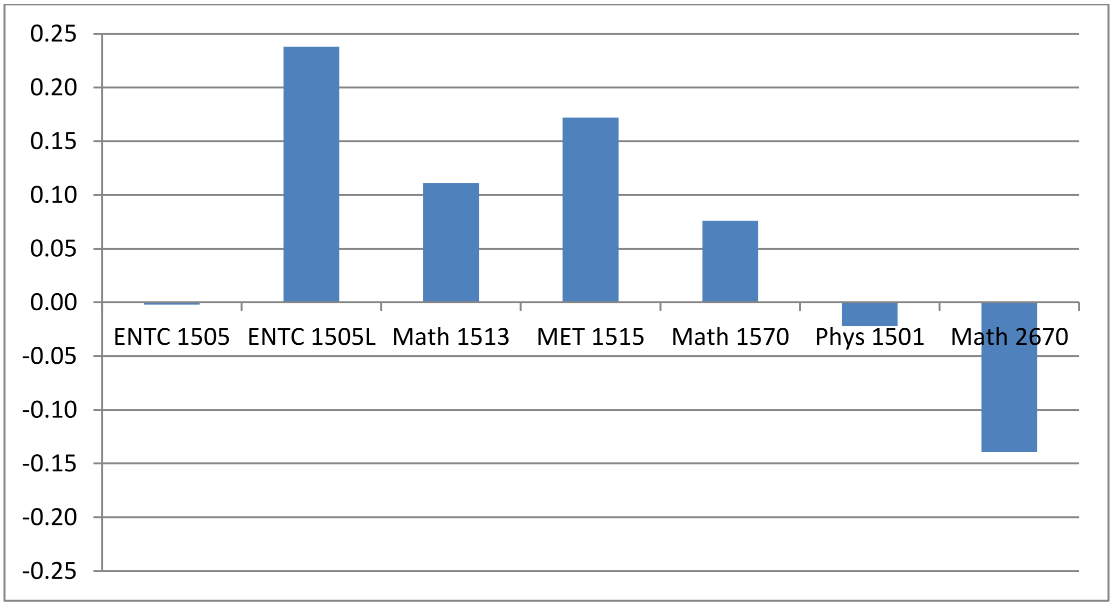

Figure 9. *Effect Size by Course for ENTC 1505 Semester Cohorts (New vs. No Treatment)*

The low cluster sizes obviated a multivariate analysis (i.e., MANCOVA) of the 7 follow-up classes (dependent variables) against treatment. Therefore, the plan was to perform simple correlations of the dependent variables against the *New Treatment* group with the hope of pulling in other variables (besides achievement in ENTC 1500) to form predictive regression models.

The top of Table 35 includes some of the variables that were expected to have medium or large correlation coefficients with the seven follow-up classes. Cohen (1988, 1992) holds a small effect threshold at r = .10 (effect accounts for 1% of the variance), medium effect threshold at r = .30 (effect accounts for 9% of the total variance) and a large effect threshold at r = .50 (effect accounts for 25% of the variance) (Field, 2009). In point of fact, high school GPA had a medium but non-significant ($p > 0.05$) effect on overall percentage in ENTC 1500 and a large significant ($p < 0.05$) effect on Math 2670.

An exhaustive search could not uncover other factors that had a medium or large effect on the seven follow-up classes. Note that a medium negative correlation between ENTC 1505L and ACT Math is both non-significant ($p > 0.05$) and counterintuitive.

Surprisingly, while ENTC 1505L (previous Figure 7) is the course over which the *New Treatment* group enjoys the greatest advantage over *No Treatment* students; the actual % achieved in ENTC 1500 has a small effect on letter grade in ENTC 1505L. This suggests that successful completion of the *New Treatment* version of ENTC 1500 is in and of itself the best predictor of achievement in ENTC 1505L.

Table 35. *Correlations for New Treatment ENTC 1500 Students*

	Percentage (%) ENTC 1500	Letter Grade ENTC 1505	Letter Grade ENTC 1505L	Letter Grade Math 1513	Letter Grade MET 1515	Letter Grade Math 1570	Letter Grade Phys 1501	Letter Grade Math 2670
% ENTC 1500		.271*	.110	.386**	.606**	.239	.400*	.646*
SES (EFC)	.078	−.051	−.050	.158	.113	.009	−.126	.247
ACT Math	.183	.078	−.375	.074	.269	.257	.153	−.264
HS GPA	.348	–.005	–.031	.288*	−.049	−.141	.271	.669*
Age	.002	.095	.115	–.015	.147	.152	.238	−.263
Attend	.762	.383**	.439**	.162	.111	.387*	.108	.734*
HW #1	.641**	.382**	.148	.298**	.436**	.290	.492**	.727*
Median Test	.749**	.343**	.290	.387**	.604**	.145	.451*	.462
Median Lab	.665**	.112	.039	.246	.427**	.305	−.013	.560
Day/Nite	.160	.171	–.059	.138	.396	.343	−.176	.216

*Significant ($p < 0.05$), **Significant ($p < 0.01$)

For the lower half of Table 34 for the *New Treatment* group, in the ENTC 1505 class as a whole attendance, homework and test taking all rise to medium effects far above lab achievement. In the specific lab section of ENTC 1505, ENTC 1505L (eliminated in fall 2011) attendance would appear to trump homework and (surprisingly) lab performance as an effective achievement predictor. For Math 1513, homework and test taking seem to play a larger role in predicting achievement than attendance or lab work. Homework and lab performance correlate at a medium effect and test taking at a high level for MET 1515 (mechanics). For Math 1570, the medium effect size link is attendance while in Math 2670 (the next Calculus class in the sequence) attendance and homework performance signify large effects. For Physics 1501, homework and test taking (both medium effects) would appear to hold more promise as predictors of achievement.

To make sense of the paucity of factors other than the *New Treatment* itself on follow-up coursework achievement, Table 35 was constructed to look at the effects of the same 4 factors (SES, ACT Math, HS GPA and Age [this time for *No Treatment* students' direct entry into ENTC 1505]). SES as measured by Effective Family Contribution again consistently showed less than a medium effect size for all of the remaining six dependent course grade variables. On the other hand, ACT Math score has a medium effect on MET 1515, high school GPA has a medium effect on ENTC 1505, Math 1513, ENTC 1505L and Physics 1501. Age has a medium effect on Math 1570.

Table 36. *Correlations for No Treatment ENTC 1505 Students*

	Letter Grade ENTC 1505	Letter Grade ENTC 1505L	Letter Grade Math 1513	Letter Grade MET 1515	Letter Grade Math 1570	Letter Grade Phys 1501	Letter Grade Math 2670
ENTC 1505		.763**	.653**	.353**	.470**	.504**	.256
SES (EFC)	–.014	.056	–.021	.021	.125	–.055	.094
ACT Math	.123	.074	.047	.277*	.075	.159	.286
HS GPA	.424**	.419**	.354**	.046	.157	.359**	.325
Age	.079	.011	.164	.120	.282**	.127	–.042

*Significant ($p < 0.05$), **Significant ($p < 0.01$)

Chapter 5

Summaries, Conclusions and Recommendations

"You will not apply my precept," he said, shaking his head. "How often have I said to you that when you have eliminated the impossible, whatever remains, *however improbable* must be the truth?"

Sherlock Holmes, *The Sign of the Four* (1890) (//www.bestofsherlok.com/top-10-sherlock-quotes.htm).

Introduction

This section will begin by recapping the process followed to analyze the relevant treatment and control groups in Chapter 4. Next, the research questions will be addressed. Where appropriate, quantitative analysis will be used but where this approach is unworkable, a qualitative method of attack will be employed. Implications of results will follow and the chapter will conclude with recommendations for future research.

Recap of Chapter 4 Treatment and Control Group Process

The study began with the *New Treatment* group and three control groups identified as *Classic Treatment*, *Fidelity Failure Treatment* and *No Treatment*. After initial pass rates in ENTC 1500 were determined for *New Treatment*, *Classic Treatment* and *Fidelity Failure Treatment* replicate efforts by students to pass ENTC 1500 (or at least sign up for ENTC 1500 multiple times) were eliminated. This totaled 30 cases. Only the final attempt by a *New Treatment* student in ENTC 1500 was maintained. In contrast, for follow-up target courses taken by students from any treatment, only the initial attempt grade was counted.

Prior to running demographics on the individual groups, those *New Treatment* students (26) who were no shows or who submitted no major assignments in ENTC 1500 were placed into a group called *Intent to Treat*.

Mixed effects analysis was chosen so that results could be generalized beyond the current population. The *New Treatment* was run against four control groups (*Classic Treatment*, *Fidelity Failure*, *Intend to Treat* and *No Treatment*). It was decided to eliminate the *Intend to Treat* control group because it proved too sycophantifically weight in the mixed effects analysis.

Ultimately, the *Classic* and *Fidelity Failure Treatments* were also eliminated because individual sample sizes were too small and/or data were too limited in time. This left a head to head comparison between *New Treatment* and *No Treatment*. From a time perspective the data were placed into individual ENTC 1505 cohort semesters (S09, F09, S10, F10, S11, F11, and S12).

Research Questions and Key Conclusions

1. Compare Engineering Technology students who successfully completed the *New Treatment* version of ENTC 1500 in seven follow-up classes with their counterparts (*No Treatment* students) who placed directly into MATH 1513 and ENTC 1505 owing to higher ACT (or equivalent) math test scores.

The seven follow-up classes can be divided into two categories (Chapter 4, Table 33 and Figure 9). The first category includes five target classes through which five or more waves of *New Treatment* students have reached and 40 or more *New Treatment* students have received grades. In four of the five classes, the *New Treatment* students outperformed the *No Treatment* students and in one the performance was equivalent.

- ENTC 1505 *New & No Treatment* had equivalent performance
- ENTC 1505L *New Treatment* outperformed *No Treatment*
- Math 1513 *New Treatment* outperformed *No Treatment*
- MET 1515 *New Treatment* outperformed *No Treatment*
- Math 1570 *New Treatment* outperformed *No Treatment*

The second category includes the remaining two target classes through which four or fewer waves of *New Treatment* students have reached and total *New Treatment* students < 30. For Physics 1501, this is four waves and a total of 28 *New Treatment* students (Table G18). For Math 2670 this is two waves and a total of 12 *New Treatment* students (Table G20).

- Phys 1501 *New & No Treatment* had equivalent performance
- Math 2670 *No Treatment* outperformed *New Treatment*

Waiting additional data on Phys 1501 (end Spring 2013) and Math 2670 (end Spring 2014); best available information is that *New Treatment* students outperform *No Treatment* students in 4 of 5 target classes and perform equivalently in the remaining class.

2. Examine ENTC 1500 *New Treatment* as causal to retention (and eventual student achievement).

For a typical yearly seed-corn quantity of 40 students seeking to matriculate into engineering technology (CCET, EET, or MET), the loss from the *Fidelity Failure* method which predominated in the 2006 and 2007 academic years would be 26 students per year, and from the *New Treatment* method 12 students per year. Based on a simplified assumption of equal distribution among freshmen, sophomores, juniors and seniors and the fall 2010 fourteenth day engineering technology enrollment indicated in Chapter 4, Table 10 (i.e., 239 students [60 per class]) the percentage drops in freshmen students for the *Fidelity Failure* method over the *New Treatment* method would constitute a net loss of an additional 23.3% freshmen students [(26 – 12)/60 x 100%]

The notion that such losses are the price of filtering out a large residue of students who couldn't handle engineering technology anyway is invalidated by the results to research question (1). We now know that the likelihood of future achievement of the cadre of *New Treatment* students who pass ENTC 1500 over the next several years is, in fact, very strong.

3. Examine ENTC 1500 *New Treatment* and interaction of developmental mathematics (e.g., Math 1508, trigonometry) as causal to retention (and eventual student achievement).

Based on the **Literature Review**, it was expected that Socioeconomic Status (SES) would play a major role with both *New Treatment* and *No Treatment* students and their ultimate achievement. The numbers do not bear this out. The singular medium effect was for *New Treatment* students in Math 2670 (r = 0.247) and this was mitigated by the low number of effect sizes (n = 2) as indicated in Chapter 4 Table 27.

It was also unexpected that essentially no factors (e.g., age, ACT Math, HS GPA, age, learning style preference, Kolbe modes of operation, *other developmental coursework*, involvement in Reading & Study Skills, or Student Progress) could be found to explain the generally better follow-up grades for *New Treatment* students versus *No Treatment* students with the exception of the *New Treatment* intervention itself. An exhaustive search among these variables turned up nothing; the positive improvements suggested by Chapter 4, Tables 32 and 33 and Figures 8 and 9 for time and follow-up courses pointed to one and only one remaining factor—the *New Treatment* itself.

4. Examine in detail (qualitatively) what specific aspects of ENTC 1500 *New Treatment* and follow-up classes contribute to student retention (and eventual student achievement).

The key facet of this question involves distilling the spirit of ENTC 1500 into a simplified model that captures its essence. We have returned to the sign Einstein kept in his university office: “A model should be as simple as possible but no simpler”:

1) Cooperative Learning
    a. The style of cooperative learning is built around two member homogeneous teams performing hands on labs that simulate how engineers attack and solve problems
2) Problem Solving
    a. Employ the same six step problem solving methodology widely used by engineers when they need to solve a novel problem. This problem solving can then be extended to . . .

3) Creativity

    a. Ensure that at least two of the three second half labs require originality and creativity to perform. If student results start looking too similar and of a boiler plate or cookbook fashion then change the labs.

4) Practice based

    a. Use primarily text homework in the first half semester to provide practice in solving problems that will be reflected in the labs. In the second half use the labs themselves as the primary practice vehicle and more modest homework assignments to support.

5) Learning Paradigm based

    a. Adopt John Tagg's New Learning Paradigm shown in Chapter 2, Table 2. It will mesh with the Hattie based Table 4 items I through IV as well as raise the urgency for Formative Evaluation of Programs (d = 0.73; standard error medium)

5. Examine potential causal effect that ENTC 1500 *New Treatment* and other developmental classes have on degree completion

Over short and medium term (one to three years after taking ENTC 1500), the *New Treatment* group showed advantages when considered in terms of both time and target follow-up courses over the *No Treatment* control group. For this time period, which would correspond to two years into an accredited program (i.e., Engineering Technology) and fulfillment of an associate degree, the learning advantage was both positive and sustainable.

However, beyond this window (e.g., into third or fourth year Math 2670) the results are murky. Only a small grading sample of the leading wave of *New Treatment* students is currently available. Therefore, it is not currently possible to infer degree completion or learning sustainability beyond the medium term.

Research Questions Detailed Discussion of Items 2, 3 and 4

2. Examine ENTC 1500 *New Treatment* as causal to retention (and eventual student achievement);

Based on experience, students unable to pass ENTC 1500 will typically change to majors outside the STEM College or drop out altogether. Students can move into Math 1513 (pre-calculus) either as a result of success in ENTC 1500 and developmental math courses (e.g., Math 1507 and Math 1508 or Math 1504) or direct placement into Math 1513. When such students (*No Treatment* or *New Treatment*) are unsuccessful in Math 1513 they will be less likely to drop out but highly likely to transfer to another college (typically to the Williamson College of Business). Such actions mirror the larger global issue of STEM retention discussed in the **Literature Review**.

Refer to Table 6 in Chapter 4. While the numbers appearing in this table are somewhat conservative of pass rates; (e.g., they fail to factor in no shows, and medical or financial withdrawals); they do provide an apples to apples comparison. The predominant method for teaching ENTC 1500 from fall 2006 through spring 2008 (discontinued after fall 2008) was the *Fidelity Failure* method. Students received C or above in roughly one-third of cases. This conservative pass rate approximation suggests that nearly two-thirds, 66% of students, failed to pass the course and hence would show up as an estimated enrollment loss to the STEM College. Over an identical timeframe (fall 2006 through fall 2008), 40% of *Classic Treatment* students and over the fall 2008 through spring 2012 timeframe, 30% of *New Treatment* students would be lost to the STEM College. The results noted in key conclusions flow from this data.

3. Examine ENTC 1500 *New Treatment* and interaction of developmental mathematics (e.g., Math 1508, trigonometry) as causal to retention (and eventual student achievement);

The data do not disclose the expected interaction between ENTC 1500 *New Treatment* and other developmental classes (e.g., Math 1507, Math 1508, and R&SS 1510). The role of these classes in the short and medium term improvement of *New Treatment* vs. *No Treatment* students surprisingly did not emerge.

For data specific to R&SS 1510 refer to Chapter 4, Table 16. In 2008 and 2009, 39 and 34 students respectively completed R&SS 1510 and ultimately ended up in either ENTC 1500 or 1505. This dropped to 16 in 2010 and thus far only seven from 2011 have moved into either ENTC course.

On a personal note, R&SS 1510C, STEM Advanced College Success Skills which incorporates a lab component, team teaching by a study skills and a science/math teacher, study skills instruction and peer (upper class student) tutoring, could be a very powerful combination for math deficient STEM university students. The problem is that this version of course designed for STEM students and co-listed as STEM 1510 did not make its debut until fall 2010. Prior, STEM students would have been in either R&SS 1510A or 1510B; neither of which incorporated a lab component or a science based team teacher. It is ironic that just as a configuration was designed with a potential to aid STEM students in general, few students were referred. This term, spring 2013, no STEM 1510C class is offered.

Is there a way to make sense of the wild Figure 7 excursions experienced in spring 2011 and fall 2011? Perhaps, but it will take a qualitative approach.

The Spring 2011 Peak

In spring 2011, three interesting factors converged. Typically, two sections of ENTC 1505 were offered each term and spring 2011 was no exception. The first factor was that the lead (more experienced) instructor was the second instructor besides the researcher who taught ENTC 1500 with the *New Treatment* approach (spring 2010). Spring 2011 was his third occasion to teach ENTC 1505 while an adjunct (part time instructor) taught ENTC 1505 for the second time. The second factor was that, for the first time, the number of labs run by each was three rather than the more typical two. Finally, the mix of *New Treatment* (ENTC 1500) students was much larger than any previous cohort (≥ 12.2%). This is illustrated in Chapter 4 Table 34, as developed from Table 15.

All three of the factors above would have favored *New Treatment* students over *No Treatment* students: (a) a lead instructor familiar with the *New Treatment* method, (b) more labs (*New Treatment* students are used to 5 labs per term) while *No Treatment* students could have been overwhelmed by the imposition of a third lab along with an unanticipated intense first term load, and (c) a heavy concentration of fellow *New Treatment* students in the ENTC 1505 cohort.

The Fall 2011 Valley

As noted above, in spring 2011, the number of hands on labs was increased in ENTC 1505 from two such labs per term to three labs per term. Since then (fall 2011 & spring 2012), it has increased to three to four labs per term. However, there were a number of factors that conspired to make fall 2011 a peculiar cohort term for ENTC 1505 students in general and *New Treatment* students in particular.

First, ENTC 1500L (the separate lab portion of ENTC 1505) was incorporated back into the basic ENTC 1505 course. The hands-on lab portion of total course grade was ultimately weighted at 20%. Second, unlike spring 2011 where 45.5% of the class came from *New Treatment*, the fall 2011 cohort dropped to more historic levels, 35.0%. Third, the textbook used in ENTC 1505 from fall 2006 until fall 2011 was an algebra based technical mathematics book. In fall 2011 the text was changed to a calculus based technical mathematics book. Besides a major step up in conceptual mathematics there was a fourth factor, the issue of instilling in the students an engineering problem solving methodology.

The problem solving methodology employed in the former text used an eight step methodology similar to the traditional engineering methodology specifically:

1. Identify and list the given information;

2. Identify and list the unknown variable. Sketch a figure if applicable. Identify the known and unknown variables in the sketch. Be sure to use the same notation in the sketch that is used in the "Given" and "Find" statements;

3. Find the equation that relates the known and unknown variables. In the following examples the equation will be given . . .;

4. Rearrange the equation to solve for the unknown. Here you will apply your basic algebra skills;

5. Plug in the known values. Include units. If they do not agree, perform necessary conversions . . .;

6. Use your calculator to find the preliminary answer;

7. Adjust the decimal point so that a metric prefix is produced, if necessary, and

8. Round the answer to the proper number of significant digits. Use your knowledge of precision and accuracy (Donovan, 1996, 170-171).

Contrast this structured engineering-like approach with the more freestyle five step approach recommended in the new text:

1. **Study the Problem.** Look up unfamiliar words. Make a sketch. Try to visualize the situation in your mind;

2. **Identify the Unknown(s).** Give it a symbol, such as "Let x = …" If there is more than one unknown, try to label the others in terms of the first. Include units;

3. **Estimate the Answer.** Make simplifying assumptions or try to bracket the answer;

4. **Write and Solve an Equation.** Look for a relationship between the unknown and the known quantities that will lead to an equation. Write and solve that equation for the unknown. Include units in your answer. .., and

5. **Check Your Answer.** See if the answer looks reasonable. See if it agrees with your estimate (Calter & Calter, 2011).

Fifth, the same lead instructor taught one section (fourth time) but the other instructor (full time), then beginning his second year, taught the class for the first time.

Fall 2011 marked an untypical term in light of a brief but tense faculty strike. This resulted in both an uncertainty to the start of the term (factor 6) and a negative impact on enrollments (factor 7) as shown in Chapter 4 Table 10.

Spring 2012: A Return to Normalcy?

The same two instructors taught ENTC 1505 in spring 2012. Assuming the swings in spring 2011 and fall 2012 were atypical what would the pattern be if the specific semesters of spring 2010, fall 2010 and spring 2012 were considered? Chapter 4, Figure 7 was modified to create Figure 8 to look at just that situation. The pattern that emerges is clearly linear ($R^2 = 0.9997$) with a positive slope.

Are three points really enough to solidify the pattern of *New Treatment* vs. *No Treatment* target time based achievement? No, to clearly uncover the pattern, two more semesters of supportive data would be necessary. However, this linear relationship is the best available information and is most likely to prove to be a conservative estimate.

Recall that S09 and F09 cohorts were dismissed due to small sample sizes but another factor parallels the ENTC 1505 text change. The text used in F08 ENTC 1500 (all treatments) was the classic text that lacked a problem solving methodology (Spangler & Boyce, 2000). The new text (Cleaves & Hobbs, 2006) was first used in F09.

4. Examine in detail (qualitatively) what specific aspects of ENTC 1500 *New Treatment* and follow-up classes contribute to student retention (and eventual student achievement), and

Major hurdles at the outset of application of the *New Treatment* method were engagement, student preparation and a core belief that the vast majority of students who sought matriculation into engineering (primarily engineering technology) could ultimately thrive in the major.

Based on the **Literature review**, John Hattie identified a number of factors under control of educators (reference Chapter 2 Table 4) associated with visible learning (above the d = 0.40 hinge point). Ten of these, it was noted, match with the preliminary or the evolutionary design of the ENTC 1500 *New Treatment*. The list has been reordered from Chapter 3 but contains the same line items:

1. Teacher expectations (must be high);
2. Student motivation;
3. Concentration/engagement;
4. Teacher-student relationships;
5. Feedback (teacher to student yes but especially from student to teacher);
6. Spaced vs. massed practice;
7. Cooperative learning;
8. Homework (at post junior high level);
9. Problem solving teaching (a teaching strategy), and
10. Creativity programs.

Expectations as to quantity and quality of work in ENTC 1500 are extremely high as evidenced by syllabus Appendix A, and homework list Appendix H. Also note Labs and Objectives, Appendix D and Lab Guide, Appendix E.

Student motivation, concentration, engagement and teacher-student relationships all appear synergistic. For example, Lab 3 (Appendix D) deals with the concept of area. It has an extreme emphasis on calculations and a surprising requirement for creativity. Although this is a very time consuming and exacting lab, students generally come away from it with a very positive attitude and a greatly enhanced ability to manipulate composite (geometric) shapes.

> This lab was very informative and interesting. The varying complexities between … shapes … required more brain power. … It's a surprisingly deceptive lab that appears to start out easy enough but rapidly turns into a time consuming problem that really forces you to think (Standohar & Cordell, 2013, page 16).

Feedback has been enhanced over time. Originally, the emphasis was on providing quick turnaround of graded homework, tests and labs to the students. However, as Hattie states; the real gains are realized based on feedback from students to the teacher. In lab performance, for example, it allows the instructor to form and reform groups that maximize performance and peer learning.

In similar fashion, when the course was originally developed; classes met twice per week for 3 hours per session. When labs were assigned, students (working typically in teams of two) were required to run, write up and submit each lab within one class period. Over time, both as a necessity (e.g., classes meeting 3 times per week for 2 hours per session) and as a perceived strength; lab times were extended over multiple sessions. On the two earliest labs, this allowed students to concentrate on structuring their labs with the opportunity to write or re-write an analysis with a fresh perspective. As students were given more total time (and reflective time between creating patterns and analyzing them) the quality of labs and the quality of learning improved. Learning and retention are improved.

The cooperative learning style in the *New Treatment* developed around the labs themselves. The emphasis is on students working together (typically as a group of two) and teaching/peer learning within this context. While the first half semester remains somewhat heavy on lecture and twin disciplines of homework and a consistent problem solving methodology; the second half flows rather seamlessly from labs to tests with less time devoted to lecture and less emphasis on book style homework. The practice is taken up more by the labs themselves.

Homework (as well as attendance) is key to student achievement in the ENTC 1500 class itself (see Appendix A, Syllabus Charts 1 and 2). In addition, one explanation for the high correlations between ENTC 1500 attendance and/or homework percentage over the first half semester and letter grades in all 7 targeted follow-up courses (see Chapter 4, Table 34) could be that these characteristics were ingrained in students to the extent that they were well served in the future. Homework in particular, shows up as larger than $r = 0.298$ (and significant for $p < 0.05$) in 5 of the 7 targeted courses.

Problem solving teaching is multilayered within the ENTC 1500 *New Treatment*. As a result of reflecting on where students go awry in problem solving, this researcher has become convinced of the central nature of a problem solving methodology in getting STEM students over the hump to approach ever more complex problems . The discussion of the potential role of a text without a strong “engineering style” problem solving methodology in the Fall 2011 Valley was only one in a long line of personal experiences reinforcing this conclusion. But beyond the emphasis on a structured approach there is a need to stimulate creativity.

Murray Gell-man, 1969 Nobel Prize winner in Physics was highlighted in the **Literature Review** in a counterpoint to Gary Lynch’s bottom up learning model. Gell-man took simple problem solving to a higher level by looking at how one comes up with creative ideas. Based on a creative thinking model originally devised by the scientist Helmholtz, Gell-man observed that science colleagues, artists and all sorts of highly creative people follow fixed stages of thinking.

The *first stage* is saturation in which the mind is filled with all the contradictions between the problem one is working on and existing ideas (models) that are just not good enough. In *stage two*, the preconscious processes the material in a stage called incubation. One day when performing an unrelated task or by slip of tongue or by sleeping or dreaming an idea, *stage three*, illumination evolves. The final, *fourth stage*, verification, is to see if it really is a good idea (Moyers, 1990).

John Tagg looks to formative assessment as a powerful tool for shaping the academic curriculum. He states the goal as to first identify intended student abilities;

then integrate these abilities into all courses in the curriculum. The result would form common threads linking connected learning experiences. Embracing the Learning Paradigm (see Chapter 2, Table 2) would enhance engineering technology results currently obtained. Certainly, the ABET accreditation process (see Appendix I) encourages this direction.

Tagg advocates eloquently for adoption of the Learning Paradigm:

> Teaching is valuable if and when it leads to learning, but not otherwise. … To say that the mission of a college is instruction is like saying that the mission of General Motors is to produce assembly lines. . . . [T]he means are secondary and are to be judged by how well they achieve the end. … [W]hat is fairly clear, I suspect, to everyone who teaches freshmen: One of the fundamental challenges that colleges face today is to change the way incoming students think about the school setting, about academic work, and about their own relationship to academic institutions (Tagg, 2003, pp. 18, 31, 47).

Implications of Results

This dissertation began with a statement of purpose—The purpose of the current investigation is to explore what to do with (university) students who possess both a desire and ability to matriculate into technical fields but who present in need of math remediation and/or development and typically lack effective problem solving skills. This study strongly suggests that learning by math deficient engineering technology students over a medium term (two to three years; roughly half of a bachelor's degree) is attainable for a very large proportion of students who select such a major. Furthermore, this learning over the same medium term is sustainable.

Recommendations for Future Research

This researcher is currently working on a class, STEM 1513 which is at the same level as ENTC 1500 but intended for other STEM majors (e.g., biology, chemistry and engineering). The class was first offered in Fall 2012 with a goal of improving student achievement in Math 1513 (pre-calculus) and the student's follow-up chemistry class (class required varies by major). Some similar approaches were attempted with the two sections offered in Fall 2012. One of these was taught by the researcher; the other by an adjunct chemistry professor. Lab portions were coordinated between the two instructors. This may prove to be an interesting vehicle to determine what works for which majors.

Tagg also advocates that changing student goals and theories can have a positive effect on student achievement. This researcher could find no prescriptive methods for obtaining this effect. The concept of ingraining basic understandings in students was raised relative to homework, attendance, methodology and creativity. Then too, it doesn't appear to matter how well students score in their ENTC 1500 labs relative to how well they did in ENTC 1505L. This may suggest that a critical threshold was exceeded among virtually all the *New Treatment* students. It suggests to this researcher that a study which might uncover how to go about changing student goals and theories to obtain sustainable student learning would be extremely valuable. Various sources for pursuing potential instrumentation or developing a survey instrument are noted in Tagg (2003).

A major model for this study was the Lesik study cited earlier. A limitation of this study is that no matter how carefully other potential causes for the positive effects on the *New Treatment* students, the structure of the study makes it impossible to make causal arguments of the sort possible with randomized control trials or regression discontinuity. So while it is hoped that the exhaustive nature of the search for other explanations is persuasive; there is always the nagging thought that some other factor might have gotten to the *New Treatment* students (first).

There may be a way around the lack of statistical power that ruled out a traditional regression discontinuity approach. D. Black, J. Galdo and J.C. Smith put out a working paper in 2005 that seeks to apply regression discontinuity to small clusters of data. It uses a novel combination of multivariate parametric and nonparametric tools. Although first proposed some eight years ago, this approach is still in its infancy and might allow clustering across groups as well as time. If workable, it would provide the vehicle to make a true causal set of arguments.

One approach would be to repeat the study with the BG&S technique to compare results. Then once Spring 2013 grades are posted a second analysis could be performed with each method. This would not only provide a potential causal explanation for the effect of *New Treatment* but would provide a means of testing out the methodology itself.

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Appendix A

ENTC 1500 Fall 2012 Syllabus

Youngstown State University

STEM, ENGINEERING TECHNOLOGY

42990 ENTC 1500	Technical Skills Development	Fall 2012
42990 ENTC 1500	W F 1:00-3:50 pm	Moser 3290
Prof. George	Office: Moser 4108 via 4120	(330)-941-**3738**
jhgeorge@ysu.edu	Office Hrs: Mon 10 am - Noon, Wed 10 am - 11 am Fri 10 am - Noon	
	Final Exam: Mon. 12/10/12 1:00 pm – 3:00 pm	

Text: Cleaves & Hobbs, Essentials of College Math, 2nd Edition, Prentice Hall, 2006. $133 new, $ 50 used

AVAILABLE HELP:

Formal **office hours** above. If these times don't work let me know; we'll set up a time that does.

If you have a **documented disability** and require accommodation(s) to obtain equal access, contact the Office of Equal Opportunity and Disability Services at the beginning of the semester. If appropriate; they will provide you a *letter of accommodation*. It's your responsibility to present this letter to me. Verify your eligibility through the *Office of Disability Services*, 275 Fifth Ave., 330-941-**1372**, 8 am till 5 pm Mon-Fri.

Campus assistance: *FREE* campus services:

Center for Student Progress	330-941-3538	Kilcawley Center West
Maag Library	330-941-3677 330-941-3099 & 3055	Maag R&SS 154, Writing 171
Math Assistance Center	330-941-3274	Lincoln Building 408
Advisement (Crouse & Coyne)	330-941-2292 & 1743	Moser 2305 & Lincoln 632
VA Office (Jim Olive)	330-941-2503	Tod Hall 310A

COURSE DESCRIPTION/OVERALL OBJECTIVES:

Develop the technical, analytical and **problem solving** skills of students planning to enter an engineering or technical career. Complement Algebra class work by stressing the importance of mathematics and by working through technical math applications. Gain an understanding of the roles of technicians (ATS or AAS), application engineers (BSAS or BE) and development engineers (BE) in the workforce. I will try to help you achieve the following **Course Goals**:

1. Training: How do I develop a dependable problem solving approach? ←6 Step Method
2. Training: How can I ethically max scores on technical exams? ← Above + "understanding units" + "no blanks"
3. Training: How can I use Excel as an analysis tool? ← Ref 6)

----

4. Education: How to develop an effective personal learning strategy? ←epls = f(*1*-pract time {10K hr rule}, *2*-reps {Rule of 5}, *3*-**A**ction →**R** e f l e c t →**A**ction, *4*-hw, *5*-attendance)

5. Education: How can I "make sense of mathematics"? ←Applications (contextual learning) & visualization (see 6))
6. Education: How can I spot trends & analyze data to produce effective technical (lab) reports? ← Data: 1) **G**ather, 2) **A**rrange (tabulate), 3) **M**anipulate (assemble/disassemble), 4) **G**raph (visualize), 5) **A**nalyze (to understand relationships), 6) **M**ake good decisions.

MEASURABLE OBJECTIVES:

Table 1—Success Rates for ENTC 1500 "new" approach

Section	Instructor	Raw pass Numbers	Success Rate	True Success Rate*
F08 Day	George	14 of 25	56.0 %	
F08 **Night +**	George	20 of 25	80.0 %	
S09 Day	George	16 of 29	57.1 %	
F09 Day	George	16 of 27	59.3 %	
F09 **Night +**	George	22 of 30	73.3 %	
S10 Day	George	21 of 26	84.0 %	
F10 Day	George	19 of 27	70.4 %	
F10 **Night +**	George	19 of 22	86.4 %	
S11 Day	George	18 of 22	81.8 %	
S11 **Night** ?	George	6 of 9	66.7 %	
F11 Day	George	10 of 18	55.6 %	
F11 **Night** +	George	19 of 20	95.0 %	
S12 Day	George	10 of 15	66.7%	
S12 **Night** ?	George	7 of 10	70.0%	
Total "new"	George	216 of 302	71.5 %	77.0 %*
Total "old"	2006-08	93 of 275	33.8 %	

* Factor in no shows, financial withdrawals, suspensions and medical withdrawals.

Table 2—Success Rates subseq/*concur courses*init attempt (students passed ENTC 1500)

Major	Class	Course Title	Raw Numbers	Success Rate	Target	Rating
EUT	MATH 2623	Survey of Mathematics	44 of 58	75.9 %	70 %	Good
EUT	EUT 1500	Electrical Fundamentals	74 of 80	92.5 %	80 %	Excellent
EUT	EUT 1500L	Electrical Fund's Lab	78 of 81	96.3 %	80 %	Excellent
concur	MATH 1501	*Elem Alg concurrent*	31 of 43	72.1 %	70 %	Marginal
∑	MATH 1504/7	Subsequent or *concurrent*	76 of 111	68.5 %	60 %	V Good
∑	MATH 1508	Subsequent or *concurrent*	28 of 41	68.3 %	60 %	V Good
ENTC	MATH 1513	Alg& Transcendental Ftns.	45 of 68	66.2 %	58 %	V Good
ENTC	ENTC 1505	Eng Technology Concepts	55 of 63	87.3 %	80 %	V Good
ENTC	ENTC 1505L	ENTC Concepts Lab	37 of 40	92.5 %	80 %	Excellent
ENTC	MET 1515	Mechanics 1	23 of 29	79.3 %	70 %	V Good*

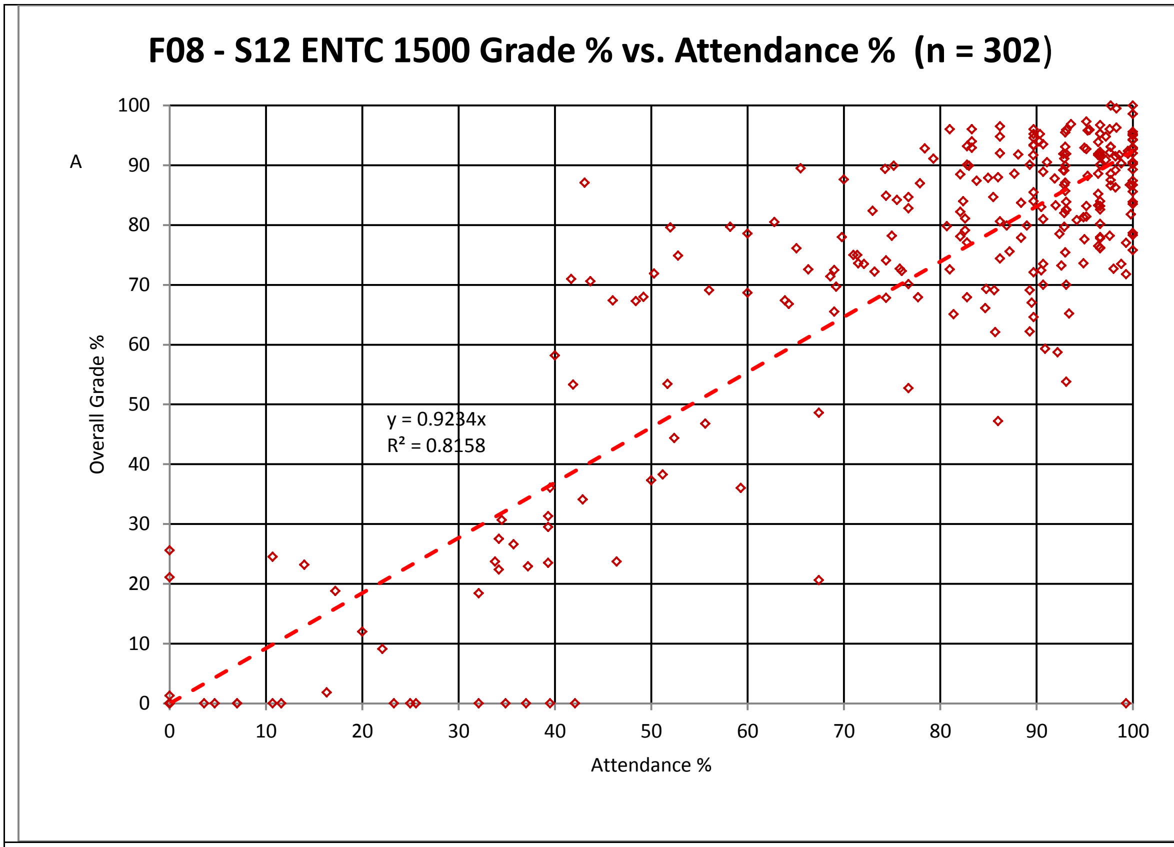

Chart 1—Overall Grade vs. Attendance N = 302

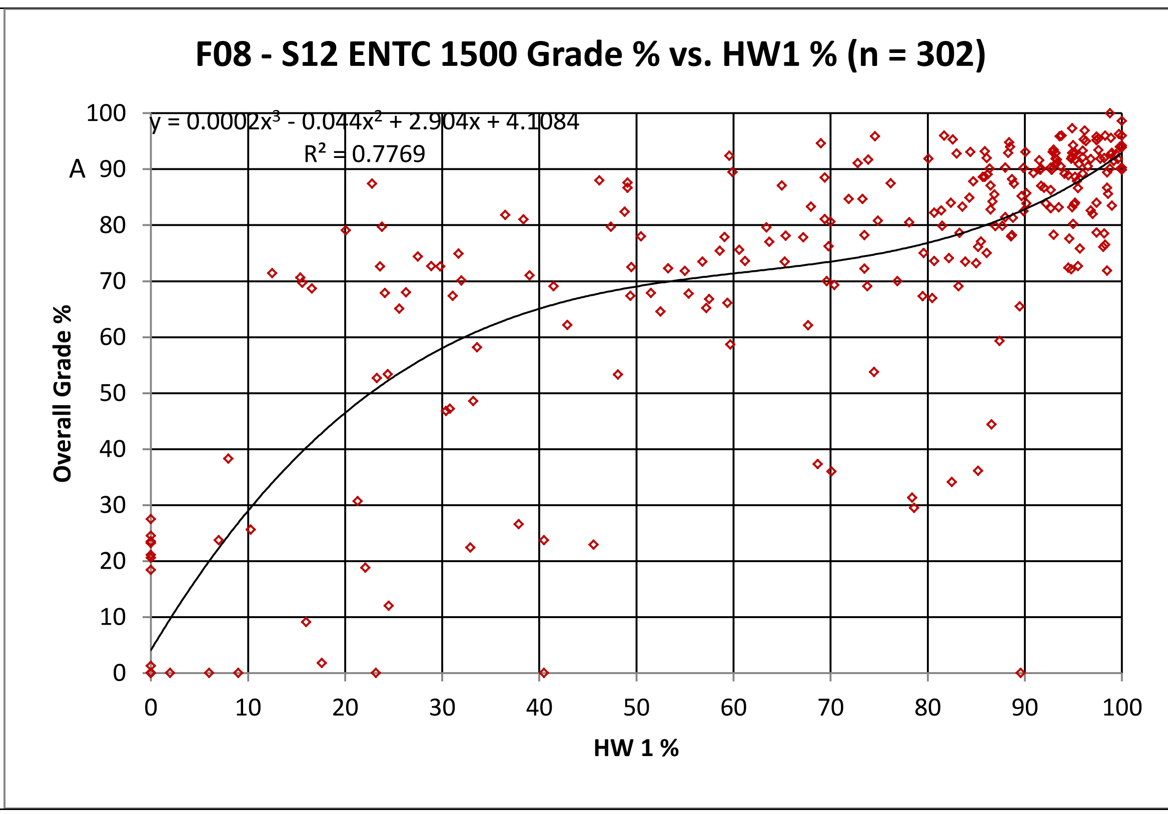

Chart 2—Overall Grade vs. 1st 7 week HW Score N = 302

Attendance trend: 97% (A), 87% (B), 75% (C)

→ {10/302 ≈ 3.3% who attended 77% of classes did not pass}.

HW #1 set trend (1st 7 weeks): 85% (A), 75% (B), 67% (C)

→ {10/302 ≈ 3.3% who did better than 67% on initial homework did not pass}.

PREREQUISITES and REQUIREMENTS:

→ Concurrent or Prereq: **MATH 1501** Elementary Algebraic Models or Level 2 Math Placement ←

All homework problems and Lab Sample Calculations MUST be done on **8-1/2 x 11***Engineering Technology paper (blue), Engineering Calculation paper (green)* or ***8-1/2 x 11*** *(4 or 5 block per inch)* ***quadrille paper***. With generic quadrille paper you will need to create your own Name, Course/HW Assignment, Date and Page # of Total Pages block.

Regular notebook paper is NOT acceptable for homework. If you use backside expect a deduction; if you cram problems expect a deduction. On green "Calc" paper backside is the heavy ruled grid side; use front side. Engr Technology paper available only from the bookstore; "Calc" paper and generic quad paper are available at most office supply stores as well as bookstore. If you use generic quad paper make sure it is 8-1/2 x 11 preferably 3 hole punched.

Besides the text, a **scientific calculator** is required. A basic CASIO fx-260 calculator will be provided. A **3 ring notebook** (D ring, 1-1/2" recommended) is also required. Notebook dividers, pencils, erasers, a key (flash) disk and basic sketching tools are recommended.

You can use your Banner number (or Patron ID with PA prefix) to log on to any of the Moser computers. Send saved files to your personal reserved disk space (or flash drive). Computer Room has been reserved to be available as needed.

Homework problems are assigned regularly. I encourage students to work in small groups. However, working together should NOT extend to outright copying of homework. Learn from each other but do your own work.

GRADING POLICY

Homework problems and/or spreadsheet exercises will be assigned at each lecture.
Some or all of a homework assignment will be collected. Late homework will be accepted up to the beginning of the following class. Expect a 10% late penalty. Beyond this date expect ZERO credit. Generous partial credit is given for all reasonable attempts as it is on tests. On homework you will get limited credit for setting up the problem (i.e., Steps 1 & 2) of 6 step methodology, additional credit for additional steps (i.e., Steps 3 & 4) whether you obtain "answers" or not. I am much more interested in **HOW** you approach solving a problem than the "final answer(s)". Working together is encouraged; copying is NOT.

5 Preliminary exams, at least 5 labs and a **comprehensive final** are planned. No makeups except in extraordinary circumstances where arrangements made PRIOR to the exam date. Expect any approved makeup to be significantly TOUGHER than the class exam. Tests—closed book, closed notes, outline provided unless otherwise specified. You can skip Givens & Finds on the tests. **Do all you can to avoid missing exams**.

Late labs accepted up to the beginning of the next class. Beyond this expect a score of zero. Missing running a lab carries a 10% or 20% penalty depending on how much was missed and a late lab submittal carries its own 10% penalty. **Do all you can to avoid either missing labs or submitting them late**. Note: 10% penalty translates to 1 grade level drop.

COURSE GUIDELINES:

1. The class SCHEDULE (*ref HW list for more details*) is subject to change depending on individual class needs. Schedule changes will be announced ASAP.
2. Rule 3: All **cell phones**, **pagers**, **blue tooth**&**media players** are to be turned **off** during class. Rule 2: Mutual respect. Rule 1: Make life as easy as possible for (1) instructor (2) students . . . For detailed description of what the university views as inappropriate classroom behavior refer to the Student Code Handbook found on the YSU website.
3. **Attendance** in **class** does not directly affect your grade *except*for missing TESTS or LABS. Nonetheless, attendance and homework are 2 key factors associated with grades. See Page 3. To ensure no loss of homework points turn in the full assignment prior to any class you'll miss. Whether you attend or not; you are responsible for handouts, lecture material, readings and corresponding assigned problems.
4. All **exams closed book & closed notes** unless otherwise specified. Students permitted or provided a FORMULA SHEET on exams. If student prepared, formula sheet must be on a single 8-1/2" x 11" paper (ss or ds) and contain only formulas from text.
5. There will be **NO MAKEUPS for missed exams without PRIOR approval** by the instructor. Expect approved makeup to be significantly TOUGHER than the class exam.
6. **Attendance at LABS** is mandatory. Lab report format to be supplied. *See HW list for dates to especially avoid missing.*
7. **Late labs** will be accepted up to beginning of next class with a minimum 10% REDUCTION IN GRADE. Labs more than 1 class meeting late receive NO CREDIT.
8. **GRADE SCALE**:

   100-90 A   89-80 B   79-67 C   < 67 NO CREDIT

   Instructor reserves the right to adjust the grade scale DOWNWARD.
   Consideration will be given to final exam score, homework scores, attendance, effort and attitude if student is just below a cutoff ("on the bubble"). However: no student will "jump" above another student based on these factors.
9. COURSE GRADE will be determined as follows:

   ENTC 1500 (4 s.h.)

5 Prelim Exams, 5 Labs (1 double) (100 pts each)	= 50 %	(1000 pts)
→Notebook if only 4 exams. Drop lowest of 11 scores be it exam, lab or notebook ←		
HW, Excel, Other Assign's (200 pts)	= 10 %	(200 pts)
Comprehensive Final (500 pts)	= 25 %	(500 pts)
Median Preliminary Exam (100 pts)	= 5 %	(100pts)
Median Lab (100 pts)	= 5 %	(100pts)
Better of Median Prelim Exam & Median Lab (100)	= 5 %	(100pts)
Total	=100 %	(2000 pts)

Appendix B

ENTC 1500 1st Week Survey

GENERAL INFO Mr. George 23605 ENTC 1500

* NAME: __________________________ Tentative Major: ________________
(CE, CCET,DDT,EUT [(LW) or (PP)],EE, EET,ME, MET, Other)

Email Address: __________________________ Phone Number Day: __________________

H.S./Yrs since Grad: __________________/______ Phone Number Nite: __________________

* Typical Employment hours per week: ________ Technical/Nontechnical work? ___________

MATH Intro Alg, IntermAlgebra+Trig, PreCalc, Numbers, Survey

* Math class taking this term ________________ MATH 1501, 1504, 1513, 1500, 2623.
If no Math class this term . . .
then what is highest Math class completed (C or better) ________________

Comments on your math experiences

____

SPREADSHEETS (especially Excel)

* Excel or other spreadsheet experience? Where (class, hobby, work)?

____

* Know how to create Formulas in Excel? _________ * Graphs in Excel? _________

* Know about absolute vs. relative addressing? ________

* **LAB Report Writing Experience**

____

↓↓ NO TIES ON RATINGS (3, 2 & 1 1st Column, 4, 3, 2 & 1 2nd column)!!!! ↓↓

Rate **3**=Best, **2** = Middle, 1 = Worst I learn best→ worst	Rate **4** = Best, **3**, **2**, **1** = Worst What I like to do best → worst (Pay being same)
___ Seeing information	___ probe, research, formalize, prioritize, calculate
___ Hearing information	___ structure, consolidate, coordinate, arrange, plan
___ Hands on activity	___ invent, originate, play hunches, improvise, take risks
	___ form, mold, demonstrate, build, construct, repair

* **What do you hope to learn from this Class?**

____

____

Appendix C

ENTC 1500 End of Term Survey Fall 2011

Name: ________________________ Date: ____________

Part 1 of 3: Contrast math with ENTC 1500

Consider our ENTC 1500 class. At this point you've completed 12 weeks & 4 labs (400 points), 3 exams (300 points), homework (200 points) and covered subjects like basic descriptive statistics, unit conversions, problem solving methodology, lab writing procedure, rudiments of Excel, measurement accuracy & precision, review of algebra, direct & inverse proportions, composite areas & volumes, and are just starting right triangle properties & trigonometry.

Consider a math class; either one you are taking this term or one you have taken in the past.

Math Subject (e.g., Basic Algebra, intermediate algebra, survey, trig):

____

Taken **when & where**? (e.g., NOW at YSU, 2010 in MILITARY, . . .):

____

For each of scales below place M for math class and E for ENTC 1500 on where each fits for you.

| -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |

Abstract — Concrete

| -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |

Team Based Learning — Individual

| -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 | 5 |

Peer interactive Driven — Instructor

-5	-4	-3	-2	-1	0	1	2	3	4	5

One Method — Multiple Methods

-5	-4	-3	-2	-1	0	1	2	3	4	5

Concepts — Applications

Part 2 of 3: Develop list of ENTC 1500 positives, negatives & (math) complements

First: Where you show differences between M and E which of these do you consider **positive** aspects of ENTC 1500? Why?

____

____

____

Second: What other **positive** aspects does ENTC 1500 currently have?

____

____

____

First: Where you show differences between M and E which of these do you consider **negative** aspects of ENTC 1500. Why?

____

____

____

Second: What other **negative** aspects does ENTC 1500 currently have?

____

____

____

Do you consider the math and ENTC 1500 class as compatible? Yes? No? _________

If answer above is Yes, where you show differences between M and E which if any do you consider **complementary** aspects of the math class you cite & ENTC 1500. Why? Add other complementary aspects that occur to you.

____

____

____

Part 3 of 3: Rate achievement of ENTC 1500 course objectives

Identify with single **X (**0 = Useless, 5 = Extremely helpful) how ENTC 1500 working so far as:

a) Developing your **problem solving** skills:

| | | | | | | | | | | |
| 0 | | 1 | | 2 | | 3 | | 4 | | 5 |

b) Developing your ability to **spot trends**

| | | | | | | | | | | |
| 0 | | 1 | | 2 | | 3 | | 4 | | 5 |

c) Developing your ability to **analyze data**

| | | | | | | | | | | |
| 0 | | 1 | | 2 | | 3 | | 4 | | 5 |

d) Developing your **technical skills**

|	|	|	|	|	|	|	|	|	|	|
0		1		2		3		4		5

e) Developing an effective personal **learning strategy** (what it takes **to succeed in your major**)

|	|	|	|	|	|	|	|	|	|	|
0		1		2		3		4		5

f) Helping you **make sense of mathematics** (complement to math classes)

|	|	|	|	|	|	|	|	|	|	|
0		1		2		3		4		5

Appendix D

ENTC 1500 Labs & Objectives

Lab	Title	Objectives
Lab 1	Lightning Reflexes?	Simple + Lab Assembly + Statistics (esp. standard deviation)
Lab 2	Bouncing Ball	Simple + Patterns in rebound + Analysis of Results + Concept of Conservation of Energy + Direct Proportion
Lab 3	Area Lab	Concept of Area + Emphasis on Calculations + Creativity
Lab 4	Volume Lab 1	Concept of Volume + Concept of Composite Volume
Lab 5	Volume Lab 2	More advanced Composite Volumes + Creativity

Appendix E

Lab Guide

References: Youngstown State University—"The Engineering Report" circa 1990.
//www.ecf.utoronto.ca/handbook-lab.html, 08/19/2002.

Lab Report Structure:

A. **__Title Page__**: Title Page should include the Lab Report Number, Title of Lab, Section and Course (i.e., 24517 PHYS 1500L), Name of Student Reporting, Names of co-workers, Test Date and Submission Date. Title Page is unnumbered.

B. **__Table of Contents__**: Table of contents. All pages in the report after the Table of Contents should be numbered sequentially and titled so that they are clearly referred to from the Table of Contents. Starting Page Number for each of the 6 standard Sections that follow are all that is necessary.

1. **__Description of Apparatus__**: First make a simple **__complete__ and accurate list** (table) of all Materials and Equipment used. **__Complete__** implies all manufacturers, serial numbers and attributes (e.g., color, size {diameter if circular}, hardness, etc.). Sketches (or pictures) of equipment used and how arranged shows the Apparatus.

2. **__Test Procedure & Theory__**: Typically the procedure and theory will be furnished to the student. The procedure explains all steps in the order they actually happened. If you did not follow the procedure exactly then document the exceptions (e.g., "At step 4 we performed four repetitions instead of three and ignored the data from the second repetition"). **Inclusion of the supplied procedure is acceptable**. Unless you enhance the Theory you don't need to include it at all.

3. **__Results__**: Results are typically dominated by __tables__ and __figures__ (synonyms include graphs, curves or charts).
   A. **__Tables__**: All calculated data observed or calculated should be included in tables. Headings identifying sets of data should be included. Numbering (i.e., Table 1, Table 2, etc.) is recommended since necessary for involved labs.
   B. **__Charts__**:
      i. For Y vs. X scatter-gram plots place the independent variable on the horizontal axis and the variable that depends on it on the vertical axis.
      ii. Choose reasonable scales (e.g., increments of 1, 2, 5, 10 etc.)
      iii. Draw a smooth average curve that approximates the shape of the data but do not force the curve through each and every point.

iv. Place a title on each curve. Numbering (i.e., Chart 1, Chart 2, etc.) is a helpful reference for your Analysis of Results.
v. Identify each axis and include the units; (e.g., Distance (cm), time (sec))

4. **Analysis of Results**: As you develop your ability to write reports the analysis of results will clearly be the most important part of your report. Here, you show that you understand the experiment beyond the level of completing it. **Explain. Analyze. Interpret**. This part of the lab should focus on understanding "**What is the significance or meaning of the results?**"
   A. **Pure Analysis**:**What do the results indicate? What did you find?** Explain what you know with certainty based on your results and draw conclusions.
   B. **Interpretation**:**What is the significance of the results? What is ambiguous? What questions can be raised?** Find logical explanations for problems in the data.
   C. **A Strategic Approach to Writing an Analysis of Results**:
      i. **Compare expected results with those obtained.** If there were **significant differences** (i.e., typically > 5%) **how can you account for them?** Claiming all error was human error implies*your group wasn't very competent*. Be specific (e.g., instruments could not measure precisely, the sample was contaminated or the effect of friction was ignored in calculated values.

      ii. **Analyze experimental error.** Was it avoidable? Was it equipment related? To determine if the experiment was within reasonable tolerances (typically 5% but sometimes more) **calculate a % difference from theory or from a different method**. Again, values within 5% are almost always good. For some experiments a reasonable difference will be even higher. **How could the experiment be improved?**

      iii. **Explain your results in terms of theory.** How well has the theory been illustrated?

      iv. **Relate results to lab objectives.** How well did you match up with any objectives stated at the beginning of the lab?

5. **Sample Calculations**: This section should provide clear detail on *one typical sample of a complete calculation* (i.e., show equation, plug in with units and then solve for the calculated value) of each type involved in determining calculated data.

6. **Original Data Sheet(s)**: The original lab data sheet(s) should be the last page(s) of the report. It should be an original (substitute Xerox or hand copy if original unavailable). Meter readings should be recorded as read (i.e., before any corrections). Record serial numbers and other identifying descriptors of all equipment used in the test.

Appendix F

6 Step Problem Solving Methodology

(1) **G**: (Given): [Known Facts]:

- What relevant facts are known or GIVEN?

(2) **F**: (Find): [Unknown Facts]:

- What Fact(s) are missing from the problem?
- What are you trying to FIND??

(3) **Sk/T**: (Sketch(es)) or Table: [Visualize]:

- Pictures are *extremely* valuable in beginning to decipher (start to solve) a problem especially when enhanced (e.g., dimensions added and information marked up on them).
- Sketching relates to both a visual and a kinesthetic perspective.
- This matches with "methods of learning" !!
- Visualize: "If you can dream it; you can do it."
- A **TABLE** is another picture that is sometimes more appropriate

(4) **Eqs**: (Equation(s)): [Relationships]:

- How are the Known Facts and the Unknown Facts related?
- How are the Givens and the Find(s) related?
- What formulas (or definitions) can you use to establish a (geometric, algebraic or trig based) model?

(5) **P→C**: (Plug then Chug): [Calculations]:

- Perform the operations identified in the relationships.
- Include UNITS in the calculations.

(6) **U&RC**: (Units & Reality Check): [Estimation & Interpretation]:

- Do the UNITS check? ← Not in C&H but VERY important
- Is the answer *reasonable*?
  - Are the intermediate or final "answers" too large?
  - Are the intermediate or final "answers" too small?
  - Can you check "reasonableness" with "round numbers"?
- Have all unknown facts (finds) been found?
- Can you *check* the finds to get back to the givens?

Appendix G

Tables of Course Grades

Table G1. *Concurrent Math 1501 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	0	NA	NA
1 = Intend for New Treat	7	0.14	0.378
2 = Fidelity Failure	3	1.33	2.309
3 = Classic Treatment	27	1.67	1.359
4 = New Treatment	52	1.69	1.489

Table G2. *Concurrent Math 1504 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	2	3.50	0.707
1 = Intend for New Treat	2	0.00	0.000
2 = Fidelity Failure	8	3.13	1.356
3 = Classic Treatment	9	2.33	1.414
4 = New Treatment	47	1.91	1.427

Table G3. *Subsequent Math 1504 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	6	3.00	1.549
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	1	4.00	0.000
3 = Classic Treatment	1	3.00	0.000
4 = New Treatment	19	1.58	1.427

Table G4. *Concurrent Math 1507 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	0	NA	NA
1 = Intend for New Treat	2	0.50	0.707
2 = Fidelity Failure	0	NA	NA
3 = Classic Treatment	0	NA	NA
4 = New Treatment	25	2.08	1.441

Table G5. *Subsequent Math 1507 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	2	2.50	0.707
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	0	NA	NA
3 = Classic Treatment	1	1.00	0.000
4 = New Treatment	18	2.33	0.970

Table G6. *Concurrent Combination Math 1504/1507*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	2	3.50	0.707
1 = Intend for New Treat	4	0.25	0.500
2 = Fidelity Failure	8	3.13	1.356
3 = Classic Treatment	9	2.33	1.414
4 = New Treatment	69	2.03	1.424

Table G7. *Subsequent Combination Math 1504/1507*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	8	2.88	1.356
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	1	4.00	0.000
3 = Classic Treatment	2	2.00	1.414
4 = New Treatment	36	2.11	1.214

Table G8. *Concurrent Math 1508 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	0	NA	NA
1 = Intend for New Treat	2	0.00	0.000
2 = Fidelity Failure	0	NA	NA
3 = Classic Treatment	0	NA	NA
4 = New Treatment	26	1.81	1.650

Table G9. *Subsequent Math 1508 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	2	2.50	0.707
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	0	NA	NA
3 = Classic Treatment	0	NA	NA
4 = New Treatment	27	2.04	1.344

Table G10. *Concurrent Math 2623 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	0	NA	NA
1 = Intend for New Treat	2	1.00	0.000
2 = Fidelity Failure	2	2.50	0.707
3 = Classic Treatment	4	2.75	0.957
4 = New Treatment	27	2.00	1.468

Table G11. *Subsequent Math 2623 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	2	2.00	0.000
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	3	2.00	1.732
3 = Classic Treatment	28	3.54	0.576
4 = New Treatment	42	2.60	1.289

Table G12. *Subsequent EUT 1500 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	0	NA	NA
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	2	2.50	0.707
3 = Classic Treatment	37	3.00	1.054
4 = New Treatment	82	2.84	1.036

Table G13. *Subsequent EUT 1500 Lab Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	0	NA	NA
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	2	3.50	0.707
3 = Classic Treatment	37	3.62	0.639
4 = New Treatment	82	3.39	0.885

Table G14. *Math 1513 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	130	2.05	1.493
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	5	2.20	1.304
3 = Classic Treatment	9	2.44	1.333
4 = New Treatment	81	1.98	1.341

Table G15. *ENTC 1505 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	175	2.75	1.416
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	5	3.40	0.894
3 = Classic Treatment	8	3.13	0.835
4 = New Treatment	77	2.88	1.277

Table G16. *ENTC 1505L Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	131	3.09	1.327
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	5	3.60	0.548
3 = Classic Treatment	7	3.43	0.787
4 = New Treatment	42	3.38	1.103

Table G17. *MET 1515 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	87	2.34	1.209
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	5	3.40	.548
3 = Classic Treatment	3	3.67	.577
4 = New Treatment	41	2.37	1.318

Table G18. *Phys 1501 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	80	1.58	1.357
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	3	1.67	0.577
3 = Classic Treatment	5	1.60	1.517
4 = New Treatment	28	1.46	0.962

Table G19. *Math 1570 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	110	2.54	1.254
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	5	3.60	0.548
3 = Classic Treatment	6	2.67	1.033
4 = New Treatment	41	2.41	1.245

Table G20. *Math 2670 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	44	2.86	1.047
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	4	2.75	1.258
3 = Classic Treatment	5	1.80	1.789
4 = New Treatment	12	2.58	1.165

Table G21. *CCET 3705 Grades*

Group Treatment	Frequency	Mean	S.D.
0 = No Treatment	23	3.35	1.027
1 = Intend for New Treat	0	NA	NA
2 = Fidelity Failure	3	2.67	0.577
3 = Classic Treatment	2	3.50	0.707
4 = New Treatment	3	3.33	0.577

Appendix H

ENTC 1500 Beginning of Term HW Plan List

Wk	Day	Date	Sect	Subject	HW Assign
1	M W	08/20/12 08/22/12	No class Handout	Unit Conversions	#1: Unit Conversion Worksheet Read Ch 15 Statistics pp. 611-627
2	M W	08/27/12 08/27/12 08/29/12	15-2 1-1,2& 3	Descriptive Stats Problem Solving	# 2: 15-2 (622): 1,4,7,10,13← mean, S.D., median, Range Read Ch 1 pp. 2 thru 44 (*p. 43 very important*) #3: 1-3 (45): 31→45 odd; 1-3Rev(54): 93,95⇨*#1E*
2	M W	09/03/12 **09/05/12**	**Holiday** Handout	 **Lab #1**Reflexes	**(Labor Day)** ** Last Day add classes 08/29/12 ** ⇨**L1**Reflexes Lab
3	M W	***09/10/12*** 09/12/12	2-5, 2-7 3-1, 3-2	Percentages Measurement units	#4: 2-7 (125): 5→25odd #5: 3-1 (154):17,21,24,25,39→49; 3-2(159):13→23 odd
4	M W	09/17/12 09/17/12 **09/19/12**	3-3, 3-4 Handout	Accuracy, Precision Excel **Test #1**	#6: 3-3 (166):7→19 odd; 29; ⇨*#2E: Handout in class or on own (TBD)* ⇨**T1**
5	M W	09/24/12 **09/26/12**	4-5, 4-6	Powers of 10 **Lab #2** Bouncing Ball	#7: 4-5 (225): 25→45 odd; 4-6 (232): 13→29, 43→53odd ⇨**L2** Conservation of Energy (Bouncing Ball) Read Ch 5 pp. 244 thru 257
6	M W	***10/01/12*** 10/03/12	5-2 5-3,4 5-4,5 6-1,2	Algebra Solve Linear Eqs. Linear Equations Proport/VarDir/Inv	#8: 5-2 (258): 9,13,15,19,23,27,31,35,41,43,49,53,55 #9: 5-3 (261): 15→29odd; 5-4 (274): 31→47odd #10: 5-5(279): 15→31odd #11: 6-1 (296):17→53odd; p. 304 15→29odd
7	M W	10/08/12 **10/10/12**	6-3	Variation **Test # 2**	#12: 6-3 (311):3→17odd *#3E* ⇨**T2**
8	M W	10/15/12 10/17/12	11-3,12-3 12-3	Quad Eq.; Circles Radians Composite Areas Ellipse	#13: 11-3 (449): 3→17 odd; 12-3 (504); 11→23 odd #14: 12-3 (504):27→49 odd #15: Handout #16: Handout
9	M W	**10/22/12** **10/24/12**		Comp Area+**St Lab** **Lab #3** Area	⇨Start **L3** ⇨**L3**Area Lab ** Last day Withdraw 10/27/12 **
10	M W	10/29/12 **10/31/12**	12-4 12-5	Volume & Surf Area PythagThm **Test #3**	#17: 12-4 (514):6→20evens #18: 12-5 (520):10→20 evens ⇨**T3**
11	M W	11/05/12 **11/07/12**	12 Rev 13-1	Composite Volume Right Triangle Trig **Lab #4** Volume 1	#19: Ch12Rev (528):31,40,50,51,52,55,56,59,60,63,64,75 #20: 13-1 (542): 13→25 all; ⇨*#4E*: Excel; ⇨**L4**Volume Lab 1
12	M W	11/12/12 11/14/12	**Holiday**	 **Test #4**	**(Veterans Day)** ⇨**T4**
13	M W	**11/19/12** 11/21/12	 **No class**	**Lab #5** Volume 2	⇨**L5**Volume Lab 2 *Thanksgiving Holiday 11/22/12 * **University open but no classes**
14	M W	***11/26/12*** **11/28/12**	13-2	More trig **Test #5**	#21: 13-2 (553): 13→19 all, 43→49 all⇨*#5E*: Excel ⇨**T5**
15	M W	12/03/12 12/05/12	13-2	More Trig Review for Final	#22: Ch 13 Rev (561): 40→50evens #23?: 14-4 (592): 10→20 evens; p. 598: 1, 5, 9, 11
	M	**12/10/12**		FINAL	**5:00-7:00 Monday 12/10/12**

Appendix I

Key Terms

ABET: Accreditation Board for Engineering and Technology (ABET) provides national accreditation of engineering programs through the Engineering Accreditation Commission (EAC) of ABET and national accreditation of engineering technology programs through the Engineering Technology Accreditation Commission (ETAC) of ABET;

Active learning: Process in which the learner takes responsibility for his/her learning and in which the student has the opportunity to make personal decisions regarding dimensions of the learning process. The goal is to enhance problem solving skills, develop critical thinking and through problem solving gain the ability to learn how to learn (Akinoglu & Tandogan, 2007). An active (guided discovery) learning is a student centered and typically involves hands on activities that allow the student to construct knowledge out of his experiences. (See Constructive learning, Akinbobola & Afolabi, 2009);

Achievement: Student achievement connotes a move toward fulfilling some predetermined goal, meeting some standard of performance or acquiring some desired knowledge. Student achievement is typically determined by comparing a student product to a desired outcome (teachnm.org/programs/professional-development-dossier/pdd-glossary.html accessed 11/23/12);

Applications Engineer: An engineer who takes existing product(s) and, working with customers and manufacturing or construction crews, handles day to day issues of providing and as necessary modifying products and processes to solve problems arising as regard quality, turn-around time, manufacturability and customer satisfaction;

Artificial Intelligence: The term Artificial Intelligence (AI) was coined in 1956 as a summer project for scientists from IBM, Bell Labs and several Ivy League colleges. The goal was to discover how machines might "use language, form abstractions and concepts, solve … problems … and improve themselves" (Gazzaniga, 2009, p. 358);

Cognitive: Concerned with psychological processes of perception, memory, thinking and learning;

Cognitive enclosure: The necessity for humans to form a structure which focuses attention in a purposeful manner to problem solving. "The trick to problem solving is to find the *right* knowledge—to divide the problem into just the right sub-problems and in this way to navigate the right path to solution" (Duncan, 2010, p.140);

Cognitive neuroscience: "[T]akes psychological theories about the mind . . . and explores them by measuring electro-chemical activity in the brain" (Goswami, 2008, p. 382);

Conative: Expressive of instinctive effort and will to achieve;

Constructive learning: Learning is an active process in which students construct or reconstruct existing knowledge networks;

Contextual learning: Learning always takes place in a context; that is, all learning is situated. Transfer of knowledge can be facilitated by anchoring learning in meaningful contexts and by revisiting the context from different perspectives networks;

Convergent thinking: Thinking directed toward finding a single correct solution to a well- defined problem. Contrast with divergent thinking;

Cooperative learning: Students working in groups need each other for task completion (Willis, 2006). Cooperative learning is synonymous with a collaborative (learning) process;

Demonstration: Teaching approach in which the student is shown experiments with the goal to link explanation with practice (Akinbobola & Afolabi, 2009);

Developmental coursework: For purposes of this dissertation, developmental refers to courses which would not be accredited toward the degree; yet it would be unreasonable to expect the vast majority of mainstreamed students who wish to matriculate into the major to possess sufficient skill upon university entry;

Design: Art of developing creative solutions to open ended problems (Cabrera, Colbeck, & Terenzini, 2001);

Design Engineer: An engineer who typically begins with a basic concept and develops new product(s) or process (es) ready to turn over to construction or manufacture. At this juncture, the work project is normally turned over to an applications engineer;

Design skills: Ability to solve complex and ill-defined problems that may have many solutions (Cabrera et al., 2001);

Divergent thinking: Exploratory thinking involving seeking various solutions to ill structured problems;

Effect size: A measure of difference in averages of distributions divided by the standard deviation of the distributions. A large effect size indicates a small overlap while a small effect size indicates a large overlap of the distributions (Hinton, 1995);

Extrinsic motivation: Desire to do something in order to obtain an external reward. Contrast with Intrinsic motivation;

Formative assessment: Evaluation carried out in the course of an activity so that the information obtained is used to improve learning and/or instruction. Contrast with Summative assessment;

Intrinsic motivation: Desire to do something for the sake of the experience itself;

Kolbe A: Adult test version of Kathy Kolbe's conative model consisting of four instinctive action modes—Fact Finder (need to gather information), Follow Thru [sic] (need to organize information), Quick Start (need to deal with risks and unknowns) and Implementor [sic] (need to mold and build physical tangible objects);

Meta-analysis: Process of synthesizing a range of experimental results into a single estimate of effect size;

MBTI: Myers-Briggs Type Indicator (MBTI) questionnaire identifies different psychological types based on work of Carl Jung;

Problem Based Learning: Combines principles of constructive, self-directed, collaborative and contextual learning. PBL requires at least one tutor in addition to instructor (Dolmans et al., 2005, p. 732). This approach was loosely based on Dewey's 1938 call for "learning by doing and experiencing." It was firmly implemented at the medical school of Case Western Reserve in the 1950s. The steps involved are: problem statement, solution, practice, research, questioning/reflection, reality check, original solution and integration (Akinoglu & Tandogan, 2007);

Remedial coursework: Remedial refers to courses which are attempting to address a loss or lack of knowledge generally expected of students entering the institution. An introductory algebra class is considered remedial while an intermediate algebra course is considered developmental. While passage of the intermediate algebra class would not provide credit toward an engineering technology degree, the expectation is that many students who wish to matriculate into the major will lack sufficient skill upon university entry to move directly into college algebra, trigonometry, pre-calculus or calculus;

Self-directed learning: Learners play an active role in planning, monitoring and evaluating the learning process (Dolmans et al., 2005);

Skill: Refers to expertness, practical ability or facility in doing something. While skill overlaps with ability, the term skill refers to specific areas of performance rather than general areas;

Socio Economic Status: An individual's social ranking or socioeconomic status (SES) is based on their educational attainment, income, occupation and neighborhood (Lewis, 2010);

Success: According to John Wooden, "Success is the peace of mind which is a direct result of the self-satisfaction in knowing that you made the effort to become the best of which you are capable" (Nater & Galimore, 2006, p. 25);

Summative assessment: Evaluation of performance at the end of a piece of work;

Sustainability: "Change in education is easy to propose, hard to implement, and extraordinarily difficult to sustain. . . . If the first challenge of change is to ensure that it is desirable and the second challenge is to make it doable, then the biggest challenge of all is to make it durable" (Hargreaves & Fink, 2006, pp. 1- 2);

Team Based Learning: TBL, formally, is an instructional strategy developed by Professor Michaelson at the University of Oklahoma's business school in the early 1990s stressing preparation, readiness and group application including meaningful peer evaluation. Today, this approach is used extensively in medical training (Parmelee, 2010);

Visual analysis: Visualization techniques provide a particularly powerful and long lasting contextual perspective. Today's world is data rich; visual representations allow discovery of meaningful patterns in complex numeric information (Few, 2009).

Appendix J

Youngstown
STATE UNIVERSITY

One University Plaza, Youngstown, Ohio 44555
Office of Grants and Sponsored Programs
330.941.2377
Fax 330.941.2705

September 26, 2012

Dr. Karen Larwin, Principal Investigator
Mr. John George, Co-investigator
Department of Educational Foundations, Research, Technology & Leadership
UNIVERSITY

RE: HSRC Protocol Number: 015-2013
Title: Preparing Math Deficient University Students for STEM Success: The Special Case of Engineering Technology

Dear Dr. Larwin and Mr. George:

The Institutional Review Board has reviewed the abovementioned protocol and determined that it is exempt from full committee review based on a DHHS Category 5 exemption.

Any changes in your research activity should be promptly reported to the Institutional Review Board and may not be initiated without IRB approval except where necessary to eliminate hazard to human subjects. Any unanticipated problems involving risks to subjects should also be promptly reported to the IRB.

The IRB would like to extend its best wishes to you in the conduct of this study.

Sincerely,

Peter J. Kasvinsky
Dean, School of Graduate Studies and Research
Research Compliance Officer

PJK/cc

c: Dr. Richard McEwing, Chair
Department of Educational Foundations, Research, Technology & Leadership

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