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Cover Page Footnote

I would like to acknowledge the editors of the International Journal for Mathematics in Education, published by the Hellenic Mathematical Society (HMS i JME), for guiding comments on my earlier paper that led me to the work of Ivor Grattan-Guinness. I also thank this journal's editors and expert reviewer, whose comments encouraged my revision of this paper. Any mistakes or misinterpretations are my own.

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Synopsis

The *logos* or rational language of the fifth-century B.C.E. teacher, Gorgias, as contained in the fragment *On the Nonexistent* [3], challenges a reader to understand the relationship between the existent and the nonexistent; yet the text also offers an accessible idea of logos. Inspired by William M. Priestley's approach to the study of logos through ratios [10] and by Ivor Grattan-Guinness's recommendation to broaden the study of historical texts in the history of mathematics and mathematics education, and pursue their significance in a heritage sense [4, 5], this article suggests that this ancient non-mathematics text by Gorgias may inspire and refresh elementary mathematics educators' teaching of visualization and beginning points.

Following the idea that a humanist is dedicated to participating in civic life more than strict contemplation [6, page 122], I have studied a non-mathematics ancient Greek text to think about teaching elementary mathematics. That text is *On the Nonexistent* [3], which is a set of lecture notes of the fifth-century B.C.E. Sophist teacher Gorgias. A historically significant teacher, Gorgias is thought to have taught rhetoric and philosophy, not mathematics. Yet he, like Protagoras, "answered any question anyone put to him" [14]. Looking at his text for ideas on how he taught a range of subjects and answered questions, I have found that his thoughts about concepts such as *logos* and *beginning* inspire me to think about how to teach several of the earliest elementary-school level mathematics concepts.

1. Historical Gorgias or Heritage Gorgias

Gorgias, after establishing himself as a thinker, teacher, and public speaker in his birthplace of Leontini, Sicily, travelled to Athens in 427 B.C.E. Taking up the typical wandering path of the Sophist teacher, he "refused to settle down in any city but went all around Greece to deliver his speeches" [7, page 92]. Several of his lectures survive through notes taken by students. In our time, he has been interpreted mostly as a rhetor or a philosopher. Only Edward Schiappa, a historian of ancient rhetoric, has suggested Gorgias was a "proto-scientific" Greek thinker [13]. However, Schiappa's view is considered controversial in the field of rhetoric; most history of rhetoric scholars emphasize what there is to learn from Gorgias about the rhetorical artistry of his speech forms (see for example [2]). In addition, insofar as it is studied as philosophy, there is dissension on whether there is any value to *On the Nonexistent* [3]. Taylor and Lee [14] state the following in the entry of "The Sophists" in the online Stanford Encyclopedia of Philosophy:

> We have a philosophical essay 'On Non-Being or On Nature' (DK 82B3), purporting to be a rebuttal of Parmenides, in which he maintains that nothing exists, that if anything did exist it could not be known and that if anything could be known it could not be communicated. What can definitely be said is that it shows some knowledge of Parmenides, that it at least raises serious philosophical questions, such as the relation of thought to reality and the possibility of referring to things which do not exist, that no question which it raises is developed to any significant extent and that most of its arguments are extremely feeble. It reads like a piece written by a clever man with no real interest in philosophy, but it is doubtful whether we shall ever know why he wrote it.

To make clear from the start, I am not entering into any such debates. Instead, when reading this text for teaching inspiration, I am drawing on the scholarly understanding I have gained from Ivor Grattan-Guinness, a historian and philosopher of mathematics and logic, who believes that renewed attention "to the broad features of history may well enrich the inheritance" of mathematics education [4, page 168].

As a proposition for the applicability of studying ancient texts, Grattan-Guinness suggests that when interpreting a "mathematical notion N" one should pursue a full range of approaches, from looking at one notation to a whole branch of mathematics. He includes within this broad range the "ways of teaching" mathematical notions [5, page 1]. Furthermore, Grattan-Guinness carefully admonishes scholars not to confuse "history" with "heritage" readings [5, page 1].

Since I am interested in ways of teaching mathematics, I am only reading Gorgias as a Sophist teacher willing to take "any question" insofar as I am rhetorically asking questions about how to teach when I read Gorgias, in Grattan-Guinness's heritage sense. I am not doing any scholarship related to anything in the field of the history of ancient Greek mathematics or philosophy. I find in Gorgias pedagogical ideas and "ways of teaching" elementary mathematics concepts that are difficult to teach. In fact, I have found inspiration within *On the Nonexistent* for quite a few "ways of teaching" elementary-school level mathematics lessons (see [15]).

2. Questions of Sophistic or Misguided Teaching

I do not know Greek, so I am working only with a translated text, in this paper, when I am sharing how Gorgias's *On the Nonexistent* [3] has inspired me to think about what I am doing, as a teacher. As another proviso, I note that the historical figure, Gorgias of Leontini, is the subject of one work by Plato, Gorgias, and that Plato's work is sometimes considered as the only "Gorgias," but that book and the historical figure Gorgias should not be so confused; I have not included anything from Plato in my consideration of Gorgias. Finally, I should acknowledge that Gorgias has historically been considered, along with Protagoras, as offering "deductive schemes" such as "the scheme called 'consequentia mirabilis' in the Middle Ages (a variant of the proof by contradiction, consisting in proving A by proving that non-A implies A)" [12, page 173].

Without embarrassment, I must ask for the reader's tolerance, in hopes they do not leap to the conclusion that, by using Grattan-Guinness, I am somehow seeking to prove or to imply that Gorgias was a scientific or mathematical thinker in his day. Instead, I ask for acceptance that, as a former eighth-grade mathematics teacher for a few years, I have had challenges in communicating to students and getting them to remember and draw on very early mathematics concepts. Part of my motivation to read broadly, outside traditional mathematics pedagogy, for teaching ideas is to contemplate what is known as "math anxiety," where students forget what they have learned. Gerardo Ramirez has explained that one reason for it "is an adaptive process to reduce the accessibility of irrelevant information that no longer provides utility or value" [11, page 17].

I will discuss some irrelevant information, such as too many units of measurement that students are required to memorize, in the section "Logos and Visualization in Mathematics Education" below. Briefly here, I will note that it is generally understood that the fifth-century B.C.E. Sophists taught about mnemonic devices (see for example the `Wikipedia` article, "Mnemonic", https://en.wikipedia.org/wiki/Mnemonic, last accessed on January 28, 2019).

At the same time as I credit the ancient teacher Gorgias with inspiration for thinking about memorization, I hope to show that I am aware of the contemporary pedagogical criticism about misguided teaching of scientific language (following Berkenkotter and Huckin [1]) and also the extensive research available on the difficulties of teaching students to transfer between conceptual systems (Perkins [8] and Perkins and Salomon [9]).

With these concerns in mind, I still believe in the humanistic credo that I should participate in American civic life by sharing the ideas that I find worth contemplating about in Gorgias's *On the Nonexistent*. I suggest there is the potential to transfer such ideas into teaching mathematics. For this paper, to discuss the transfer from Gorgias into elementary mathematics lessons, I am in part drawing on suggestions offered by Berkenkotter and Huckin [1] about genre knowledge. For me, Gorgias offers a certain narrative in which I find a useful way of teaching about specific mathematics concepts. However, the question of whether this narrative conflicts with the genre of language used in mathematics instruction is highly relevant, because according to Berkenkotter and Huckin [1], from the perspective of functional linguistics,

> Children are often overly dependent on narrative at the expense of learning other expository forms more suitable for reports of scientific experiments, analyses of historical events, and so forth . . . such knowledge constitutes the hidden curriculum of the language arts classroom. (page 154)

Berkenkotter and Huckin [1] further note that scientific description uses the "universal present tense," and emphasizes "descriptive/expository elements," whereas in distinct contrast to scientific writing, "true narrative" uses "past tense verbs to describe a chronological sequence of events." A story with such "unfolding of events" includes "the story complication expected of narratives" (page 157). As a result of the privileging of language arts and its emphasis on narrative, many students may have difficulty "becoming communicatively competent in patterns of discourse other than narrative" (page 160). While this is a tremendous challenge for elementary teachers of scientific subjects, including mathematics, I am not simply looking at the "story of Gorgias," as I see it, as a potential narrative for students. That is, I am not seeking to make a "past tense" explanation of how Gorgias inspires me, into a mere narrative story. If I were to narrate a story about Gorgias to students, I would be telling a language-arts narrative story. Nor do I seek to describe him as though his writing is a scientific source. However, it is indisputable that fifth-century B.C.E. Athenian civilization is, in reality, within the American elementary school the repeat focus of very important lessons about art, myth, history, and government, such as lessons about Pericles and democracy. There are also biographical and historical lessons about identifiable historical Greek thinkers, no matter their subject content.

Subsequent to such relevance of ancient Greek topics in contemporary curricula, I am distinguishing between the narrative use of Gorgias's *On the Nonexistent* by me as a scholar of STEM rhetoric, and the necessary language to use in the mathematics classroom. I am certainly aware I cannot insist that Gorgias contains "descriptive/expository elements" for our science and mathematics students today. Yet, ancient Athens is a positive historical reference for American elementary students. I do not mean to confuse the issue, but reaching back to that era, I have a narrative about Gorgias available when thinking about *logos* for the mathematics classroom, because Gorgias himself spoke about *logos*. However, I want to use scientific or mathematics language and sources for my mathematics lessons. Mathematics language should be rigorously inculcated in students. That is why I emphasize that Gorgias's *On the Nonexistent* is a resource, not an authoritative text, for what seem to me to be relevant language and rhetorical constructs, which once focused upon in my mind I can transfer into the lessons I teach. In other words, I believe I am of the position that there is a possibility for a transfer of my narrated thoughts here about Gorgias's language into the explanatory language of the mathematics genre. I cannot insist upon their validity for all teachers or readers, even though I think there is a strong possibility that other elementary-school level mathematics teachers would, like me, be up to the challenge of thinking about the language they use for their own ways of teaching while examining and notating Gorgias's text.

3. *Logos* and Visualization in Mathematics Education

Basically, as a work of rhetoric, I believe *On the Nonexistent* is worth reading for its definition of *logos*, the study of which is a given nowadays in introductory college writing, composition and public speaking classes. However, Priestley [10] has explained that *logos* should not be limited to being considered as strictly a term of rhetoric, because its meaning includes the mathematical concept of "ratio":

> In Greek mathematics, *logos* (plural, *logoi*) means ratio—"the size of one thing relative to another" according to *Euclid V*—but the word is more familiar outside mathematics. "In the beginning was the *logos*," the phrase from the New Testament that opens the fourth gospel, contains perhaps its most famous usage, written at a time when the word already signified a wealth of related notions... *Logos* still plays a unifying role in liberal education, as suggested by such English derivatives as logic and analogy, and by the host of modern academic words, such as ecology, possessing the suffix -logy. (pages 117–118)

As Priestley [10] points out, *Euclid V* can be accessed for a "historical" meaning for "the size of one thing relative to another." In comparison, Gorgias defines *logos* as "that by which we reveal." To me, Gorgias's meaning of *logos* is relevant to my mathematics teaching especially when he elaborates the difference between words and visible bodies that have substance:

> [E]ven if *logos* has substance, still it differs from all the other substances, and visible bodies are to the greatest degree different from words. What is visible is comprehended by one organ, *logos* by another. *Logos* does not, therefore, manifest the multiplicity of substances, just as they do not manifest the nature of each other. [3, page 86]

As a teacher with experience teaching elementary mathematics, I know that there are many students who have difficulty visualizing terms. They are also required to memorize a plethora of terms as well as equations required for success in elementary mathematics. Ramirez [11] believes that elementary students can become so full of "math anxiety" that they choose to forget extraneous material, even if they are still tested for it. He furthermore suggests that "motivated forgetting processes may play a role in the retention of educationally relevant material" (page 8). Ramirez offers test data, not examples. However, his discussion of "math anxiety" resonates with me, because my primary example of such forgetting processes is how often students have difficulty remembering and caring about mastering knowledge of both the English-unit measurement system and the international system, S.I. or metric system. This, in my experience, is especially true for retention of units of S.I. distance measurement (millimeter, centimeter, meter).

Many students prefer the comfort of sticking to their mastery of English units (inch, foot, yard, mile) that our civic and home life reinforce. As another example, "m" stands for meter, yet "mph" means "miles per hour," which could be a source of confusion to my students, where I would have to go off the lesson, as it were, to teach the abbreviations of the words rather than the visualization of the distances being measured. Most of them could visualize inches, yards and miles, by their immediate reference to the hours spent at after-school activities engaging in football, baseball, basketball and cheerleading, all American athletic activities where coaches teach, officials judge and parents support with only English units. By contrast, students involved in playing soccer or international football learn, and are supported by mentors, using only the metric measurement system. No matter how creative and caring teachers are, they are requiring students to learn two distinctly different measurement systems, when the students' choice of sports necessitates specializing in only one.

I argue that it is difficult for students to remember both systems on a daily basis in the mathematics classroom and, referring to Ramirez [11], that they may even be considered to be motivated not to remember both systems but only the one they can run with most after school. It is rare, if not impossible, to find students who have mastery in both systems. Many can automatically show what inches or yards look like, but they have difficulty, or even will dislike explaining, what a millimeter or meter looks like.

They can discuss their own body's weight automatically, with reference to doctor's office visits or a home scale, but they do not have immediate knowledge of how many kilograms that translates into. In my view, these words are not at all equivalent as usable terms to measure the same things. Students need to be taught that the words are different, as are the visible results.

This tension extends into high school and college; the College Board SAT mathematics exam requires knowledge of both. In contrast, the Graduate Record Exam (GRE) that is taken by all college students worldwide to earn admission into American graduate schools requires motivated memorization of metric units only. (I described this issue in [17].)

Leaving rote curriculum requirements and seeking inspiration from ancient Greece, Gorgias's explanation that words are different from visible bodies would, I suggest, be very helpful ancient wisdom for teachers required to teach lessons that necessitate teaching the two different measurement systems. I think that how these units are words used in similar contexts but which describe and explain different "substances" is not easy or automatic for American students to visualize or conceptualize. As Perkins [8] has explained, "integrative mental images of varied kinds can help students toward a cohesive understanding of particular subject matters and, more broadly, of the interrelations among the subject matters" (page 119). Be that as it may, visualizing the different images created by different measurement systems is difficult to master. At times, the proverb "he who hesitates is lost" seems evident to me in students when English units and metric units are used interchangeably in textbooks and tests, as if the transfer between the two different, yet interrelated, measurement systems can be taken for granted.

Perkins and Salomon [9] have noted that when "teaching for transfer," there is a difference between "the reflexive activation of well-practiced patterns," or "low road transfer," and "high road transfer" of the "effortful, mindful abstraction of principles" from one context to another (quoted in [8, page 124]). Making the different measurement words visible to students is not a simple matter; it requires a great deal of teaching and learning for the transfer between knowledge of English units and knowledge of metric units measurements. Teaching both systems requires more than interchanging the words representing the two sets of measurement. Such switching involves a visualization step that is too often left out of American mathematics curricula.

To do such teaching, I could of course stick to contemporary pedagogy, such as that offered by Perkins and Salomon [9] and their ideas on the difficulties in teaching for transfer. Nonetheless I also believe understanding Gorgias's ancient ideas about *logos* will help any teacher when seeking to teach the difference between words and visible substances. I think that first by cultivating a teacher's ability to teach the words-into-visualization step, and then teaching students themselves how to attach the required math words to visible bodies, will help everyone stay on the lesson when a textbook or test requires rapid shifts between conceptual systems that are not automatically or easily visualized. Concentrating the mind on the ancient idea of *logos* as the difference between words and visible bodies could spark the teacher's own engagement and the students' participation in making a difficult transfer between different conceptual terms and different required visualizations.

4. Beginning Points

For another example, to my knowledge, any theory of "beginning" in mathematics is considered to be authorless, a concept that just exists in mathematics education, without history or biography involved. Gorgias's statement that introduces the notion is: "for everything which is generated has some beginning" [3, page 69]. To me as a teacher, rather than a storyteller using a "once upon a time" style of "beginning" narrative, the concept contained in Gorgias's text allows me to conceptualize and stayed focused on what a "beginning" is, without needing any narrative. One basic aspect to this idea is that the mathematics student generates a beginning whenever he or she solves, rather than answers being supplied them. Such as, solving for x, which is a very early lesson that is necessary for elementary mathematics students to comprehend. They must learn that the Greek letter represents a real number that they must find, and that the answer will not be supplied them, or else they flounder with algebraic concepts. At many levels, the idea of beginning point as being generated by a person, rather than a result of a teacher or a worksheet supplying coordinates to fill in a graph, is also an important activity to teach.

There are of course numerous examples for why it is required for students to know "beginning," such as a point on a number line, a time line or on a graph. In the following, I share several examples of how students achieve this understanding through games. (These illustrations are elaborated from

[15] and [16].) Any early childhood educator or parent, who has initiated playing a board game by showing students or a child how to use dice or a number spinner, knows that games can teach the essential basic lessons about where to start in a count of numbers. The normal young math student turns into a mathematical whiz kid when noticing that the dice or the spinner has no "zero," and such a student is to be praised for showing he or she has a mathematical mind to notice the absence of that integer from the counting numbers offered. Then, it is the movement of the count, along the path described on the game board, which must be taught, even drilled, into the first-time player; there is nothing natural about realizing that the first space or square or position is counted as "zero." The number one is counted through the movement from the "zero" to the next position delineated in the game. However, the first-time player, if very inexperienced at board games, may consider the count to begin with one. Then, at the next turn, the number of spaces moved in the previous turn does not matter. There is no adding to the number rolled on the previous turn. The count begins again with one. These discrete changes of position, movement, and counting at each turn create the momentum of engagement. How to coordinate the counting at every turn with the movement from the beginning point must be learned for the player to play the game. Where the player's piece is at any point is determined through familiarity and ease with counting numbers. But the idea that at the beginning of each turn, a player must begin with zero, even if the dice or the spinner do not suggest that zero exists, takes scaffolding, sometimes drilling, because returning to zero to begin one's count is not an automatic idea.

Another example to illustrate how a beginning point involves a choice of numbers is that old children's game, Hopscotch. The design typically has the numerals 1 through 10. Players begin by standing outside the design, in what is essentially a "Nonexistent" space — a zero place that is never labelled or described as zero. The unnumbered place is designed and determined to be the beginning point, before one hops into the game and begins counting. Conceptually, I think Hopscotch is a good game to illustrate why zero is a number that is excluded from the counting or natural numbers, but included in the set of whole numbers. The confusion on when to "except zero" from the set of numbers is very evident in elementary mathematics, a drill-like formula required, for example, when teaching fraction denominators and also division, with no recourse to infinitesimal calculus to explain limits and other notions of the use of the number zero. Learning games to illustrate "beginning" may be enough for students to visualize when or if different numbers, including zero, need to be brought into play. But I suggest it would also aid a mathematics teacher at the elementary school level to keep in mind the language that Gorgias offers, "for everything which is generated has some beginning" [3, page 69]. What number to keep in mind to begin various games, or by extension hopefully mathematics assignments, would be for teachers and students both, inspired by Gorgias-like *logos* ("that by which we reveal"), inquiring into notions of numbers and sets, not a drill-like memorization of textbook terms.

In conclusion, I suggest that by looking back at the words of a great teacher from ancient Greek civilization, Gorgias's *On the Nonexistent*, a mathematics educator can find inspiration to think of new ways to teach and transfer knowledge to students today. It may be difficult to contemplate, but mathematics educators need to refresh the current idea of what elementary mathematics is.

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