Ethnomathematics:
Concept Definition and Research Perspectives

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ABSTRACT

Although the term ethnomathematics has been in use in the anthropological literature for quite sometime now, a standard definition of the construct has yet to emerge. More than one definition exists, causing confusion and inhibiting systematic research on the subject. Most definitions loosely refer to it as the study of mathematical ideas of non-literate peoples (e.g., Ascher and Ascher, 1997), thereby ignoring or underplaying its profound relationship to culture. More importantly, current definitions are restrictive and too narrow to adequately explain phenomena that rightfully fall within its realm. Providing a conceptually grounded definition is a necessary first step to galvanize the thinking and investigative activity on the subject. My aim in this thesis is to offer such a definition and to descriptively examine its relevance for theory building and research on ethnomathematics.

I start with a brief review of the current definitions of ethnomathematics, highlighting their parochial nature. I then propose an over-arching definition that derives its grounding from interaction and reciprocity-based models. My definition suggests ethnomathematics as the study of the evolution of mathematics that has shaped, and in turn shaped by, the values of groups of people. I then use this definition to historically examine how mathematics, despite its universality and constancy themes, suffers from culture-based disparities and has been influenced in its development by various social groups over time. Specifically, I examine the role of culture in the learning and use of math, gender capabilities in math, and how even racism has played a significant part in the evolution of math.

Using my framework and descriptive analysis, I identify and elaborate a set of topics for future research on ethnomathematics. I conclude my thesis with a discussion of the implications of my framework for current thinking and future research.

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PART 1 - ETHNOMATHEMATICS: THE CONCEPT AND A PROPOSED DEFINITION

The term ethnomathematics, although as yet undefined by the Oxford English Dictionary (Simpson, 1991) or other standard dictionaries, has been frequently used by the anthropological literature and by popular writings on culture. Several recent scholarly books, devoted singularly to the subject (e.g., Borba, 1990; D'Ambrosio, 1997; Powell and Frankenstein, 1988), discuss its import and relevance as a topic of academic interest. In the popular press, The New York Times visited the term in detail in a 1997 article reviewing Reuben Hersh's book, "What is Mathematics, Really?" and questioned its description as a cultural construct. On the Internet, it can be found as a sub-topic on the Yahoo site, located within major fields comprising Cultural Anthropology, Anthropology and Archaeology, and Social Sciences.

From the root, mathematics, and the prefix, ethno- from ethnography, we can presume that ethnomathematics refers to the study of mathematics in relation to culture. However, despite its seeming popularity as a theoretical concept, it is still ill-defined. Although its importance as a research construct is well recognized by scholars, any reference to it in the academic literature is often fleeting and, at best, tangential. As a result, ethnomathematics does not permit rigid measurement and fine-grained analysis of its attributes. A respectable body of research literature on the topic is consequently missing and only a handful of books on the subject are presently available. Providing an acceptable definition of ethnomathematics is, therefore, the first step toward a systematic study of the subject.

1.1 Current Definitions

Before proposing a definition, I would like to examine the current definitions of ethnomathematics within anthropological literature. Ascher and Ascher (1997), two researchers of African counting cultures, define ethnomathematics as "the study of mathematical ideas of non-literate peoples". This definition is too restrictive to permit a generalizable investigation of the topic. It implies that mathematics contains a cultural component only when discussing the mathematics of non-literate peoples (Borba, 1990). Further, it implies that a people can have a culture only if they are non-literate (or in some alternate way, an Other to the examiner of culture). This interpretation of ethnomathematics is a concrete example of ethnocentrism and an encouragement of the idea that proper mathematics is a notion defined only by the literate peoples. More importantly, with anthropology's acceptance of Boas' theory of cultural relativity in the early 1900's, this definition also seems grossly antiquated. Boas argued for the integrity of separate cultures which were equal with respect to their values. Differences between cultures with respect to technological or other development conferred them with neither moral superiority nor moral inferiority, including differences when compared to one’s own culture (Rosaldo, 1993). Boas’ theory of cultural relativity, which is ignored in the definition above, largely helped in efforts to combat racism.

D’Ambrosio presents us with a similar definition which is slightly broader than that provided by Ascher but still ethnocentric. He defines ethnomathematics as:

> the mathematics which is practiced among identifiable cultural groups, such as national-tribal societies, labor groups, children of a certain age bracket, professional classes, and so on. Its identity depends largely on focuses of interest, on motivation, and on certain codes and jargons which do not belong to the realm of

> academic mathematics. We may even go further in this concept of ethnomathematics to include much of the mathematics which is currently practiced by engineers, mainly calculus, which does not respond to the concept of rigor and formalism developed in academic courses of calculus (D'Ambrosio, 1990).

We note from Ambrosio's treatment of the term that it does not involve the standard study of mathematics, implying that the term only suggests mathematics studied by other cultures.

A somewhat refined definition of the concept is found on a University of Idaho web page: "Ethnomathematics is the study of mathematics which takes into consideration the culture in which mathematics arises" (1). While this definition relates culture to mathematics and opens the door for testing hypothesized relationships between the two, it too seems inadequate to permit a more eclectic investigation of the topic. A broader definition of the concept that emphatically links its roots to the mores and values of groups of people is thus warranted.

1.2 Entomology and Proposed Topics

An ideal starting point for defining a term is by borrowing its meaning from the dictionary. However, as mentioned earlier, the word ethnomathematics is not found in a standard dictionary. To the point, the definition of ethnomathematics has not been standardized at all. Nonetheless, few would disagree that etymologically ethnomathematics is the concatenation of the prefix ethno- onto the word mathematics. Thus, what is obvious is that there are two different literatures that examine ethnomathematics: Anthropology and Mathematics. From this, one can gather that ethnomathematics is at the crossroads of culture and mathematics. But, because these two subjects are so divergent, it is unclear exactly how they interrelate and give birth to ethnomathematics. A fitting definition can, however, be created if we examine the word itself and the definition of the prefix ethno- and the root mathematics. The prefix ethno comes from the word *ethnology*. The **American Heritage College Dictionary** (1993) defines: *ethnology as "the science that analyzes and compares human cultures; cultural anthropology*. The same dictionary also defines *mathematics as "the study of the measurement, properties, and relationships of quantities, using numbers and symbols."*

Upon examination of these etymologies and upon examination of the conceptual differences in the mathematics of different cultures, it becomes apparent exactly how large a topic we are discussing. Ethnomathematics does not only include the meekly interesting facts about how cultures count on their toes, fingers, or ears. It also includes a myriad of other topics that can be analyzed and studied:

- What is the function of mathematics within culture?
- How does mathematics affect one's culture (leading also to how technology affects ones culture)?
- Why is there a cultural feeling that mathematics is a universal subject?
- What conceptual differences are found in the mathematics of different cultures?
- How do different cultures count? Do these methods suggest something about the values of the underlying society?
- What mathematical areas of study a society stress, and what about the culture that dictated that those topics be studied?

- How do social hierarchies within a culture affect the development of mathematics within that culture?
- How do gender relations and status positions affect conceptual mathematics?
- How does mathematics affect gender? Are they interrelated?

1.3 Proposed Definition

To accommodate the myriad of topics above, the definition of ethnomathematics itself must not be a restrictive one. It must be simple and yet provide a basis to study divergent topics that emerge because of variations in human cultures. For the purposes of this paper, therefore, I define ethnomathematics as:

> *the study of the culturally-related aspects of mathematics; it deals with the comparative study of mathematics of different human cultures, especially in regard to how mathematics has shaped, and in turn been shaped by, the values and beliefs of groups of people.*

The above definition describes ethnomathematics as a legitimate offspring of the interaction between culture and mathematics. It suggests that the study and use of mathematics has cultural overtones and must be viewed as such. It offers a framework to discuss and explain evolutionary issues in mathematics as due to differences in human subcultures. At the same time, it suggests that the economic and technological disparities of societies can be explained by the influence mathematics has had on the thinking and behavior of people of those societies.

Figure 1 diagramatically describes the relationships of variables specified in the above definition. Relationships emphasize reciprocity between culture and mathematics. Culture affects mathematics, as does mathematics affect culture. The interplay within culture and mathematics is ethnomathematics.

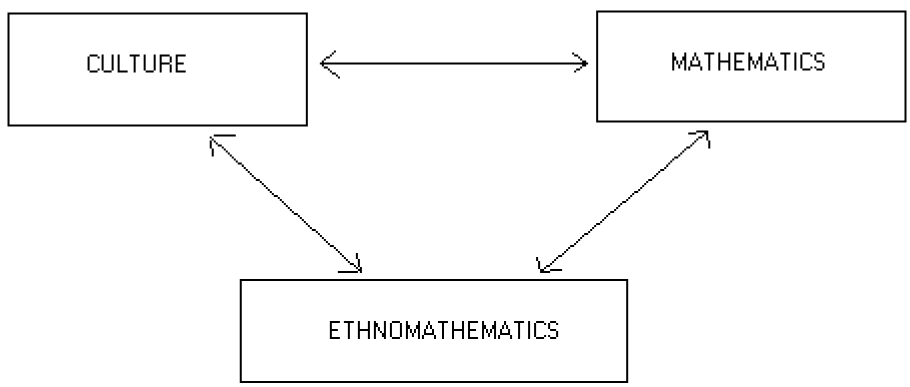

Figure 1: Ethnomathematics: interaction between culture and mathematics

For the purposes of this thesis, I define culture and mathematics as follows:

<u>Culture</u> refers to a set of norms, beliefs, and values that are common to a group of people who belong to the same ethnicity. These attributes are enduring, indicating that their impact on the outcome variable is longitudinal. The following definitions of the term, culled out from different sources, are equally relevant for the purpose of this thesis.

The Oxford English Dictionary defines culture as:

> a. "The training, development, and refinement of mind, tastes, and manners; the conditions of being thus trained and refined; the intellectual side of civilization. b. A particular form or type of intellectual development. Also, the civilization, customs, artistic achievements, etc., of a people, esp. at a certain stage of its development or history" (Simpson,1991).

The OED defines culture as: "Relating to civilization; esp. that of a particular country at a particular period" (1991). A Cultural Anthropology textbook defines culture as a concept distinctly pertaining to humans. "Cultures are traditions and customs, transmitted through learning, that govern the beliefs and behavior of the people exposed to them. Children learn these traditions by growing up in a particular society" (Kottak, 1994). The concept of culture can be problematic since the word has numerous definitions and elaborations. "What most have in common, and what is significant for us, is that in any culture, the people share a language; a place; traditions; and ways of organizing, interpreting, conceptualizing, and giving meaning to their physical and social worlds" (Ascher, 1998). Even within this definition, defining a group of people and their cultural aspects can also be problematic. "Because of the spread of a few dominant cultures, there is no culture that is completely self-contained or unmodified" (Ascher, 1998).

Mathematics refers to the study and use of numbers and symbols in relational terms. The focus is not only on the evolutionary aspect of its contents but also on how they are learned and used. The Oxford English Dictionary defines mathematics as follows:

> Originally, the collective name for geometry, arithmetic, and certain physical science (as astronomy and optics) involving geometrical reasoning. In modern use applied, (a) in a strict sense, to the abstract science which investigates deductively the conclusions implicit in the elementary conceptions of spatial and numerical relations, and which includes as its main divisions geometry, arithmetic, and algebra; and (b) in a wider sense, so as to include those branches of physical or other research which consist in the application of this abstract science in concrete data. When the word is used in its wider sense, the abstract science is distinguished as pure mathematics, and its concrete applications (e.g. in astronomy, various branches of physics, the theory of probabilities) as applied or mixed mathematics" (Simpson, 1991).

We must keep in mind, however, that mathematics is a cultural construct. Other cultures, although they do have the ideas or concepts that we deem as mathematical, do not distinguish them and class them together as we do (Ascher, 1998). The definitions of mathematics are based solely on the Western experience, even though they are often phrased universally. Even within the Western culture, the definition of mathematics can become confused, and is generally defined to include whatever the Western professional class called mathematicians do.

In the ensuing sections, I describe how mathematics developed and the role of culture in its evolution to set the stage for understanding ethnomathematics and an agenda for research. I then describe specific areas for research, using the proposed framework, and discuss how they are ideal candidates for studying ethnomathematics. Systematic investigation of these topics should help build a respectable body of research literature on ethnomathematics.

What follows is a discussion of culture's effect on the history of mathematics. Then, there is a discussion about the current ideals of mathematics, why culture needed these ideals, and similarities of mathematics and religion. The final section examines of mathematics in today's world, especially noting the lack of woman within the mathematics and providing cultural reasons for this disparity.

PART 2 – GENESIS AND EVOLUTION OF MATHEMATICS

A brief examination of the history of mathematics displays some of the relationships between culture and mathematics. Mathematical ideas and concepts as defined by Western culture, including arithmetic and geometry, were developed simultaneously across the world, and different strains of mathematics were pursued in each culture. Different cultures stressed different aspects of mathematics and treated mathematics differently. For instance, many cultures classify mathematics differently and do not have a strong dividing line between Mathematics or Physical Sciences and the Social Sciences. In these cultures, mathematics is taught integrated within the humanities. Culture also greatly affects our truth of mathematics; racism and misguided ideals have changed the history of mathematics itself. Founding fathers and mothers have been forgotten so as not to disturb the perpetuation of the myth that white man is the only intelligent being on the Earth.

2.1 Why was Mathematics Developed?

The foundations of mathematics may have emerged from the need to trade. Philosophers such as Adam Smith have always claimed man to be an economic animal who invented math to facilitate trade with others. For example, a traditional "apples-to-pigs" exchange would consist of a variable number of apples for one pig. Such transactions were among several factors that led to the development of number systems.

When discussing the origin of mathematics, we cannot help but think about the usefulness of it and that it originated because of its use in society. Perhaps, however, it emerged because of its aesthetic quality and the enjoyment of creating order out of chaos through rational thinking. If you ask virtually any mathematician, she would agree to the statement, "mathematics, like music, is worth doing for its own sake" (Guillberg, 1997). The usefulness of mathematics is what tends to conceal and disguise the cultural aspect of mathematics. Guillberg (1997) notes that no one ever asks about the usefulness of music: "The role of music suffers no such [cultural] distortion, for it is clearly an art whose exercise enriches composer, performer and audience; music does not need to be justified by its contribution to some other aspect of human existence". Mathematics, like music can exist without its usefulness, and can be appreciated as an exercise that enriches those who come into contact with it. Also, ignoring the art of mathematics does not further its usefulness. Because of mathematics utility, the subjects taught in school, are those, which are deemed most useful, and not those which are most aesthetically pleasing. Arithmetic, deemed "a wretched subject" by Guillberg, acts as the introduction to mathematics to most students because of its utility. Imagine for a moment, if music was also taught in the same way, utility of music being the first priority. Would the first music class be Musical Utility rather than Musical Appreciation? The class Musical Utility may teach how to compose influential marches or learning songs such as the ABC song or the state song, rather than the appreciation of more complicated and sophisticated techniques as taught by masters.

2.2 Who Developed What? And Forgotten History

Mathematics was developed simultaneously by different cultures across the world. Proof that each culture developed its own mathematics is presented upon examination of the different methods developed for solving systems such as quadratic equations and constants. Each culture stressed a different aspect of mathematics in its development. Babylonians invented a place value number system, knew different methods of solving quadratic equations (which would not be improved upon until the sixteenth century A.D.) and knew the relationship between the sides of a right-angles triangle, which came to be known as the "Pythagorean theorem (Joseph, 1997). Egypt pursued geometry to aid in the creation of complicated architectural structures. Egyptian fractions and the heightened accuracy of pi were developed as a tool for the development of these structures. India developed the number system and pursued more theoretical aspects of mathematics. We can examine the differences in mathematical from culture to culture and notice a culture’s effect on the development of mathematics.

Greeks have been credited with the development of a more sophisticated form of mathematics that serves as the basis of what we use today. Despite the common perception that Greeks were the founding fathers of mathematics, Greeks learned most of their math from Egyptians. Egyptian mathematics was superior to the Greeks, and the latter often went to be schooled in Egypt. Aristotle’s teacher, Eudoxus, one of the notable mathematicians of the time, had studied in Egypt before teaching in Greece. Thales (d. 546 B.C.) was reported to have traveled widely in Egypt and Mesopotamia and learned much of their mathematics from these areas. “Some sources even credit Pythagoras (fl.500 B.C.) with having traveled as far as India in search of knowledge, which may explain some of the close parallels between Indian and Pythagorean philosophy and religion.” (Joseph, 1997)

Most of the mathematical precision of the major mathematical constants (e.g., pi) came from Egypt (Bernal, 1992). Due to misconception and racism we still consider Greeks to have been the founders of modern mathematics (Bernal, 1992). To avoid the attribution of the invention of much of mathematics to Egypt, an alternate hypothesis was constructed – that the Greeks achieved a sudden, qualitative intellectual breakthrough in the fourth century B.C. – "approximating to the actual achievements of the Pyramids and the consistent ancient tradition of a superior Egyptian mathematics" (Bernal, 1987). The foundation supporting the alternative "Greek hypothesis" was the argument that the mathematical knowledge embedded in the pyramids were "chance qualities that had remained totally unsuspected to the constructors…[purely the result of] intuitive and utilitarian empiricism" (Bernal, 1987).

Joseph (1997) has said that

> "…the progress of Europe and its cultural dependencies during the last four hundred years is perceived by many as inextricably—or even causally—linked with the rapid growth of science and technology during that period. In the minds of some, scientific progress becomes a uniquely European phenomenon that can be emulated by other nations only if they follow a specifically European path of social and scientific development."

Counter evidence is found within even the Greek mathematical literature itself of the intellectual debt they owed to the Egyptians and Babylonians (a generic term that is often used to describe all inhabitants of ancient Mesopotamia), and fulsome acknowledgement is given within many of the texts. There are scattered references of the knowledge acquired from Egyptians in fields such as astronomy, mathematics, and surveying, with sources varying from Herodotus (fl. 450 B.C.) to Proclus (fl. A.D. 400). Some Grecian commentators even considered the priests of Memphis to be true founder of science. Aristotle (fl. 350 B.C.) considered Egypt to be the cradle of mathematics.

The Greeks are usually given credit for the determination of pi despite Egypt's more accurate estimate of pi. This is not surprising as the advancements of Africa are often attributed to others due to cultural misconceptions. To explain Egypt's responsibility for the development of pi, we must first examine Egyptian fractions. Egyptians used something thus-named Egyptian fractions in place of the common Western fraction format (which they had no knowledge of). Egyptian fractions have been the common technique of fraction representation and computation until the 19th century. The Egyptian fraction is represented by a sum of unit fractions, e.g. 1/a + 1/b + 1/c + … where a b c are increasing integers. For example, the fraction 5/6 can be represented by the Egyptian fraction 1/2 +1/3. Every rational number can be represented as an Egyptian fraction [2]. (I shall spare you the proof.) A famous "mysterious, so called, meaningless" triple, 13, 17, 160, was found throughout Egyptian architecture and manuscripts. When translated into Egyptian fractions, we notice that 3 + 1/13 + 1/17 + 1/160 approximates pi to 4 significant digits which is much better than 3.16 which is usually attributed to the Egyptians.

In the Middle Ages, Arabs made considerable contributions to mathematics, natural science, medicine and philosophy (Joseph, 1997). Arabian scholars are responsible for a large part of current European mathematical thought through the influence of both the course of European cultural history and the history of European thought. The technique of measurement was established by Egyptians and Babylonians and formalized by the Greeks and Alexandrians. The number system originated in India. Arabs collectivized the technique of measurement with the remarkable instrument of computation (or number system), and developed a systematic and consistent language of calculation which came to be known by its Arabic name, 'algebra'" (Joseph, 1997).

The foregoing supports the proposition that culture has occupied a central role in the development of mathematics. While economic nature seems to have given birth to mathematics, environmental factors unique to different societies have impacted its growth. Different societies in different time and space have influenced and, in turn been influenced by, mathematics' evolution. Understandably, while its theoretical components may be the same across societies, its application and usage are culturally biased.

PART 3 – CULTURAL IMPACT ON THE EVOLUTION OF MATHEMATICS

3.1 Universal theorems but Culturally Distinct Applications

> "Not much study has been done in ethnomathematics, perhaps because people believe in the universality of mathematics. This seems to be harder to sustain, for recent research, mainly carried on by anthropologists, shows evidences of practices which are typically mathematical, such as counting, ordering, sorting, measuring and weighing, done in radically different ways than those which are commonly taught in the school system" (DiAmbrosio, 1997).

There is a societal belief that mathematics is a universal and standard concept across ethnological boundaries. Its theorems and laws are viewed as generalizable and universally applicable. This belief stems from mathematics' axiomatic principle that its premises and assumptions must be held as constant despite the variations in the usage environment. This constancy principle has endowed mathematics with an ideal platform, sought by less precise disciplines, to explain varying phenomena in comparative terms. There is a perception that mathematics is an effective tool for analyzing, examining, and verifying truth. It has provided mathematics with an aura of objectivity amidst a predominantly subjective, chaotic, and nebulous world.

This belief that mathematics is a universal subject is well founded. Every culture appears to have counting, sorting, and other mathematical basics, which seem to imply something fundamental and powerful about the basics of mathematics. Every culture has a concept of numbers and the idea that 1 + 1 = 2, no matter how technologically advanced the culture is. In no culture is 2 + 2 = 5. Most math languages are base ten or some multiple due to the logical counting of fingers on the hand. All math languages have counting and multiplicative elements.

This universality notion of mathematics is further reinforced by the fact that it was invented all over the world, in a multitude of places and at different times, with little or no contact amongst its creators. The basic concepts and premises were thus identical. And, even the more advanced concepts and premises were practically identical. This seems to be too strong a coincidence. It is this constancy paradigm that made Plato proclaim mathematics as a reliable tool for pursuing truth.

While its assumptions and theorems are universal, their application, usage, and even the methods used to learn them seem to be culturally influenced. Thus, just as a language (e.g., English) is spoken or written differently by people of different cultures, mathematics-related communication appears to be punctuated by cultural oddities. Some obvious examples are the following: Many math languages are base-20, based on the number of fingers and toes. Nahuatl, a language of Central Mexico, is one of these, as is Chol, a Mayan language spoken in northern Chiapas, Mexico. The French language also expresses it numbers in a base-20 format after the number sixty. A number system of base ten may seem to be obvious to the reader because it matches the number of fingers on the hand. However, the Yuki of California think their system based on eight is the most logical for a similar reason. The Yuki's base eight system is based on the number of interfinger spaces. Knuckles are used in yet other cultures. Many cultures use different words for the same number depending on what they are counting. For instance, the Dioi language has fifty-five numeral classifiers. Glibertese, spoken on the Gilbert Islands, which is now part of the Republic of Kiribati, has 18 numerical classifiers. Some of these are animate objects and ghosts, groups of humans, days, years, generations, coconut thatch, rows of thatch, rows of things (other than thatch), customs, modes of transportation, etc (Ascher, 1991). One study showed how diversely number counting can be done on fingers (Zaskavsy, 1991). Ten children were asked to count to eight on their fingers secretly. Then all at one, they were asked to display how they represented the number eight on their fingers. The children had a multitude of different ways of representing the number eight. It is thus clear that despite its universality paradigm, aspects of mathematics have significant cultural overtones. By examining these cultural attributes, factors contributing to teaching and learning-effectiveness in mathematical can be analyzed and understood.

3.2 Logical Underpinnings, Intuitively Created

Mathematics has logical underpinnings. Logic is defined as the science of correct reasoning. Our general conception of logic is a lofty one. We refer to logical thinking as the ideal manner of thought. It is associated with systematic organization and inferential reasoning. It is thus viewed as antithetical to insight, foresight, and intuition. In fact, intuition is a "dirty" word in logic's lexicon because it contaminates reason. Logic is paired with the masculine entity whereas intuition is paired with the feminine entity. We do this without a complete interrogation of the ideas embedded in logic and intuition. Logic is the conceptual mind of a computer. A logical system is one that is predictable and invariably generates the same answer to problems each time. Logic does not provide for the concepts of intuition, fore-learned knowledge, and commonsense, because they are devoid of reasoning. These are not programmable, and thus cannot be used within the ambit of logical thinking.

In effect, logical thinking is dumb thinking that has no element of spontaneity in its repertoire; it is robotic and, consequently, does not differentiate humans from computers. In reality, however, it is only the illogical elements of intuition, spontaneity, unpredictability, fore-learned knowledge, and common sense that largely define the humans and humanistic attributes of thought. But these are not programmable. To deal with this conflict, we praise the supposedly "feminine" attributes of thought as our human-side.

This "feminine" attribute of intuition with which we are disenchanted is, however, the precursor to mathematics. A priori, it is cogent to argue that intuition must have been necessary and fundamental to invent mathematics. The human mind needed to take a leap, a radical jump, to define that there really existed a concept of having one item, and that it was concretely different from having two items. Indeed, this was no small leap of definition and it was an outcome of our intuition of the material reality around us. Intuition was thus the harbinger that laid the foundation upon which logic and, in turn, mathematics could be created.

3.3 Rationality and Emotionality

Definitions lie at the foundation of mathematics. Before we can create mathematical truths, the basic elements and their operations must first be defined. There is no physical ideal of “one”, nor “plus”. You can’t sit on a “two” nor eat a “subtraction”. These are purely conceptual ideas created to help us understand the world. The act of naming gives us a powerful control over that what we have named. We are mostly afraid of that which we cannot name. We can think of the common phrase, “If you know thy enemy, then you can defeat him”. The unnamable is the unconquerable. Mathematics is made up solely of definitions and inferences based upon these definitions.

Mathematics uses these definitions and inferences to act as a tool to demystify the inexplicable world. An axiom serves as the foundation for mathematical proofs and inferences by providing us with a model for assumptions or assertions. The existence of an axiom within mathematics allows for arbitrary statements such as “two is one more than one” (Rosen, 1991). These axioms provide the foundation of number systems that give an ordering to an otherwise uncountable universe. Axioms and number systems are combined to help create theorems and proofs to explain natural occurrences. In turn, these proofs provide us with an understanding of the universe so comprehensive that we sometimes forget that they exist on arbitrary assumptions and assertions that are impossible to prove on their own.

Along with presenting society with explanations of the chaotic world, mathematics’ conceptual definitions and inferences, also provides society with rules. Man created mathematics in his own image to provide structure to his life.

Mathematics mimics the rationality favored by humans, and not by chance. Mathematics gave man the opportunity to pursue rational and logical thought. Since this rationality is different among different cultures, the ways in which mathematics is used and pursued within these cultures can also have very different nuances. We must note that cultures, despite their many differences, are largely similar causing much of the studying of mathematics to be constant cross-culturally. Rationality is necessary for inter-cultural communication. Mathematics and its logic grew from a mimicking or standardization of this rationality. The assumptions that are commonly accepted throughout a community, such as two are more than one, helped shape the foundations of mathematics.

> The rules of language and of mathematics are historically determined by the workings of society that evolve under pressure of the inner workings and interactions of social groups, and the physical and biological environment if earth. They are also simultaneously determined by the biological properties, especially the nervous systems, of individual humans (Hersh, 1997).

This mathematics, created from our own rationality, is taken culturally as an absolute fact. We become only partially aware of our effect on the creation of mathematics when we look at other cultures through cultural relativism. Our culture has created mathematics as a basis of what is absolute, what is not relative, what is not questionable, despite its cultural dependencies. We support our concept of absolute mathematics by claiming, "mathematical entities exist outside space and time, outside thought and matter, in an abstract realm independent of any consciousness, individual or social" (Hersh, 1997). In our world where everything seems unstable, it is comforting to reach towards mathematics as a form of stability. However, mathematics is also part of and affected by our culture, and we must also view mathematics through our lens of cultural relativism.

We are reminded of a huge jolt that came to the mathematical community, when Einstein presented his own theory of relativity. Suddenly people realized that time and space were not perceived identically to everyone. While studying the mathematics of non-European cultures, we find that not all cultures count nor sort the same, nor do they have the same conception of these "universal" ideas. Mathematics grows more and more universal as communication ensues. As people communicate, and as mathematics becomes a tool for communication and trade, stabilization of these viewpoints must concur, otherwise the ideas become useless. In other words, as we become more and more global, it will become more and more important that our mathematics become standardized (less culturally-biased) since it is the basis of communication.

In many ways, we should not marvel at the cultural commonalities of mathematics. Just as every language has a way of greeting each other, we do not marvel that language is a universal entity, but merely a product of our ability to talk, so then should we merely attribute mathematics as a mimic of our simplistic/complicated human brain process. Just as we have created god in our own image, we have also created mathematics in our own image, that of our thought process. Both are attempts to describe and demysitify the world. The similarity becomes more pronounced when we examine references to math and science becoming the new religion. Ron Graham, a well-known combinatorialist, once said: "I personally feel that mathematics is the essence of what's driving the universe" (Hersh, 1997). Joel Spencer echoes this point: "Where else do you have absolute truth? You have it in mathematics and you have it in religion" (Hersh, 1997).

Kant answered his question, 'How is mathematics possible? (Kant, 1781) If not because of the existence of external mathematical objects, then, he thought, our minds ("intuitions") must impose arithmetic and geometry universally. Everyday experience finds mathematical truth to be fallible and corrigible, like other kinds of truth. Hersh discusses mathematics as a human activity:

> Mathematics is human. It's part of and fits into human culture. Mathematical knowledge isn't infallible. Like science, mathematics can advance by making mistakes, correcting and recorrecting them…. There are different versions of proof or rigor, depending on time, place, and other things…. Mathematical objects are a distinct variety of social-historic objects. They're a special part of culture. Literature, religion, and banking are also special parts of culture. Each is radically different from the others. Music is an instructive example. It isn't a biological or

> physical entity. Yet it can't exist apart from some biological or physical realization—a tune in your head, a page of sheet music, a high C produced by a soprano, a recording, or a radio broadcast. Music exists by some biological or physical manifestation, but it makes sense only as a mental and cultural entity. What confusion would exist if philosophers could conceive only two possibilities for music—either a thought in the mind of an Ideal Musician, or a noise like the roar of a vacuum cleaner…. Mathematics is a social-historic reality…. There's no need to look for a hidden meaning or definition of mathematics beyond its social-historic-cultural meaning. Social-historic is all it needs to be…. forget immaterial, inhuman 'reality' (Hersh, 1997).

Kant's fundamental presupposition is that contentful knowledge independent of experience (the 'synthetic a priori') can be established on the basis of universal human intuition. In *The Critique of Pure Reason*, Kant gives two examples: (1) space intuition, the foundation of geometry, and (2) time intuition, the foundation of arithmetic (Kant, 1781). In *The Critique of Practical Reason*, without using the term 'synthetic a priori,' he gives a third intuition: (3) moral intuition, the foundation of religion (Kant, 1788).

In *The Critique of Practical Reason*, Kant demolishes the three standard proofs of the existence of God. The first standard proof given is "Ontological", which proceeds as follows: By definition, God is Perfect. Nonexistence would be an imperfection. The second standard proof given is "Cosmological": Every event has a cause. To avoid infinite regress, there had to have been a First Cause (God). The third proof is "Teleological": A watch has a watchmaker. The World is more intricate than a watch, so it has a World-Maker (God). Kant argues that these proofs are only speculative reasoning, grounded in Leibnizian rationalism (Kant, 1788). Kant doesn't doubt God's existence; rather, he's showing the superiority of his own proof, which is based on intuition. His proof of God's existence is similar to his intuitions of time and space.

Kant explains that everyone has an intuition of duty of right and wrong. He doesn't say this proves God exists; rather, he says it justifies the postulate "God exists."

The connection between Kant's philosophy of mathematics and his moral-intuition version of religion is that, unlike Descartes and Leibniz, Kant does not use the certainty of mathematics (time and space) to support the certainty of God's existence. He considers the intuition of duty independently of the intuitions of time or space. He keeps his theory of God separate from his theory of mathematics. But they both have the same logic. Both rely on intuition: knowledge coming, not from the senses, study, or learning, bur from the nature of the Mind. Right and wrong, like time and space, are universal intuitions. Our space intuition leads to arithmetic, our duty intuition leads to Divinity" (Kant, 1988).

3.4 Evolving Rationality and Evolving Mathematics

Hersh mentions two facts. "Fact 1: Mathematical objects are created by humans. Not arbitrarily, but from activity with existing mathematical objects, and from the needs of science and daily life. Fact 2: Once created, mathematical objects can have properties that are difficult for us to discover. This is just saying that there are mathematical problems which are difficult to solve." From these we can perceive mathematics as a puzzle created by us for us, a way to keep us occupied now that we have all of this idle free time since we have conquered the animals around them and kept them at bay while we develop ourselves. In our game playing and attempt to understand the laws of mathematics, we are attempting to better understand ourselves and unravel our ways of thinking. We reduce the complexity of our own life by reducing the complexity of the mathematical laws we have based our cultural world on. As our conceptions change, so does our mathematics. This explains why mistakes are so prevalent and necessary within mathematics; as we become prepared to enhance the limitations of our thought, the boundaries of mathematics as the aping of our thought become enhanced and adjusting, allowing for the appearance of previous misconceptions.

We can see that with our definitions and our inferences, our world has actually changed along with it. We started with the world of Newtonian physics and progressed to Einstein's theory of relativity, and now we are fumbling with Brian Green's string theory. During the time of Newtonian physics, that was taken as the truth and the sole way of describing the universe. The same happened during the time of Einstein's theory of relativity, even though it does not fit within the Newtonian world of physics. Assumedly, if string theory continues along the same track, we will expand our concept of the physical world to include this new concept. We are, in effect, revamping truth as our ability to make new inferences increases.

Math has crated almost a supernatural version of truth. A glimpse of this becomes evident in Cantor's truth of infinite numbers (Dauben, 1990). He proved that there are more real numbers than integers, when they are both infinite, and that there are the same number of prime numbers as there are integers, even though we can name infinite numbers that are composite (not prime) integers. His most famous diagonalization argument stems from this, proving that the set of real number is uncountable and infinite (whereas the set of integers is infinite and countable). This was most certainly against the "certainty" of mathematics hundred of years ago, which shows the dramatic growth of truth.

As mathematics evolves and is taught to ape the new ways of thought, the followers of the old-thought seemingly will have trouble understanding the new material. A few outstanding mathematicians lead the revolution of new mathematical thought. As these exceptional people lead the way to new thought, such as in Brian Green's radical new string theory of the 20th Century, more and more fresh Ph.D. students are trained in the new way of thinking (Green, 1999). Meanwhile, some mathematicians of the older generation continue in the old style. Among them are brilliant veterans of the previous revolution who can't seem to grasp the new way of reasoning. If they don't master the new methods, that says something about mathematics. If it were simply correct reasoning from arbitrary premises, good mathematicians couldn't fail to understand good mathematics (Hersh, 1997).

If we look at the reasoning of Descartes, we learn that he presented a theoretical concept that embraced all of human thought and, thus, mathematics. If what Descartes proposed was true, then the concept proposed above affirming that math is not constant in its evolution can be argued not to be true. Isaac Beeckman visited Descartes in 1628 and wrote: "He (Descartes) told me that insofar as arithmetic and geometry were concerned, he had nothing more to discover, for in these branches during the past nine years, he had made as much progress as was possible for the human mind. He gave me decisive proofs of this affirmation and promised to send me shortly his Algebra, which he said was finished and by which not only had he arrived at a perfect knowledge of geometry but also he claimed to embrace the whole of human thought" (Vrooman, 1970). Obviously, if we examine the progress of mathematics since Descartes, we can see that the human mind could comprehend more progress than that which was determined by Descartes. Although we can conceive many counter argruments at the time of this thesis, Berkeley developed one counter attack during the time of Descartes. He attempted to show that the mathematics of Newton and Leibniz is more obscure than the Church's deepest mystery (Hersh, 1997).

Throughout the development of mathematics, each new theory that has been developed has been thought to be the one that encompasses all thought. Certainly during the time of Newton, Newtonian physics was thought to be the theory to explain all actions of the physical world. Likewise, Einstein's theory was also thought to be a simple explanation of our mathematically based universe. We are in the process of accepting a new all encompassing theory, that of string theory. Throughout history there have also been smaller advancements explaining more and widening our thought. As our thoughts widen, so does our acceptance of those who studied mathematics.

PART 4 – LEARNING MATH

With each new theory developed, we see more and more women and minorities entering mathematical study. If Math were taught in relation to humanities, as it is taught in Asia, alternative ways to view the subject would widen the audience that could understand it (Yoke, 1985). This would encourage a greater number of people to pursue Math and view its relation to art, literature, and culture and, consequently, support more people (male and female) to learn higher level mathematics. The focus would help students recognize math as essential to life, such as the notion of the circle of fifths in music. (This would foster the notion of math being recognized as a universal language - with all cultures speaking intuitively about the essentials of the subject.)

4.1 Mathematical Skills and Gender

When contemplating the interaction of gender and mathematics from a cultural perspective, we are immediately faced with the obvious disparity between the number of women and men pursuing mathematics. "Most mathematicians are men, and mathematics, like the rest of natural sciences, is seen as masculine: a subject for those who are rational, emotionally detached, instrumental, and competitive" (Martin, 1988). We know that men and women have been blessed with the same genetic mental make-up and the same powers of intelligence (Tarvis, 1970; Mill, 1863). We have determined that the x and y chromosomes (the only difference between male and females) largely alike and contain very little mental differences. But more importantly, the eggs are able to repair mutations in the sperm, implying that women's chromosomes are not lacking. "Eggs can repair sperm that are defective, including those with chemically induced mutations in the genetic code. In other words we appear to be programmed at a cellular level to fix the wounds of men" (Borysenko, 1996). This being the case, why have women refrained from pursuing mathematics for so long? It is only recently that there has been encouragement for women to eagerly pursue mathematics in an equivalent fashion to men. Grants through the national science foundation and other philanthropic foundations geared to increasing the number of women and minorities in attendance are credited with the thrust.

Traditionally, men have conducted the research in all fields. The subjects most often were other men in organizations dominated by male leadership. Even in the area of health, it was generally men who were studied to determine the reason for heart attacks, high blood pressure, and lung cancer. This capitulated the myth that man's life had greater value than women and perpetuated the notion that men had superior mental capabilities as compared to their female counterpart. Man would put down women both physically and mentally (Anderson, 1990). In fact, he often used his physical superiority to enforce his presumed mental superiority. In J.S. Mill's argument, *The Subjection of Women* (Mill, 1970), he surmised that a female is capable of everything that a man is capable of doing mentally. Society has been keeping women under a form of mental dominance because it suited the men, the main influences in society at the time. The original arguments – that males were inherently more superior in muscular strength and any other such primeval social facts - have subsequently, in the course of the ages, ceased to exist. In the second place, argued Mill, the adoption of such a system in modern time was deliberate, not for the benefit of humanity but to benefit those in power, i.e.: the males.

Perhaps we may wonder if the female posed some sort of a threat to the male, for why else would he feel necessary to keep her dominated. In early times, the great majority of men and all women were slaves. And “many ages elapsed, some of them ages of high civilization, before any thinker was bold enough to question the rightfulness and the absolute social necessity of slavery" (Mill, 1863).

There was a threat that the female posed to the male; the threat was that she did not need the male, whereas the male needed the female. Many studies, in particular Durkeim's *Suicide*, have been done on the fact that woman are happier before marriage, whereas men are happier after marriage (Durkeim, 1997). But even more significant is reproductive jealousy (Tarvis, 1970). In reproduction, men are necessary only for the first insemination, but women are required for the entire process. For a woman to possess a child, she need only have sex with any man. For a man to have a child, he must not only have sex with a woman, but also remain with the woman all through her pregnancy and earn her trust such that she would trust him with her child. In terms of dependency in order to produce a child, the woman needs the man far less than the man needs the woman. To protect against this, man perpetuated the myth that they were indeed necessary in the family. Men created the illusion that without them, the family would fall apart and the woman and child would not be able to survive. Maybe this was true in the caveman days when the threat of animal attack was imminent, but it is certainly not true now. Proof of this may be found in the number of healthy families with one mother (in the case of a single mother) or two mothers (in the case of two lesbian parents). When the mother(s) are happy with their situation, the children often grow to be more stabilized and comfortable with the world than their counterparts with both mother and father.

Man has a desire to possess, to conquer. Man wanted to conquer the female. This inclination caused him to try to make the female perceive that the female needs the male. How does this relate to math? Mathematics was something that the man found intriguing. He found it difficult and abstract. It was also something that man could attempt to conquer, and at the same time enjoy the challenge. Going back to cave man days, man instinctually enjoyed the hunt, and even more the kill. In today's societies, man still has the opportunity of pursuing the hunt and the kill, but it usually results in a merger or some other important business deal.

So, how did this social system influence mathematics? Mathematics presented another opportunity for the man to prove its power and success - bragging rights - as some may say. In this, the western civilized male would present the mathematical opportunity to the woman by saying, “You can't do it. I'll do it for you. Math is beyond you.” He did this because math was challenging and abstract. If the woman could do it, it would take away the male’s own power. He tried to subjugate the woman, and in the same way he tried to subjugate the African Americans (Anderson, 1990).

This usage of mathematics may be one reason why women did not pursue mathematics. Even the mathematical numbers themselves are assigned gender and good and bad. Odd numbers are associated with warm, bright, and sunshine. They are masculine. Even numbers are associated with dark, bad, and rain. They are seen as feminine (Worsley, 1997). We can see why women would want to stray away from a field that assigns them as evil.

Numbers also established the solvency of an operation. Men have always known that to have the fiscal knowledge of any business gives them the upper hand in negotiations. Women are still told that they are unable to handle business finances and are seen as inferior in the area of business. According to the Association of School Business Officials' 1999 (ASBO) survey, when a woman is highly qualified and is able to obtain a fiduciary position, the position title is often downgraded, compared to the male counterpoint, with the pay significantly less and responsibilities the same or more (Hammond, 2000).

This scenario is nothing new. From the following tale, you can see how one woman was affected by mathematics as a male-oriented science.

> "Let me take you on a journey back in time, when math was first developed and used as a communication device. Woman was home and pregnant. Man was jealous, and claimed his role as the social being, as she was otherwise occupied. The man saw that it was necessary to use math to communicate. He thought to emphasize the importance in his role (this enjoyable and simple role). He thus claimed superiority in it. He didn't want it to seem as if he were doing all of the easy work. Overwrought with the guilt and inferiority complex from not being able to produce a child, he boosted his ego to over compensate, and over-inflated his value of work. The man thus claimed math as invaluable to species. He did not share this new knowledge with his wife. Why? Because he did not want to facilitate her communication with others as this would allow her to leave him and would only enforce her superiority.
>
> In life, you survive by brain or brawn. Since women obviously did not have the brawn, she must have had superior brains to survive against the men.
>
> -Anonymous"

According to Travis, women have developed a better ability to integrate many components in the development of solutions (Travis, 1992). Merriam-Webster's Collegiate Dictionary defines integration as the "coordination of mental processes into a normal effective personality or with the individual's environment." Women, as opposed to men, have developed the ability to read faces in the subservient role. Men, on the other hand, traditionally learned only anger to combat for survival. Today, men often do not use their intuition, as it is not as developed as a woman's. Thus, women are better at those sciences in which she must integrate, and thus by default she is assigned to those. Unfortunately, women assigned to such jobs have resulted in both decreased pay and decreased perception of the job's value. Additionally, women's ability to work in subservient roles relied on subtlety and manipulation, which today often reflects negatively on women.

4.2 Learning Math

In most countries and cultures, there has been a noticeable inequality between the number of women and men studying mathematics. There are very few women who pursue mathematics in graduate study. This brings on the question: Why do people decide to learn math, and what part does culture play in this decision?

Three rationales exist to explain the gender imbalance shift. The first is passive biological determinism which translates into women being biological unable to do mathematics. ("They can't.") The second rationale is passive social determinism. In this argument, women are not socialized into doing mathematics. ("They don't.") In the third rationale, Active Voice, women make their own decision whether or not to pursue mathematics, i.e., they choose not to. ("They won't.") (Willis, 1989)

The first reaction that many people have is that men are genetically better than women at math. "Mathematicians are commonly thought, especially by themselves, to have an innate aptitude for mathematics, and claims continue to be made that males are biologically more capable of mathematical though that females" (Martin, 1988). The scope of this paper did not initially include such considerations. However, discussion with female Columbia students has revealed that a surprising percentage of women do believe such societal misconceptions. In reality, culture and in particular the fact that men traditionally control finances in western society has been the source of this inequality. This is discussed in further depth in the section 4.3, "Where Do Women Outperform Men in Mathematics?"

Let us first try to understand what about math is attractive to men. In a study done by Burton, she asks women and men why they like math. She is surprised to find one particular reason attributed to men only. Apparently, many men preferred to study math because of the snob value of it all. There is a cultural conception that mathematics is difficult, and they enjoyed being part of a group that could understand it. One male student said: "The fact that it was so intellectual and so hard and was so different really appealed to me… to put it bluntly, the snobbery you know, how you felt to people really stupid.'" (Burton, pg. 123) Men, in all but most recent times, were expected to be the breadwinners of the family. Intelligence was seen to be a huge benefit in the ability to support one's family. Men were continuously expected to prove themselves as capable and fit members of the productive society. Society did not have this expectation for women, although today such perceptions are changing rapidly. By studying mathematics, it gave some of the students the ability to feel that they were at least, better than their peers who did not understand these concepts. The snob-value, as the student put it, supplied the males with sufficient cultural encouragement for mathematical study. This refers back to the bragging-rites previously described.

We are also aware that subjects associated to masculinity are often valued more by society. Math being a masculine subjects, further attracts men to the subject. "The high status of mathematics as a discipline may be attributed in part to its image as a masculine area. Mathematical models gain added credibility through the image of mathematics as rational and objective—characteristics associated with masculinity – as opposed to models of reality that are seen as subjective and value-laden" (Martin, 1988).

Next we must examine what kind of cultural encouragement or discouragement women are given to study mathematics. Burton insists that women can do well in mathematics when they are given encouragement or culturally appropriate models. Unfortunately, women usually do not find it as a desirable subject to pursue, although they may be good at and enjoy it. Although men find math very useful, women do not find it to be a useful subject.   Rather, society encourages women to value careers that involve more social interaction. Perhaps this can also explain the gender differential of the other engineering or hard-science disciplines where women are a very small percentage of the overall discipline. Mathematics is an alienating subject for females. It is seen as only a stepping-stone in their education that will not play a major role in their final life or job goals. A common phrase heard from females is: "I can do math, and it's even fun sometimes, but I want to choose a career that will allow me to do something useful with my life. I want to work with/for people." (Morrow and Morrow, 1995) This statement implies that women are culturally trained to feel that their usefulness depends more on their social effectiveness within their job. Women feel that math does not allow connection with others, a common misconception about mathematics despite many evidences to the contrary. "The teaching of pure mathematics as concepts and techniques separated from human concerns, plus the male-dominated atmosphere of most mathematics research groups, makes a career in mathematics less attractive for those more oriented to immediate human concerns, especially women” (Martin, 1988).

Many studies have been done examining women in the classroom setting. In society, women are often not allowed or encouraged to speak out. This trait/expectation usually follows into the classroom where women usually sit much more silent in class and take part in class participation much less then their male counterparts. Vygotsky relates speaking to action, and this inactivity from women severely limits learning possibilities. Language is considered a significant part of the learning process. Vygotsky states: “‘Our experiments demonstrate two important facts: (1) A child’s speech is as important as the role of action in attaining the goal. Children not only speak about what they are doing; their speech and action are part of one and the same psychological function, directed toward the solution of the problem at hand. (2) The more complex the action demanded by the situation and the less direct the solution, the greater the importance played by speech in the operation as a whole. Sometimes speech becomes of such vital importance that, if not permitted to use it, young children cannot accomplish the given task. These observations lead me to the conclusion that children solve practical tasks with the help of their speech, as well as their eyes and hands (Vygotsky, 1978, pp. 25-6)’"(Fullerton, 1995). This said, it seems obvious how the woman who is encouraged not to speak up, may have a more difficult time in learning mathematics.

Women also receive a lot of cultural pressure to do feminine tasks, under which mathematics does not fall. Many women, as are men, are naturally drawn to the study of mathematics. Kaiser describes the appeal of mathematics and the guilt of pursuing it rather than other more expected or acceptable fields: "Mathematics is an addictive occupation, or preoccupation, regardless of gender. Becker has described features of mathematics that draw both women and men to the subject: ‘its logical nature, its problem-solving aspects, its objectivity and its creative nature’ (Becker, 1990). In the mid-1960’s, when I completed my degree in mathematics, I felt that the support women who were considering mathematical careers needed most was company in guilt – guilt occasioned by their avoidance of personal and communal social responsibilities. But, securing company in guilt meant being able to find other female mathematicians, and there were fewer around then than there are now"(Friedman, 1995).

4.3 Where Do Women Outperform Men in Mathematics?

As mentioned earlier, there is a cultural encouragement for women to stay away from mathematics. However, this constant discouragement of women out of mathematics does not exist in cultures where women are in charge of trade, such as Jamaica. In these places, men often do not work, and women are required to support their family.

In the United States, Hawaii is the only state where girls outperform boys (Roger and Kaiser, 1995). Hawaii's culture encourages women to study and succeed in mathematics. Kaiser has also proven that this is a trend that continues along many cultures. On the whole, girls and boys perform better on SAT tests in areas familiar to them (Association of University Women). Thus, if women are not educated in math, how can they show excellence in it? Where the discouragement decreases, the gender imbalance in mathematics scores also decrease. Kaiser says the following: "First, the cultural norms in many developing countries are responsible for producing enrolment disparities. Second, in the developed world, cultural norms operate to discourage female students in mathematics to the point that their enrolment in mathematics courses declines as soon as enrolment becomes optional. Third, in societies where the role of women has changed, gender differences in mathematics performance are beginning to decrease. Finally, in certain societies and cultural groups in which women already have more power and authority, females outperform males in mathematics."(Brandon, Jordan, and Higa, 1995)

When examining the gender differences in the mathematics performance of students between the ages of 9 and 16 years in the United States, some interesting findings emerge. The male and female African-Americans perform mathematics equally. The same phenomenon occurs within the Hispanic-American student. The female student performs slightly better than the male student in mathematics. The only group in which the male outperformed the woman in mathematics was the White students, and the gap there was small. Hawaiian females, as well as females from the Philippines and Japan, outperform the males in their ethnic group (Brandon, Newton, and Hammond, 1987) (Brandon, Jordan, and Higa, 1995).

Geffry Driver (1980) studied 2300 secondary-school graduates of both sexes, including White students and students of West Indian decent, in five multiracial secondary schools in the United Kingdom. In this study, he observed that West Indian girls outperformed West Indian boys markedly in most all subjects including English language, mathematics, and science subjects. The white boys outperformed the white girls but on a much smaller scale. The West Indian girls were in fact the highest performers of the four groups. The White boys came second after a large gap. The other two groups, West Indian boys and White girls performed equally. The high performance of West Indian girls is due in part to their culture. In rural Jamaica, the women rather than the men assume responsibility for the family's survival. This custom remains even after immigration to other cultures and it is reflected in the woman's superior academic performance (Brandon, Jordan, and Higa, 1995).

Further examples of culturally induced gender difference in mathematics can be seen in India. India is a developing country in which male dominance is the societal norm. A 1969 survey of Kulkarni, Naidu, and Ayra observed mathematical inferiority in females. Throughout India, mathematics is valued; however, a woman's education is not reflected in her dowry price. It is not economical for the woman to be educated and parents educate sons but not daughters. The only exception was found in the Mangalore region of Mysore State where females outperformed males in mathematics (Rogers and Kaiser, 1995), largely due to Mangalore's higher percentage of Brahmins in its population. The brahminical lingua, derived from the abstract Sanskrit, facilitates the easy learning of other abstract subjects such as Math. But more importantly, regions of India's southwest coast, where Managalore is situated, has a matriarchal family system in place that often promotes the causes of women. This environment apparently has encouraged women to outperform Mangalorian men in mathematics. In general, women are more competitive today than men because they have been kept down for so long. Women, through repression, have developed skills and persistence that enable them to be competitive now that many of these barriers have been removed.

In Papua New Guinea, the society is matrilineal and the women have more power than the males. In this society, the girls are treated with respect in the classroom as in society as a whole. In this environment the female and males do equally well in math. (Kaeley, 1988) There may be a question as to why the girls do not outperform the boys in this environment. I think it is due to the fact that women are not subjugated and thus do not have to strive to compete against the boys.

4.4 Social Effects Hindering Women's Success in Mathematics

In the Classroom:

There are several things that affect a woman's success in the classroom. The teacher plays a large effect in the success of the women. Many teachers assume that a woman will fail in mathematics, whereas a male will not. Several studies done in 1983 tested the performance of student when they participated in distance learning. Distance learning is a type of learning in which the teacher was separated from the pupil; students often submit assignments through the mail. These studies show the girls performance in mathematics equal to the boys, implying that the teacher as well as the classroom environment does have an effect on the student (Lancy, 1983). Teachers are known to call on males more than females in class, reducing the participation of the women and their voices producing negative effects as previously described with reference to Vygotsky.

Association of American University Women (AAUW) has done extensive research during the last two decades of the 20th Century. Their published findings include the following points in respect to math and science and gender:

- The gender gap in math achievement is small and declining. Boys are not innately superior to girls in quantitative skills: there is no math gene.

- Girls' math grades are as high or higher than boys, but boys are likely to outperform girls on standardized math tests (which ask questions of the male interest).
- Standardized tests are the gatekeepers to opportunity for students. However, a review of many standardized tests reflect gender bias in design and administration.
- Girls score better on essays, but boys score higher on multiple-choice exams.
- SAT scores underpredict college grades of girls and overpredict boys' grades in college.
- Scholarships that are based solely or largely on SAT scores go to boys over equally or more qualified girls.
- SAT verbal scores are higher when the subject matter is familiar. Boys do better on questions related to science and sports. Girls perform better on philosophy and relationships questions.
- Math confidence has a stronger link to math achievement than any other variable. As girls grow up, they lose confidence in their ability to do well in math. Studies have shown that girls' loss of confidence in their math abilities <u>precedes</u> a decline in achievement in the middle grades.
- Girls who do well in math tend to have nontraditional views of gender roles.
- The gender gap in science achievement has not declined. In fact, research indicates that it may be increasing.

- Boys have more out-of-school, science-related experiences than girls. This gap in experience continues in school, where one study showed that boys carried out 79 percent of all student-assisted science demonstrations.

- Girls and boys take difference advance science courses. Girls are more likely to take biology (less math); boys are more often to take chemistry and physics (with higher degree of mathematics needed).

- Girls who are highly competent in math and science don't choose related careers as the same rate as highly competent boys.

- Girls who pursue advanced math and science courses in high school and beyond report that teacher encouragement is a big factor in their continued interest.

- Girls who participate in career conferences or summer camps in math and science show increased interest in those fields.

- Boys who drop out of math and science courses tend to do so because they can't do the work. Girls who abandon those fields often do so even when they are doing well in class.

Single sex learning also relieved many of the pressures of the teacher effect within the classroom. It was found in Nigeria and Malawi that single sex learning was best for girls. In Malawi, girls entering college from single sex schools did substantially better in mathematics. The staff of a coed school expected less of the girls in the school, thus the girls did not do as well (Bradbury, 1991). At Chancellor College, women have no difficulty with the English class because they are expected to do well in it. They only have difficulty in the mathematics class, where they are expected to fail (Hiddleston, 1995).

At Home:

Many homes also do not give women the same support for school as they do for men. Females are expected to do many chores around the house at a young age. The male is expected to study. Women who live on campus and are relieved from their chores do significantly better than there Cinderella counterparts (Hiddleston, 1995).

In Society:

"Women's work, paid and unpaid, is often described as a 'double burden'. Frigga Haug (1992, p. 260) argues that it is more accurate to say that 'women are located in two areas with contradictory logics of time,' the measured time of paid work and then unpaid, and therefore unvalued, situations where spending more time is better than rationalization. And so, she suggests, a certain resistance to mathematical thinking may be part of women's upbringing in order to prevent schizophrenia" (Johnson, 1995).

In 1996, 6403 behavior questionnaires reviewing 915 supervisors (645 males and 270 females) were collected from subordinates who used the Windows-based *Teamview/360* software to share their perceptions. The results showed that people at work put more emphasis on what co-workers think than the traditional personnel review, which relies heavily on the immediate supervisor, thus emphasizing the findings that female characteristics of leadership are preferred over male characteristics. However, the researchers also found that issues of gender differences are a sensitive subject, often polarizing one's views, and thus, contaminating the objectivity of a study (Perrault and Irwin, 1996). If this logic carries into careers that come from the field of mathematics, which is highly dominated by males, the issues of gender become more challenging.

Wellesley University, an all-female school, boasts of outdoing its rival colleges when comparing its graduates with women graduates of coeducational colleges. By comparing women who have obtained positions in finance in senior corporate positions, Wellesley has produced proportionately more corporate women in high positions than any other university. Wellesley states that its culture of having a history of human rights that supports a culture of women struggling to succeed in a man's world is the reason for their graduates' successes.

PART 5 – CONCLUSIONS AND IMPLICATIONS FOR FUTURE RESEARCH

5.1 Conclusion

Mathematics is constantly evolving and coexisting with and around culture. Mathematics grows as our capacity for thinking grows. We use mathematics as a tool for thinking. It quickly became stabilized and, thus, gave the appearance of being a universal subject because of cultural necessity. Mathematics and rationality are fundamentals of communication; in order for people to communicate with each other, they must have a similar set of logic and rationality about the physical world. It was the forefront of communication and trade and was a tool to mimic the logical conceptions of our mind. Without this being stabilized, there could be no communication, no trade. It functions as the language of our thought process, in effect a language underneath our traditional spoken language. We created mathematics in the image of our logical brain thought, just as we created a god in the image of man. Both were based on a leap of faith and common assumptions. Both were adjusted as necessary through culture. As our needs and conceptions changed, so did our image of God, and so did our image of mathematics. Cultures take what they want from mathematics, just as they take what they want from God. Just as in language, we see that each culture stresses that which it needs most. We see how language is affected by culture. For example, one culture may have 100 words for love, whereas another culture, in particular, the Inuit, have thousands of words for snow, snow being a huge part of their everyday life. But just as language is affected by culture, so is mathematics. We notice that Egypt wrote all of its factors by units above. Perhaps that may signify that the Egyptian culture is more individualistic.

We see also many cultural influences on the way mathematics is studied. In our everyday thought, we are reminded of the Chinese abacus, and how different cultures study mathematics. Some cultures prize rote memorization and are concerned with a strong foundation of the basics whereas other cultures are more concerned with the more theoretical aspects of mathematics and don't care what calculator, computer software, abacus, or other aids are used to get there.

Another main cultural aspect of the way mathematics is studied is the impact of gender within mathematical study. Women have gone in and out of mathematical history. While women were never encouraged to study mathematics, with the exception only of maybe now, there were times when they were not strongly discouraged. We see the impact and remnants of this discouragement of women to influence and pursue mathematics strongly even in today's culture. Some schools are now implementing single-sex mathematics classes to allow girls greater opportunity to respond equally to questions that males typically were selected to answer (New York Times, 1994).

5. 2 Recommendations and Implications for Future Research

Various reasons have been proposed to account for the indisputable, widespread fear and dislike of mathematics by women. Other reasons are more generally applicable to groups in our society who miss out – all are variations, more or less sophisticated, on the theme 'you must have been away at some point', or 'you must have had a bad teacher', or 'perhaps you thought it was unfeminine', or 'maybe you haven't got a mathematical mind'. And while all this weaves into the complex pattern that is our experience, perhaps we don't take seriously enough the voices that say, again and again, 'but it doesn't make sense', and 'what's the point of it?' Perhaps what they are saying simply is true. Perhaps mathematics, their mathematics, secondary-school mathematics, doesn't make sense. Perhaps the fault is in the mathematics, and not the teaching, not the learning, nor the people. At the very least, it is a question worth focusing on for a while. (Johnson, 1995)

Mathematics is a form of stabilization, since the answers always come out as they are expected, as it is a field based on definitions and logical implications from these definitions. People with borderline personality behavior need an immense amount of stabilization in their lives to counteract the lack of stabilization in their heads or childhood. Perhaps studying mathematics could help stabilize people with borderline personality behavior. Research in this area could have potential findings for borderline personality behavior.

Recommendations for Teachers and Administrators of Elementary and Secondary Schools include 1) being prepared and encouraged to bring gender equity and awareness to every aspect of schooling; 2) having a curriculum that values and respects the experiences of women and men from all walks of life in the material presented to the students; 3) actively supporting girls to understand the relevance and importance of mathematics to their lives and future career opportunities; 4) securing girls and women to play a central role in educational reform in every aspect; and 5) reassessing the standardized tests and how they are used in identification and selection of academic scholarships and mathematics-based educational opportunities.

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