

Connecting Elegance and Eloquence to Make Mathematics Memorable

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We refer to a soundly constructed mathematical solution as “elegant.” We refer to a finely crafted verbal argument as “eloquent.” In either case, with numbers or words, expressions and equations, or phrases and sentences, we are at root talking about logical, organized communication. If we can find the string that connects these two tin cans of thought, we can pull a bit tighter and we will be better able to listen and speak to the learning needs of our students.

Overview

It is often accepted as fact that some students are just good at math and other students are just good at English, and that is just that. Not only is this not a “good at teaching” generalization to make, it also “just” lacks a sustainable argument. To be perfectly honest, early on as a teacher and years ago as a student myself, I, personally and often, considered and fell into and out of acceptance of this generality – that people simply have either more literary or more mathematical strengths. On the surface it is an easy and tempting proposition to accept.

Even though there is not a total separation of math and language abilities in students, there is often a large, easy to see division in students’ interests. By their high school years many students tend to form preferences that are biased either to math and science or to language and arts. Students also often see themselves and their abilities through a prism that is biased in this way, telling us, their math teachers, in the first days of a school year that they are either “good at math” or “bad at math,” that they “like math” or “don’t like math” with a tone of finality. The students who say that they are “bad at math” and “don’t like math” are sending a message that takes on a perspective of fatalism, which can be very difficult to overcome. We should keep this phenomenon in mind and try to teach students by directing our instruction to meet perceived strengths and weaknesses – part of which is facing realities of their preparedness and attitudes toward learning in our subject area. But ultimately, would we really be helpful to our students if we were to take their generalizations – of being either “good at math” or “bad at math” – or as being either “good at English” or “bad at English” – and leave it at that?

I use this rhetorical question with a purpose. Based solely on the way I pose the question, my answer should already be obvious – I am making the argument

that as teachers of mathematics we cannot accept so simple of a generalization. I'd go so far as to say that any teacher taking the time to read this could already tell that my answer is "No, we cannot leave it at that."

What is interesting about this certainty – that my rhetorical question is so obvious – is the fact that it is not based on scientific or mathematical proof, but is based simply and implicitly, on the language that you (as the reader) and I (as the writer) are using to communicate. Based upon the "tone" and "feeling" of my writing (which is after all "just language") I can have confidence, on the level of empiricism, that you, in your reading, "get what I'm saying." The fact that a rhetorical question can be used to make a statement – that I can pose and answer a point all inclusive of asking a rhetorical question – speaks to the logical nature of language and exhibits a connection to the logical nature of mathematics.

As math teachers we are often cast in a "cold, hard facts of math" role. The "art of language" is popularly considered the furthest thing from the "science of math" and many math teachers really find language studies, let alone literature, too variable to embrace as the means of clarity, certainty, or comprehension. I understand this purity of skepticism, but I also think it is far too limited. Math is well served by being limited in the way it is meant to be limited – to bar inessential or subjective details from consideration within specific studies and problem solving. But we have to avoid speaking out of both sides of our mouths. Math is poorly served when, even as we espouse the notion to students in our classrooms that "math is in everything and part of everything," many math teachers still draw a line, figuratively speaking, at the door to the college of humanities in their consideration of "everything."

Students today live in a language-saturated world, with a growing tendency toward verbal and truncated text communications. If people had difficulty with math before because of not understanding the way in which it was explained to them, our students, and students to come are going to be at a true disadvantage without some serious consideration of the interaction between language and mathematics. We cannot effectively teach mathematics to students without addressing relevant communication skills that are essential to their skill development and application. I would go so far as to counter that by purposefully addressing language aspects and utilizing literature, we can be far more effective in teaching mathematics to our students.

Beyond being a tool in my thesis development of this paper, a rhetorical question is a poignant way to open exploration of the road between language and mathematics. Rhetoric, as a field of study and as a historic form of human lingual and logical art, stands alone to support any anecdotal remarks I can make as to how mathematics and language are joined at the hip.

The practice of asking and responding to rhetorical questions was classically among the same skills as providing logical proofs to geometrical conjectures and developing algorithmic ways of solving problems. We often attribute rhetorical skills to ancient Greek figures like Thales, Pythagoras, and Euclid – names synonymous in academia to the sources of our knowledge and practice of mathematics. The writings of these figures are as filled with concerns of social order, aesthetics, and literary virtue as they are with mathematics. We can shift to more “to-date” references and writings by Einstein, Asimov, and Carl Sagan and find that they too are as concerned with humanity and finding beauty as they are with pure science and finding truth through mathematical principles. The fact that from these greatest names in math and science we find such application to humanities suggests to me that our dissection of mathematics from language and literature is actually more of a vivisection of what ought to be naturally living together in a whole body of knowledge and skills.

Of course there is use and reason in categorizing academic studies, as well as in categorizing aptitudes and interests that students may have for one realm or another of thought and skills. But, even if we do not all enthusiastically approach interdisciplinary instruction, it is at least the better part of dividing the house of academia to not treat reference to other content areas as counter-productive to instruction. As a primary reference for many approaches to adapting instruction for students, both in an interdisciplinary sense and in a multi-representational sense of math, I subscribe pretty closely to Gardner’s Multiple Intelligences.

Howard Gardner, a contemporary cognitive researcher at Harvard, developed a categorization of realms of cognitive ability, which covers the majority of aptitudes that people have as learners and students. The categories are treated as independent of one another. This may seem to set them apart as unconnected skill areas, yet, because they are set independently, being strong in one category does not necessarily indicate that there is a strength or a weakness in any other area. There is neither a direct nor inverse relationship between aptitude or interest in any two of Gardner’s categories, although we may be inclined to associate some of them more closely than others. Gardner’s list has been adapted and modified in a number of ways, but in its common composition it consists of seven “intelligences:” spatial-visual; bodily-kinesthetic; interpersonal; intrapersonal; musical; language-linguistic; and mathematical-logical.

As educational professionals we can delve into Gardner’s theory of Multiple Intelligences as a means of considering the unique aptitudes of our students and even introduce them to these categories as one possible tool of self-assessment. As classroom teachers who are trying to manage the myriad known and unknown facets and factors of our students in the tumultuous climate of public schools,

however, we also need practical strategies for teaching all of our students, in all of their relative strengths and challenges, in a reasonable amount of time. I am suggesting a compromise between the generalization I have already rejected above (“good at math” v. “good at English”) and the ultra-in-depth specification of each student that Gardner’s categories might provide. As such, the two areas from Gardner’s groupings that hold the greatest interest for my argument are, naturally, language-linguistic and mathematical-logical.

I won’t refer to these “intelligences” so much as have their basis in mind as I use four main categories to consider students within lesson planning and classroom activities that can be beneficial to each and all of them. These categories are somewhat superficial in that there is a spectrum of skills to be considered (and a spectrum of spectrums of skills), however, for practical purposes, it can be quickly and not inaccurately useful to recognize that some students do well with most numeric content and most linguistic content, others with most numeric but less linguistic, others with less numeric but most linguistic, and still others with less numeric and less linguistic. I’ve termed my four categories respectively: Math Strong/Language Strong; Math Strong/Language Deficient; Math Deficient/Language Strong; and Math Deficient/Language Deficient.

As a teacher I have known students who have “whole brain” capabilities and defy the one-or-the-other stereotype of mathematics v. language skills. They would be considered Math Strong/Language Strong. I have had students who can work through equations, graphing and other representations, but are confounded by word problems and/or tasks that require written responses. They would be considered Math Strong/Language Deficient. I have had students who only seem comfortable working in context of language and cannot usually approach purely numeric or graphic tasks with confidence. They would be considered Math Deficient/Language Strong. Finally, I am certain that as teachers we all also know students who struggle in both general subject areas – and who have particular difficulty connecting the two realms of math and language skills for use in solving problems. They would be considered Math Deficient/Language Deficient.

It is my assertion that students of each of these four ability groups can benefit from the adaptation of mathematics by means of including language and literature content in the curricula in creative ways. Perhaps the most creative of which is to call into question for our students what exactly it is that we call “math.”

In one sense, by relating mathematics to literature we are treating it more like an art – to be used expressively, to be articulated, and interpreted on a personal level of meaning. In another sense, not taking mathematics for granted and placing it under the figurative microscope of language, we are treating it more like

a science – to be considered, discussed, and objectively organized before the student is rashly thrust into conducting experiments with it. Ultimately, as an art, as a science, or as both, the real power of linking math and language skills is that it is expected to produce deeper conceptual understanding and more enduring retention of knowledge. The principles and foundations of mathematics need to be more firmly impressed within the conception of students if they are to be successful in their study of the subject, the most profound and basic tool for making this impression may be language.

From the perspective of a high school mathematics teacher, I want to help all of my students understand the usefulness and appreciate the diversity of math. In trying to help them learn, I must rely on the expectation of a certain level of prior knowledge in both the math and language skills of my students. However, this expectation has always to be tempered with aforethought to retention issues that students exhibit for math knowledge and skills learned in earlier years. Students don't always arrive knowing what they should know, or at least don't have the recall or ready recognition of skills that we hope for them to have in order to succeed in our course work. So it is for all other grade levels, as well as those that I teach, that I encourage development of "mathematical literacy" to "make math stick." To promote this agenda, a teacher must have deeper conceptualization and greater understanding of what mathematical literacy means and why it is so important for students to attain it.

Rationale

The major objective that I will identify below is simply to make mathematics more accessible for students. Too many students look at the tasks set before them in math courses (or are so apprehensive that they hardly look at the tasks) and feel helpless and ill equipped to accomplish, or even understand, what we are asking them to do. Even students who, based on their cognitive capacity and prior knowledge from earlier school years, could handle most or all of the assignments in a high school course, are often limited by fear of making mistakes and a self-fulfilling prophecy that they cannot understand math. If only they gain a sense of ease and comfort with the overarching realm of mathematics, they will readily learn, retain, and be able to apply more skills, more frequently. What students need in order to have this ease and comfort, while it might be considerably tricky to obtain, can be summed up under the notion of "mathematical literacy," which, aptly, sounds like a blend of math and literacy.

Mathematical Literacy means more than "numeracy" or merely comfort with numbers. If we took "literacy" to mean only "the ability to use words" then this definition might suffice. However, the concept of what it means to be literate goes further, to suggest a competency and access to the use of language. In this sense,

mathematical literacy means “competency with mathematics” – a definition that encompasses not only the ability to use math skills, but also the broad ability to make choices about when and how to use skills from the wide range of skill sets that fall under the heading of math.

Several definitions of mathematical literacy have been very helpful to me in thinking and planning what I’d like to help students achieve and how I can go about doing so. The two definitions below, from different academic writings, are particularly strong guidelines for what is goal-worthy in math instruction.

Mathematical literacy is not about studying higher levels of formal mathematics, but about making math relevant and empowering for everyone.ⁱ

Mathematical literacy is more than numeracy; it is an individual’s capacity to identify and understand the role that mathematics plays in the world... To achieve mathematical literacy, changes must be made to the traditional math curriculum. Students should approach problem solving from different perspectives that require their full range of knowledge.ⁱⁱ

For a fuller perspective yet, the hilariously sardonic opening to an article by James O. Bullock provides an example, in and of itself, as to the merits of using strong literature to convey meaning to a student (in this case me).

The immediate cause for the recent concern about mathematics education is the widespread difficulty students apparently experience with this subject. While some educators have expressed an interest in improving pedagogy, students have tended to opt for a more practical approach whenever it has been open to them: avoiding the subject altogether. Predictably, the reaction of the educational system has been an attempt to force students to learn mathematics anyway. The mandate to hold students’ feet to the fire has been carried out with varying degrees of resolve, the debate over how much pain to inflict being dominated by two conflicting lines of reasoning. According to the first ...since it builds character, everyone deserves their fair share of suffering. Those determined to adopt a more merciful attitude, ...argue that the dose of unpleasantness should be limited to what is absolutely necessary. ...Within most curricula, mathematics has been so thoroughly dissociated from all other subjects that students generally encounter little evidence [that math is ever relevant outside of academia].ⁱⁱⁱ

Although Bullock was writing a decade and a half ago, his argument has lost little relevance for me. There are most certainly some efforts to enliven mathematics for students, but they tend to reek of turpentine and resemble more

of a Frankenstein's monster reanimation of dead tissue than they do an organic introduction of math's natural connection to the world students live in. In all fairness, our own curricula in Pittsburgh Public Schools has recently introduced a number of activities and tasks that model observable, real world phenomena. But they are limited in that the language tasks they contain are all implicitly posed – taking for granted student communication skills rather than developing them purposefully. These aggrandized word problem tasks also have sequences of numbered problems and writing prompts that lose student engagement due to repetitive (to students, seemingly redundant) questions and tasks. A greater element of literary quality, that invigorates the presentation of information and introduction of activities, could go a long way toward mitigating student resistance – simply by peeking their curiosity.

Curiosity is, ironically perhaps, the centerpiece of the argument to employ more literary elements in mathematics instruction. Although it may have killed the cat... it taught other cats how to survive. Still other cats, in the beat, Ginsberg sense, have been guided by curiosity to live quite well in this world. How free and public education has become the pop-culture image of overbearing, restrictive institutionalism and the repression of curiosity is beyond me. Maybe some mix of cultural and generational gaps have led to what looks and feels like, as Bullock alludes to, a general malaise in the learning that takes place in schools today.

While there are driving goals for our districts and buildings, they have a tendency toward standardized test scores, at any cost... which inevitably peaks my own curiosity... when will these students ever again in their lives beyond academics take a multiple choice test that has a legitimate bearing on their present and future well-being? This obviates the motivations behind standardized testing – a quick, cost-effective means is needed to make sure that everyone is doing the same thing in the same way... as history so clearly shows to be a great plan.

All sarcasm aside (although it too can be a rhetorical tool) the alternative is legitimate open-ended tasks. We should be employing more and diverse problem solving models and high quality, literately posed word problems that can only be answered through rigorous reasoning on the part of students. Some good efforts have been made to decant the elixirs of math for our students, but we still are not teaching in a way that truly prepares students to be successful with valid and applicable-to-life tasks. Math imitates the test, or the test imitates math? Either way, both mathematics and the testing process have been removed a number of steps away from life, not to mention art. We need to stop accepting imitations.

I have encountered a general resistance from others to the notion of employing literary elements in math classes when I have done so in the past. I have opened lessons with short, relevant reading excerpts for discussion, riddles that promote

lateral thinking, activities in which students generate metaphors for a mathematical concept, and considerations of the etymology of mathematical terms. On several of these occasions, other teachers, administrators, and students have alternately posed the general rebuke “when do you get to the math?” I believe that this follows from the same tendency that leads to making highly generalized stereotypes about student abilities. To many people, even connected to academia at any level (especially at higher authoritative levels it seems), math simply means “numbers.” And, when they are presented with communication and interpretation tasks that do not immediately and explicitly contain numbers and operators (+, x, etc.), they believe that this is some kind of distraction from what math is really about. In my experience, a distinct cohort of people has reacted as though the “real work” of math study is not being accomplished. Other reactions from teachers and administrators have suggested that they see the use of literary adaptation as avoiding the rigorous, hard work that, to them, defines math as a subject (the “fair share of suffering” that Bullock mentions), or that bringing in supplemental elements is an unrelated, unearned reward for students.

Because of this, I think it is highly important to make these three distinctions about the practice of using literature and language that I propose as a means to adapt math instruction: it is not a practice of altering the true content of math curricula; it is not a process of “dumbing down” math studies for struggling students; and it is not a system of indirectly rewarding students for their engagement and effort with assignments in mathematics.

Much to the contrary, the use of literary content, concepts, exercises, and skills to adapt math lessons is a practice of: fortifying and supporting student attainment and retention of the content of their math curricula; adding depth to comprehension and rigor to the activities in math studies for students of all achievement levels; and inducing student motivation via intrinsic interest within math assignments.

Unfortunately, misconceptions about using non-numeric content in math classrooms can still be problematic for a teacher if an understanding is not established among administrators, fellow teachers, and the students themselves. The message, therefore, needs to be explicit that literary adaptations made to mathematics courses are very purposefully directed toward desired student achievement – and that they are strongly supported by research. The number of published articles that I found, which promote literary adaptation to math, seems to suggest it is a fairly accepted strategy to improve math instruction.

Fortunately, this necessary understanding in the environment of the school can be obtained fairly quickly. First, through a common sense consideration of student needs at each level of student ability. Second, through a pedagogical consideration of some of the more accessible writings available on the subject of

using language in math studies, which support the focus on developing “mathematical literacy” – a level of math competence that can best be achieved by using a language and literature angle to instruct mathematics.

Common Sense Consideration

For each of the four categories of student abilities I defined above it is a basic truth that strengthening their language skills will contribute to strengthening their mathematics skills – because we use language (in spoken communication, in written instructions, in problem situations and word problems, in textbook readings and assignments, and all other imaginable means) as a major vehicle for prompting and assessing student math work.

Math Strong/Language Strong

Students whom we may consider strong in both language and mathematics skills often seem to handle course curricula with little or no difficulty. These are the students who we expect (or at least dream) to have in our classes – grade level competence in reading and writing, enough number sense to quickly perform basic operations, and preparedness to deal with the new and more complex concepts and skills that we are introducing them to in our courses. Sadly, sometimes it seems like these students skip a generation (or a year at least) and we don’t have them in our classes consistently. This may be due, in part, to the same “good at math” v. “good at English” generalizations I mention above.

The challenge that we face with students like these is keeping course work challenging enough to positively motivate them, while avoiding simply giving them “extra work.” These students can benefit immensely from our incorporation of literary concepts and tasks into mathematics curricula. The challenge of using their breadth of talents altogether suits their skill development needs.

Far from having assignments “dumbed down” or diluted with literacy and language tasks, there is an opportunity created for these students to shine and produce more robust work that encourages them to develop and to articulate their deeper understanding of what is being studied. From a classroom management perspective, giving these students an assignment in which they must, for instance, analyze and write a reflection upon how they first interpreted, then approached, and finally solved a mathematical problem scenario, will constructively occupy them with more rigorous concerns (not give them “busy work”), while students who are struggling with the operations needed for the solution can be further assisted by the teacher.

Math Strong/Language Deficient

For these students the trick is that, with the exception of the math classroom or laboratory, math is not encountered in life without an accompaniment of language and complex meanings that must be interpreted. These students can be a joy to have in the math classroom because they seem to “get it” quickly and can process many raw math exercises. Subtle issues may arise, however, that make these students’ challenges more obvious. They may perfectly perform operations or skill tasks that they were not instructed to – or they may wholly arrive at incorrect solutions or answers due to not understanding or following instructions. When this occurs, even those who seemed the strongest of math students may begin to consistently perform poorly and/or become frustrated to a degree that hurts their motivation and interest in the subject.

Their difficulty is most obvious and identifiable with word problems. Even in the case that there may be only two numbers present in a paragraph of context and problem scenario, these students may mistakenly use the wrong operation(s) or entirely miss what it is that they are trying to solve or find.

The introduction of language and literacy aspects is essential for these students to practice at and improve in interpretation and translation of verbal and textual information and instructions into the efficient and accurate operations and skill in which they have already found an aptitude. Their need of literacy, within the framework of mathematical literacy, is most acute and the benefits of providing them linguistic exercise as part of a math curriculum are innumerable.

Math Deficient/Language Strong

This group category may be the most broad in terms of their composition of skills. They may be fairly proficient with basic operations, but unable to decide when or how to use them. They may just be so hampered by numeracy issues such as the concepts and notation of fractions and decimals that they never have the opportunity to deal with the problems and exercises in which these numbers appear. They may have issues with number sense so deep that they still count with their fingers (you, the reader, are either nodding knowingly or shaking your head in disbelief that this can be the case with a significant cohort of high school students – but it is quite true). Almost without exception, a major issue for these students is their self-confidence with math – they do not feel or believe that they can be “good at math.”

What these students do feel good about is their language skills. They are usually much more comfortable with reading and writing assignments, as well as

discussion of concepts, than they are with tackling a list of equations to be solved for a variable value. In my experience, teaching primarily mainstream Algebra 1 and Geometry courses, this has been the largest identifiable group. Again, they are diverse in mathematics skills, but their preference and stronger interest in “English” has been common and openly expressed.

With these students there is a strong opportunity to use their interests, aptitudes, and motivation to work with literature and language as a vector for introducing mathematics to their comfort level. Literary materials and tasks that make metaphors for mathematical concepts, reading excerpts from stylish writing with inclusions and allusions of mathematical terminology and/or principles, and writing exercises that require them to creatively express their study of math are all avenues toward their attaining an understanding and appreciation for the subject.

Math Deficient/Language Deficient

Here is where, as educators, our work is cut out for us. The specifics for these students are case-by-case and, as a categorization, I would reserve this mostly for students who have a combination of the lesser ability levels addressed above, under “Math Deficient/Language Strong,” retention issues (with difficulty carrying one concept into the next, no matter what logical bridges might seem obvious to instructors) and communication issues (with difficulty explaining what efforts they have made with a problem or why they have made any of the choices that they have made in those efforts).

The most difficult part of instructing these students is that it is often unclear how to help. Both our own observations and their abilities to express what they are having trouble with are wanting – neither we nor they know exactly how to ask what the problem is. There is the most serious need of adaptation in the instruction of these students, but the primary issue is likely to be that of communication. All of our efforts to help these students with mathematics may well be for naught if we don’t first establish a common language by which to understand each other in the mathematics classroom.

For these students, the more emphasis we can give to language, the better. Their needs in the math and language realms of skills are in need of mutual development. It is also the to-be-hoped-for outcome that prompting them with this differentiated instruction will help clarify where some of the more serious hang-ups are in their retention and skill application. It is not simply that we can use language and literature to more effectively teach them a specific curriculum, we can learn to more effectively teach these students “to learn” in a general sense by engaging them with more diverse tasks and observing their performance for clues to what is most challenging for them.

Pedagogical Consideration

Beyond anecdotal evidence, there is a strong drive, among many teachers of mathematics, to change what is not working in traditional math instruction. The 'rythmatic [sic] third of the classic "Three Rs" is not doing the job for our students. Math studies can be significantly strengthened by a blending with the other two-thirds of the traditional American education model, reading 'n 'riting.

A recent study in cognitive science shows a strong independence between numerical reasoning and language ability in the human mind. The brain is able to manipulate and work with numbers independent of using speech, writing, or any linguistic factors.^{iv} This might seem to suggest that language and mathematics are disassociated for learning purposes. This may superficially divide the two realms of organizational thought, but at the same times it supports the independent categories of Gardner's intelligences and does not preclude the positive reinforcements that can be achieved between math and language studies. It also provides an insight into a type of common occurrence that I have often seen with students, especially of Algebra, and have had other teachers of mathematics relate to me about their own classroom experience.

We often have some students who are typically very comfortable with mathematical skills but are stopped in their tracks by a word problem – or some students who are not comfortable attempting a raw skills math problem but are able to quickly interpret and correctly find the solution to word problems. These students I have defined as Math Strong/Language Deficient or Math Deficient/Language Strong. The former students can "work the numbers" but are tripped up by the language, the latter students can extract the meaning of the problem situation and correctly find a solution, seemingly intuitively, but are not always able to articulate what math skills they used or why. In either case, there is a break between what they are able to do and what they are able to communicate about doing. In both cases, all of the necessary abilities are evident in the students, but at alternate levels and in different forms. These students, who may have long been disparagingly considered exclusively "good at math" or "good at English" would be better considered and instructed with the intention of working from their "stronger" realm toward improving their "more challenging" realm.

There is further variation in student skills based on what part of problem solving we might consider. The language abilities are perhaps more complex because they involve both the input of the problem situation (reading, listening) and output of the solution (writing, speaking), while the math involved, whether very simple or complex, is more often a linear process moving in one direction from given information to solution(s). This means that there may be issues with knowledge and skills in either direction of the language processing, and/or issues

with any number of mathematical processes, depending on the nature of the specific problem at hand. Any combination of these issues calls for a similar pedagogical remedy – language skill improvement and direct, explicit application of those skills to the study of mathematics.

Working from this cognitive research application to the subject, it is possible to craft some strong arguments to dispel the three major misconceptions about literary adaptation of math instruction noted above. Breaking these down as unique issues should help to more precisely rationalize against them. It will also lead my narrative into strategies for implementing literary adaptation.

Misconception: Literary Adaptation Alters the True Content of Math Curricula

The sheer volume of teaching texts, pedagogical articles, and educational theory writings that promote literary adaptation of math instruction should go far toward eschewing this misconception. Even a casual Internet, journal database, or library query will return a bulk of diverse sources of support for “using literature to teach math.” In her online journal submission to the Department of Education’s ERIC database, June Lundy Gaston specifically discusses children’s literature as a tool for teaching mathematics,^y but the ramifications expand to other forms of literature and higher student grade levels.

Gaston cites the NCTM conference of 2000 in her premise that, since students inevitably use language to learn in their study and prove their knowledge in assessment of math skills, “students need to be able to read, write, speak and listen in mathematical terms.” This means not merely using language as the unavoidable device for mathematical learning, but making the way in which language is used to learn and express math an explicit component of math studies. Gaston cites significant additional educational research findings that suggest not that we change what we teach in math, but rather that we should not continue to take for granted what is at the heart of our mathematics teaching.

Language and its use relative to mathematics is true content of all math curricula already – the question is not whether this content should be “added” to instruction, but how well this content is being instructed already. The answer is that this content has been taught in a largely negligent way when it has not been a focal point within the classroom. This line of thought leads directly to proposing mathematical literacy as a goal for students.

Previous publications of the Yale National Initiative have articulated this goal within the context of word problems that are developed and employed in mathematics instruction. Roger Howe of Yale states that word problems should not be considered a separate topic in the curriculum because they play a central

role in the curriculum. Following this logic, Howe expands the definition of mathematical literacy and exemplifies the argument that literary adaptation is not an alteration of math content.

There is no substitute for careful reading and understanding. Particularly with multistep problems, ability to read and understand and translate into mathematics is essential, since the proliferation of possible problem types easily outstrips efforts at classification.^{vi}

This statement from Howe contributes to proving that literature and language are not invasive species in the land of math. They are in fact aboriginal natives to the logical interpretation of the world in mathematical terms. In so much as mathematics is a form of communication and the use of mathematics relies on a fluid comprehension that must deal with problems that are not pre-defined or categorized within the established canon of math knowledge, the ability to “talk out” a problem with language is absolutely fundamental to math.

An example from Howe’s article of how adaptation might be incorporated to strengthen, rather than change, the content of math course work is what amounts to the application of comparative literature. Students could be asked to analyze two versions of the same basic word problem and write a comparative statement about the phrasing, style, clarity, and quality of each of the versions. This would create the opportunity for students to self-evaluate their understanding. And, since through this activity students would be proving their ability to interpret language in mathematical terms, it would also put them into a position of personal accountability for whether or not they “get it” when reading a word problem. The clear motivation here is to improve instruction of the core concepts and skills that make up the various mathematics curricula within our education system – not to distract from or work against those curricula.

Misconception: Literary Adaptation is a Dumbing Down of Math

The two most prominent points I have to make here are that: making mathematics accessible to students does not equate with making math studies less rigorous for students; and using significant ratios of verbal materials to numeric materials does not dilute the content or rigor of mathematics course work.

Literary adaptation to mathematics is not a dumbing down, but a smartening up of instruction. For a number of reasons it is particularly damaging to take language for granted in mathematics studies. An excellent resource of these considerations is a free, well-written, and easily down-loaded text, *Teaching Reading in Mathematics*.^{vii} This book is unencumbered by any theoretical aloofness of the classroom environment – in very straightforward language that represents real teaching, it provides a summary of supporting research and

recommendations for useful and helpful ways to, as the title says, “teach reading in math.” Among its most critical arguments in justification of taking the time to address literacy in mathematics are: math texts contain more concepts per word, per sentence, and per paragraph than any other kind of text; math students are required to shift their decoding of what they read from language to symbolic figures and back again to language frequently; students have habits of scanning pages of math text looking for quick examples, graphics, or numbered exercises, often missing crucial information from worded passages and skipping actual instructions; students are anxious to learn the “how” of math skills and need guidance in their reading and communication in order to appreciate and understand the “why” of the math skills that they are developing.

Many educational professionals could read the points in the paragraph above and still be perturbed by the notion of using some forms of literary adaptation to mathematics. Because the above seem more like technical details of language, which have an inherent comfort level in most people’s general concept of math, they may be ready to accept this type of adaptation – while something along the lines of poetry or a fiction excerpt in a math classroom still feels unjustified. If there are still doubts as to employing literary exercises beyond the most pragmatic, utilitarian means, I would ask: Given a curriculum component of learning (for instance, the commutative property of multiplication in an Algebra 1 course), is it less rigorous for a student to read a brief piece of engaging literature that develops a mathematical concept and then write an explanation of her or his understanding of that concept using points from the reading?

The commutative property of multiplication could be written, as is often the case, in abstract form as $(a * b = b * a)$ on the chalkboard and reiterated in several examples of the form $(2 * 3 = 3 * 2)$, but, while this may be readily understood in that moment, it lacks a connection to any purpose. It is easy to understand, but it does not immediately lend itself to usefulness. Without applicability, it therefore runs the risk of being forgotten at a later time when, for instance, the student may need the flexibility of thought to recognize that the variable “x” times two ($x * 2$) can be equally expressed in the simplified form $(2x)$ – or when the concept of commutative relationships can be applied to inform students of the subsequent associative property of multiplication. Also, perhaps more basically, without the expectation that students articulate their understanding of a concept such as the commutative property of multiplication, via some language skill application, we would be hard pressed for a viable method of assessing students’ conceptual development. Their mere repetition of a series of symbols that their teacher has written is not proof of comprehension, let alone application.

Misconception: Literary Adaptation is a System of Indirectly Rewarding Students

This consideration may be largely mitigated by many of the statements above, but I believe it is worth a brief rationalization: in part because of my own experience with administrators and colleagues who have questioned my use of literary adaptations on the basis that student activities “did not seem focused;” and in part because, as Bullock states, many education administrators seem to see mathematics as a study that is only being taught correctly when pain is being inflicted upon the students (albeit to an unknown motive or application).

The concept and practice of using rewards in education is hotly debated, yet ever-present in many school environments. One negative take on rewards is that of the reactionary: “These kids are soft, we didn’t get a pat on the back every time we did something right – we got a smack if we did it wrong!” A more legitimate negative view of rewards is that they can actually be detrimental to student motivation and achievement when they induce a sense in students that the only reason to engage with and give effort toward a learning activity is for the sake of the reward itself.^{viii} This and other research results presented in an outstanding article from the American Federation of Teachers quarterly, have convinced me that the “blowout” reward systems in place in many schools are an artifice that cannot be maintained without hugely negative consequences in the near term.

The three key guidelines proffered in this article are: find an alternative; reward only for specific reasons; and use rewards only for a limited time.^{ix} I believe that literary adaptations to mathematics answer to the first of these guidelines by finding a route other than the ubiquitous pizza party to generate student engagement with math. However, in this same breath, what literary adaptations can do that may lead to the misconception that they are an extrinsic reward is make the mathematics study far more intrinsically interesting. The sheer shock and awe of students involved in activities that shake up and conceptualize math with the use of literature and language can be too much for those with a “math is numbers, period” attitude.

While I hope that many of my arguments obviate the fallacy of this attitude, it will still need to be addressed by teachers who creatively adapt. So a firm reliance upon clear goals in literary adaptation is prerequisite, as objectives always should be, to beginning any type of lesson planning.

Objectives

The key features that denote quality in writing are simplicity and clarity. So, I will try to state the four main goals I have for using literary concepts and skills in my mathematics instruction as succinctly as possible. (PA state math standards are addressed in the corresponding appendix)

First and foremost, I aim to improve the accessibility of mathematics for students in my Algebra 1 and Geometry courses. I expect to help students that I have termed above as “Math Deficient/Language Strong” in particular, as they are the largest group I have worked with and primary candidates for the potential success of adapting mathematics content with language and literature content and concepts. Nevertheless, I expect that through fulfilling this first objective I will be enriching the content and rigor of the courses for every student that I teach.

Second but not secondary to my first goal, I aim to improve both student numeracy and mathematical literacy. It is not merely my intention to bridge a gap that exists between students’ comfort with language and literature and their discomfort with numeric/symbolic structures and mathematical expression. I expect to also help students achieve a confidence level with the numeric, symbolic, and graphic language of mathematics, which they can retain and carry forward in their math education – as a knowledge and skill set related to the realm of language, but also as a set distinctly belonging to the realm of math.

Third and to extend the prior two goals, I aim to guide students in developing an evermore robust connectivity between their mathematics and language studies. As they progress through academia and life beyond their formal education, I expect my students to continue to see that logic, if it were personified, is an embodiment of what anthropologist Joseph Campbell called “The Hero with a Thousand Faces.” Whether they see truth emerge from math, literature, visual arts, music, observations of nature, or any other category of human endeavor or experience – I want students to have a sense of the eternal logical connection between mathematics, language, and these many, seemingly disparate mediums of expression.

Fourth and forthwith, I aim to use my experience in employing these lessons and activities, both the successes and challenges that I meet with, as a springboard for continued efforts to introduce progressive interdisciplinary theory and adaptations to traditional mathematics curricula. To do anything other than “adapt” teaching methods is an affront to both the evolutionary quality of language and the logical progression of the study of mathematics.

Strategies

The strategies that are most appealing to me are ones that creatively engage students with intrinsically interesting reading and writing tasks, while retaining the value of the mathematical content necessary to promote skill development. Before moving into two specific classroom activities, it may be most fitting to organize strategies for literary adaptation in the style of a form of literature itself, journalism. We so often “de-humanize” mathematics that we easily forget that the field of math study is a viable “human interest story,” complete with its own accompanying: who, what, where, when, why, and how.

Who: Our Students

Students’ interests, especially adolescents, are somewhat slippery, but not intangible. They are as diverse as can be – though we do not always, especially in mathematics, get the opportunity to find out what they might find most engaging. Knowing the students, like knowing one’s opponent in Sun Tzu’s philosophical text The Art of War, is a necessity. Luckily, it is possible to count on the fact that high school students (and younger students to an even greater degree) are still open to become interested in topics and literature that will also introduce them to mathematics in a palatable form.

A real strength can be gained from the considering the “who,” prior to considering the “what” and “how” of implementing literary adaptation in mathematics. Knowing what students are already reading and absorbing from literature in their English and social studies courses can offer a variety of literary topics that can be related to math curricula. This follows the basic interdisciplinary models prominent in middle school education – which can be highly effective within high school environments as well. For instance: last year students were reading Upton Sinclair’s The Jungle for ninth grade English, this can be an opportunity to introduce students to exponential functions through a consideration of immigration and population growth; or, while introducing the application of ratios and proportions to freshmen students who are currently in a civics course, the concept can be presented in a robust form by using the relationship of congressional representation per capita as a context.

What: Texts, Tasks and Supplemental Readings

Of the math teachers I know personally, most do not care for the greater part of their textbooks, but continue to use them, not only as mandated by district curricula, but on a daily basis for many activities. One of the reasons for this may be that math teachers do not always feel fully confident critiquing written materials for their style and structure. While we can readily articulate issues we

have with content and organization, we don't always feel as certain about what it is, exactly, that we would like to see changed. If math teachers were to apply a simple rubric, of sorts, to measure literary quality in math texts and supplementary readings, it might go a long way toward narrowing and improving selections for the sake of both instructor utility and student accessibility. Then it might be easier to move on to choose supportive and supplemental literature for math instruction.

Still, it can be difficult to choose quality materials, and a strain on time to be occupied with such "additional" work within the constant task of planning lessons. It would be extremely helpful to have more resources for literary adaptation to mathematics instruction readily available. To some degree this is totally within the power of any teacher to rectify, so long as he or she has access to the Internet and a library – however, there is also an understandable aversion to independently seeking out adaptations to math curriculum. There pressure from administration and the central office of curriculum development to meet directives, which do not leave much room for literary adaptation. And, even without this pressure, the "school house" environment as a whole has not been overtly supportive to literary adaptation of mathematics.

The [research reveals] that messages available to content-area teachers about literacy neglect, deemphasize, or misrepresent mathematics and/or mathematics education. These findings may help explain why content-area teachers, particularly mathematics teachers, resist ideas related to content-area literacy instruction.^x

In our current core curriculum units for Algebra 1 and Geometry, there is some significant break and careful handling of the course textbook materials, as well as some reflection writing - but there is not significant inclusion of literary adaptation, nor is there time allotted to teachers for making these or other such progressive adaptations. More flexibility and even encouragement, on the part of educational administration, to use of literary and literacy based math instruction would be a significant help. Dealing with the situation as is – the consideration of "what" adaptations and supplementary materials to use must realistically be based on keeping closely connected to mandated curricula. As June Lundy Gaston concludes in her analysis of applying children's literature to mathematics:

Teachers can find many effective ways of unleashing the potential of literature in the mathematics classroom. The search begins with knowledge of the mathematics curriculum and their personal literary preferences. The search is modified by the needs of the students. The search is continuous because the ways of linking literature and mathematics are endless.^{xi}

The real key (perhaps quite obviously) to “what” to use, is making certain that each piece of reading, each literary concept, and each literacy based task has a direct mathematical antecedent from the curriculum. If this protocol is being met, then the “what” becomes as variable as the imagination of the teacher. Magazine articles, poetry, the etymology of vocabulary words, excerpts from novels, newspaper articles and statistics, application of “grammatical structure” to writing equations and inequalities, riddles, writing exercises that challenge students to generate similes, metaphors and analogies for properties and axioms, and expansions of the conceptualization and application of word problems, can all be used if they can be coordinated with curricular objectives.

As a point of emphasis, of all the focus we might give to different aspects of literacy in adaptation, the most important may be that which we give to vocabulary. Words have power – even students who aren’t typically very motivated to learn in the classroom recognize that it is important to know the meaning of words and don’t want to be left in the dark as to the usage of terms that is going on around them. While students may say “Whoa! Stop using big words!” this is primarily because they feel undermined by vocabulary that they have not mastered. They more often than not would like to know these words and be able to employ the terms – this content is a type that they are intrinsically motivated to learn because it fits with the continuum of learning that they have experienced with language since earliest childhood. The familiarity alone makes vocabulary relatively welcome as a subject of study within mathematics.

Where: The Classroom and the World

The literary adaptations that I can make for students will primarily be applied in the classroom. Students, especially freshmen and sophomores in the concrete-operational stage of cognitive development, need serious support and scaffolding in their Algebra and Geometry course work. With the added rigor of literary adaptation, a good deal of modeling is necessary to show students what complete and valid results of their work on assignments should look like. As we apply rubrics to consider student comprehension and application of skills and concepts, there is a great need for careful formative assessment and early intervention with any students who find a great deal of difficulty with literacy-based tasks.

As the expectations and experience become more engrained, student assignments and activities can range out farther into homework assignments and projects that are completed through a combination of class work and independent work outside of the classroom or school. For example, use of mathematical skills within some statistical analysis, which would then be linked to a persuasive essay writing assignment in students’ English courses, would be an optimal adaptation.
When: Introduction, Body, and Conclusion

Literary adaptations may fit into a mathematics lesson or activity at nearly any time. Turning to literary composition as a reference again, I think it useful to compare a lesson plan to the age-old outline of an academic essay. There is an introduction, the opening of a lesson is an excellent time to employ a “hook” to capture students’ attention and focus it on the content for that class meeting. There is a body, the tasks and skill-development that fulfill the majority of a lesson can be in the form of literacy based work or simply employ some form of reading and writing as concept building and strengthening of comprehension. There is a conclusion, the end of a lesson is crucial for reflection on what was covered and what students should take away in terms of understanding and skill – writing exercises are frequently promoted for this portion of a lesson.

“When” to employ adaptations might also be considered in terms of “During which units and topical content do I as a teacher see the best moments for a piece of reading or a relationship between mathematics and language?” I also consider “when” in pure terms of timing specific sequences of subtasks that are already firmly established in math courses. Separating the reading of instructions at the beginning of exercises – in order to prevent students from skimming, too quickly scanning, or altogether skipping the instructions can be a particularly strong tool. By presenting the instructions in an isolated fashion, students can be better influenced to actually read, because reading is the only task set before them. This also opens opportunities to clarify the meaning of instructions for all students prior to setting to computational skills. This strategy may be especially useful for algebra problems, which may present the same set of problem solving tasks to be performed by students for each of several sets of given information.

Why: the Eternal Question

Students ask “why?” so frequently that it is difficult to estimate how often the question occurs in even a single day of classes, let alone throughout the course of a school year. It is not always asked so simply, often taking on the context of an activity or specific problem at hand, for example “Why do we use $-b/2a$ to find the vertex of a function?” All too often, though, the question comes across as a vague request to help a student to understand what it even is that they do not understand. Such a large proportion of our ability to teach students and their ability to understand us is based on communication that our instruction cannot afford to ignore language. As the notion of mathematical literacy suggests, we must find ways to attach literal meaning to the math that we invest with so much importance for students in academia. So, we should at minimum use literary adaptation to consider our conversations with students about their many “whys.”

How: Teaching Math Like English; Teaching English Like Math

Our use of tools to improve students' communication skills in mathematics is often less developed than it could be. While our texts have glossaries, and we have solution guides to model ideal written responses to open ended questions, these tend to be more in the way of simplistic concepts and raw math skills – the language of mathematics and the communications skills that go along with it are treated as more implicit and are dealt with rather obtusely (as in awkwardly, rather than as in “an angle between ninety and one-hundred and eighty degrees in measure”). Mathematics is wrapped and delivered in language that often lacks some lyricism, lacks some power of analogy. We might easily attain this power from a more concerted effort to make the explanation and exemplification of concepts an everyday task for both our students and ourselves.

Asking students to write complete sentence responses, explanations, or observations has been a constant struggle for me because students have the conception that “writing is English” – a different, disassociated skill set that they feel overtaxed to perform in math class. This strain and struggle is for the most part purely attitudinal and can be rectified by early and frequent modeling of regular and relevant literacy-based skills in the mathematics classroom.

Classroom Activities

I see making the arguments for literary adaptation and presenting general strategies for making these adaptations as my real task in this writing. Once a teacher is convinced of the utility and feasibility of literary adaptation to math the path is boundless, because, as articulated above by Gaston: “the ways of linking literature and mathematics are endless.” From this point it is dependent upon the interest and discretion of the individual teacher to appropriately adapt lessons.

For my part I have too many notions and lesson inclusions to expand upon here, so I will focus on two of my favorite ideas for linking math and literature, in one example for Algebra 1 and one example for Geometry.

Algebra 1: Functional Poetry

The structure, alliteration, and even personal/political/social poet's intent are among the many ways in which poetry might be related to concepts in math. Poetry suggests itself to me as one of the most profound tools for literary adaptation of algebraic conceptualization and reasoning. This may have most to do with the power of metaphor – the variable value and meaning of words and phrases within a poem can be quite akin to the variable values in an equation. One way that I will use poetry is to approach the central concept of “functionality.”

I will use Robert Frost's popular "The Road Not Taken" as an instructive verse for the concept and definition of a "function." In the second and third lines of the poem comes the phrase "I could not take both [roads]/ And be one traveler," which I see as a great representation of the limits that fall upon a function. For each input of a function, there can be only one output. The line from the poem might be reformulated as "I could not take both and be one function."

The lesson in which I will use this poem will follow some work with linear functions and precede work with absolute value and quadratic functions. The natural environment represented in the poem's imagery, "... I looked down one [road] as far as I could/ To where it bent in the undergrowth." provides the opportunity to begin considering functionality in a very tangible sense, since these non-linear functions bend and twist. This nature imagery also offers a literary means to consider the terms "domain" and "range," which both have strong definitions in both mathematics and landscape. These terms are very important in the conceptualization of how a function, well, "functions."

I will begin this lesson by briefly grounding students with the task of comparing the outputs of several, complete t-tables of "x" and "y" values. Some of these tables will prove to be functions based on having unique outputs, some will not. What students will likely notice is that some tables have "repeats" or "different/plural outputs for the same/singular inputs." I will then have students read the Frost poem, which is only twenty lines in four stanzas, and prompt them to compare the language of the poetry to the observations they have already made about how a function behaves. I expect at least a handful of students to independently make the connection I am looking for here, however, even if only one student grasps the metaphor at first, I will facilitate with discussion and further examples of tables and graphs that represent functions and non-functions in order to build the concept of a function from the accessible language.

Geometry: A Good Argument Can Save a Perfectly Awful Tea Party

It is often no picnic to cover the Reflexive, Symmetric, and Transitive properties, as well as the usage of converse, inverse, and contrapositive conditional statements, early in the Geometry curriculum. These are inherent literary inclusions in the mathematics continuum and absolutely essential to the method and nomenclature of mathematical proofs. These literary pieces of content are difficult for students to master quickly – definitions are often given in stilted, cursory form, and phrased in "unnatural" ways that don't speak to students' previous experience. This is a case of literacy-based activity that need not be freshly introduced by an adaptation, but a central piece that needs to be refreshed via adaptations to the presentation and methods provided for students.

A key objective is for students to apply conditional statements to geometric principals such as “If two angles form a linear pair, then they are supplementary angles,” while also being able to understand and articulate that the converse of this statement is not always true: “If two angles are supplementary, then they form a linear pair” is not true unless the angles are adjacent and share a segment or ray. However, for students who are apprehensive about math, delving into geometric examples immediately may not always be the best approach.

The majority of my students have a propensity for argument – unfortunately they often argue at the wrong times, about the wrong things, for the wrong reasons. Helping them focus their enthusiasm for debate in a productive direction can improve their communication skills and serve as a vehicle for deeper comprehension of the core logical properties of geometric proof.

Many alternate examples can be developed – and having students develop and write examples of the logical process of converse, inverse, and contrapositive statements can be an excellent activity. Presenting students with playful and interesting examples can draw them into more serious consideration and a greater willingness to flex both creative and logical mental muscles. Toward this purpose, there are many highly accessible reading excerpts to make use of. Some, notably from *Alice in Wonderland*, read quite like conditional statements themselves, which in the case of *Alice* is no surprise as the author, Lewis Carroll, was a mathematician. The famous Mad Hatter’s tea party scene serves quite well:

“Then you should say what you mean,” the March Hare went on.
“I do,” Alice hastily replied; “at least—at least I mean what I say—that’s the same thing, you know.”
“Not the same thing a bit!” said the Hatter. “Why, you might just as well say that ‘I see what I eat’ is the same thing as ‘I eat what I see!’”
“You might just as well say,” added the March Hare, “that ‘I like what I get’ is the same thing as ‘I get what I like!’”
“You might just as well say,” added the Dormouse, which seemed to be talking in its sleep, “that ‘I breathe when I sleep’ is the same thing as ‘I sleep when I breathe!’”

Alice in Wonderland is one-in-a million as a literary resource for mathematics, and a million-in-one as a source of ideas for literary adaptation. I will begin a lesson with the above reading excerpt, having students write a brief interpretation. Then I will facilitate a brief discussion of what students have written, followed by an introduction of the terms: conditional statement; converse; inverse; and contrapositive. I will ask students to identify which statements they can see in the excerpt and move on to have students write their own examples. I will make this part of a unit in which students will go on to debate steps taken in proof scenarios.

Annotated Bibliography

Carroll, Lewis. *Alice's in wonderland and other favorites*. Canada: Pocket Book Editions 1951.

There are numerous editions of Carroll's work, mine contains other useful pieces for math adaptation. Puzzles from Wonderland is particularly good as a resource.

Abbott, Edwin A. *Flatland: a romance of many dimensions*. New York: Dover Thrift Editions, 1992.

Although it is not visible, Flatland is floating just "above" this entire paper and influences my entire notion of literary adaptations to geometry instruction.

Szpiro, George G. *Poincare's prize: the hundred-year quest to solve one of math's greatest puzzles*. New York: Penguin Group, 2007.

Vis-à-vis a consideration of the concepts in Flatland, I have become increasingly interested in the mathematical field of topology. This novel provides an historic account of the development of the field and has many excerpts suitable for introducing geometry students to this extension of the principles of geometry.

Nasar, Sylvia and David Gruber. *Manifold destiny: a legendary problem and the battle over who solved it*. *The New Yorker*, August 28, 2006.

In this article Nasar, author of the novel A Beautiful Mind, and Gruber explore the recently accepted proof of Poincare's famous problem. I was influenced by its focus on the importance of collaboration and documentation in mathematics work. The content makes a strong case for the need of language and communication skills in order to be successful in the field of mathematics.

Lathem, Edward Connery, and Lawrence Thompson, ed. *The Robert Frost reader: poetry and prose*. New York: Henry Holt and Company, (reissued) 2002.

Frost's poetry is very accessible and offers a blend of metaphorical concepts that can be readily related to math, as well as visual imagery easy to connect with. His prose may be used in excerpts as well to consider logical structure and argument.

Haddon, Mark. *The curious incident of the dog in the night-time*. New York: Random House, 2003.

The autistic narrator in this novel is incredibly entertaining and, in a number of ways eye-opening, for me as a teacher. Many excerpts tie directly to math topics and make them accessible through humor and context that students will relate to.

Juster, Norton. *The phantom tollbooth*. New York: Random House, 1961.

Although I do not directly reference this book, I would be remiss not to mention it here. Its metaphor for learning has directly influenced me in thinking of, as I frequently phrase them, two major "realms" of study: mathematics and language.

Notes

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- ⁱⁱ Lott, Johnny W. *Correcting the course of math education*. *Principal Leadership*, v 7 n5 p27-31, January 2007.
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- ^{iv} Ross, Philip E. *Math without words: numerical reasoning seems independent of language*. *Scientific American Magazine*, June 20, 2005.
- ^v Gaston, June Lundy. *A review and an update on using children's literature to teach mathematics*. Educational Resources Information Center, ED503766, December 28, 2008.
- ^{vi} Howe, Roger E. *Leading the seminar on the craft of word problems*. On Common Ground, Yale-New Haven Teachers Institute, n12, Spring 2008
- ^{vii} Barton, Mary Lee and Clare Edema. *Teaching reading in mathematics: a supplement to "teaching reading in the content areas teacher's manual (2nd Ed.)"*. Morel, Washington, D.C.: Office of Educational Research and Improvement, 2000.
- ^{viii} Willingham, Daniel T. *Ask the cognitive scientist: should learning be its own reward?* *American Educator*, Winter 2007-2008
- ^{ix} Willingham, Daniel T. *Ask the cognitive scientist: should learning be its own reward?* *American Educator*, Winter 2007-2008
- ^x Siebert, Daniel and Roni Jo Draper. *Why content-area literacy messages do not speak to mathematics teachers: a critical content analysis*. *Literacy Research and Instruction*, v47 n 4 p229-45, 2008
- ^{xi} Gaston, June Lundy. *A review and an update on using children's literature to teach mathematics*. Educational Resources Information Center, ED503766, December 28, 2008.

Appendix: Applicable Pennsylvania State Mathematics Standards

Depending upon the specific task or activity a teacher may use in instruction, any of the mathematics standards might be addressed. Here I have compiled some of the standards that either have explicit reference to language skills or could only be assessed by some application of communication skills on the part of the student. This should not be considered the extent of applicable standards – because, although it is possible to interpret many standards as raw computational skills, using language skills in meeting these standards will make them more enriching.

All standards listed are for eleventh or eighth grade, however they have antecedents in the fifth grade lists that are readily available in the same sections of the standards. In fact, there are more numerous standards that are explicitly literacy-based in the fifth than in the eighth grade lists, and again in the eighth than in those for the eleventh grade. This begs the question, in my mind, as to why the emphasis should diminish for “accountable talk” in the mathematics standards at higher levels.

Again, this list is only comprised of some of the most obvious mathematics standards that justify and support the use of literary adaptation to math studies. The options are only bound by the teacher’s ability to expand and develop the communications that are essential to mathematics into a stronger framework for education in logic and reasoning.

2.2.8.E - Determine the appropriateness of overestimating or underestimating in computation.

2.2.11.D - Describe and explain the amount of error that may exist in a computation using estimates.

2.3.8.E - Describe how a change in linear dimension of an object affects its perimeter, area and volume.

2.4.8.A - Make conjectures based on logical reasoning and test conjectures by using counter-examples.

2.4.11.A - Use direct proofs, indirect proofs or proof by contradiction to validate conjectures.

2.4.11.B - Construct valid arguments from stated facts.

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- 2.4.8.C - Use “if...then” statements to construct simple, valid arguments.
- 2.4.11.C - Determine the validity of an argument.
- 2.4.11.D - Use truth tables to reveal the logic of mathematical statements.
- 2.4.8.E - Distinguish between inductive and deductive reasoning.
- 2.4.11.E - Demonstrate mathematical solutions to problems (e.g., in the physical sciences).
- 2.5.8.C - Justify strategies and defend approaches used and conclusions reached.
- 2.5.8.D - Determine pertinent information in problem situations and whether any further information is needed for solution.
- 2.5.11.D - Conclude a solution process with a summary of results and evaluate the degree to which the results obtained represent an acceptable response to the initial problem and why the reasoning is valid.
- 2.8.8.B - Discover, describe and generalize patterns, including linear, exponential and simple quadratic relationships.
- 2.8.11.B - Give examples of patterns that occur in data from other disciplines.
- 2.8.11.G - Analyze and explain systems of equations, systems of inequalities and matrices.
- 2.8.11.S - Analyze properties and relationships of functions (e.g., linear, polynomial, rational, trigonometric, exponential, logarithmic).
- 2.9.8.D - Identify, name, draw and list all properties of squares, cubes, pyramids, parallelograms, quadrilaterals, trapezoids, polygons, rectangles, rhombi, circles, spheres, triangles, prisms and cylinders.