Pioneering a Math-Based Grammar Course for Engineering and Other STEM Majors

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Introduction

This paper discusses my and my students’ experience piloting a college grammar course custom-designed for engineers and other STEM majors, during spring quarter 2015 at University of California, Davis. As a member of ASEE’s Liberal Education / Engineering & Society (LEES) Division, I champion intersections in scholarship and teaching between the humanities and STEM disciplines. This paper examines one such intersection: the application of a math-based system called “Sentence Algebra” to provide students skilled in math with a user-friendly pathway into learning how words form sentences and operate within them—a subject usually studied within the context of linguistics. The paper’s style and structure also meld two distinctive document types—technical report and narrative essay—in order to reflect upon a small-scale, field-test type experiment and to identify initial positive or negative trends within the experience.

Instructional Concept

The development of a specialized grammar course for engineering and other STEM students was predicated upon four assumptions. The first was that possessing a complete functional understanding of how sentences work can help students to produce technical documents that are clear, concise, and correct; and second, that adequate grammatical skills are too often missing in engineering and STEM majors.

Another assumption was that engineering and other STEM students already have mastery in the language of math, and consequently, math metaphors, symbols, and equations can provide a universal point of entry into learning subjects that link to math. And finally, I assumed the Sentence Algebra method for teaching grammar through the lens of math would be an effective instructional method for a STEM grammar class. Aside from these premises, which were informed by my 25-year career as an engineering writer and writing instructor, as well as by some exciting precursor studies published by others (see literature review segment at the end of the paper), there was no formal needs assessment nor feasibility study conducted prior to the trial.
The chief driving force behind the pilot was firm belief that a grammar class for STEM students was an idea worth trying. This belief was shared by me, a number of my engineering writing students (past and present), as well as several engineering education colleagues within my professional network.

*Sentence Algebra*

To fully explain the Sentence Algebra system is not the purpose of this paper. Springer will soon publish a book presenting the entire Sentence Algebra system and also a math-based method for teaching engineering documents. Here, however, is a macroscopic introduction to the system’s core concepts.

Underlying most systems, organic or inert, there is order, and math-based models identified by engineers and scientists that describe and define that order. This also applies to systems of language. Language scientists (linguistics scholars) have been characterizing English sentences using formulaic recipes for instance, “Subject + Verb + Object” and graphics such as grammar diagrams and trees for many years. In the 21st century, computational linguists are creating sophisticated voice recognition software products built out of computer code and algorithms that interpret vocal sound waves and translate them into lines of word-based text.

Sentence Algebra can be understood as a way to code sentences written in words into sentence equations formed out of variables and math operation symbols. Sentence Algebra models grammar patterns and principles that have long since been defined, published, and taught by linguists. What is unique about Sentence Algebra is that it systematizes a math-based model that captures how words and word groups function and interrelate in sentences when we use the English language to encode and communicate human thinking into textual (or spoken) messages.

Sentence Algebra codes the Eight Parts of Speech as N (noun), V (verb), X (pronoun), Mₐ (adjective), Mᵥ (adverb), L (preposition), C (conjunction), and I (interjection); and uses the plus sign (+) to join variables and the multiplication symbol (*) to indicate attachment of specificity multipliers. Examples would be an adjective modifying a noun, such as “Mₐ * N,” as in “accurate numbers”; or an adverb modifying a verb, such as “Mᵥ * V,” as in “quickly calculated.”
The variables and operators, in turn, plug into five basic (B1 through B5) and a variety of advanced (A) sentence equations. An example of a basic sentence equation is \( B_2 = N_s + V + N_o \), where \( N_s \) = noun subject, \( V \) = main verb, and \( N_o \) = noun object, which is a version of the traditional grammar recipe mentioned earlier, “Subject + Verb + Object.” Advanced Sentence formulas (As) allow numerous combinations and variations, such as the two basic sentences connected together as shown below. Here, the connector is the subordinating conjunction \( C_{\text{sub}} = \) “even though”, which can also be represented by the sentence-algebra operation symbol, “/”. The example also includes a couple of pronouns (Xs), or words that stand in for (replace) nouns, as well as one instance of the article “the” (a specialized modifier), which appears in the second sentence’s text version. In this case, the complementary equation has been simplified and codes “the” and “numbers” together as \( N_o = \) “the numbers.”

Here are the two Bs:

\[
\begin{align*}
B_1 &= X_o + V + (M_n * N_o) = \text{She produced accurate results} \\
B_2 &= X_o + (M_v * V) + N_o = \text{She quickly calculated the numbers} \\
C_{\text{sub}} &= “/” = \text{“even though”}
\end{align*}
\]

And here are the two Bs joined together:

\[
A = \frac{B_1}{B_2} = \frac{X_o + V + (M_n * N_o)}{X_o + (M_v * V) + N_o} = \text{She produced accurate results, even though she quickly calculated the numbers.}
\]

The Sentence Algebra system can code (parse) nearly any word sentence into a formula representing the sentence’s key functional units (words and word groups). The ability to do this allows writers to see an objective, quantitative structure and logic underneath text sentences—rather than a subjective, qualitative blur. Once a “sentence engineer” is able to see the formulas beneath sentences, he or she can then also detect and repair common sentence errors, such as pronoun reference errors, which to reconcile, often involves moving terms around in a sentence equation, so the reader can more easily locate what noun a pronoun replaces, or seen through the lens of math—“solve for X.”
Benchmark: As an attempt to design the experimental class so that it might viably articulate into the university’s undergraduate General Education (G.E.) curriculum, I developed my STEM grammar course so it covered the same general content as the university’s existing sophomore/junior-level grammar course—a 4-unit offering cross-listed as ENL/LIN/UWP 106—meaning the course is jointly owned, yet separately delivered, by the English Department, Linguistics Department, and the University Writing Program. All sections, no matter which department is host, feature a similar catalog description:

“Survey of present-day English grammar as informed by contemporary linguistic theories. The major syntactic structures of English; their variation across dialects, styles, and registers; their development; and their usefulness in describing the conventions of English...”

After examining sample course outlines and course-level learning outcomes from previous sections of ENL/LIN/UWP 106, I synthesized a set of common, top-level Course Learning Outcomes (CLOs) to serve as scaffolding for an experimental offering of 106 standard as 106 STEM. Here are the six resulting top-level CLOs:

- **CLO #1:** know the parts of speech (“noun,” “verb,” “adjective,” etc.) and basic sentence structures (“Subject – Verb Intransitive” and “Subject – Verb Transitive – Object,” etc.).
- **CLO #2:** know advanced sentence structures, such as compound, complex, compound-complex, questions, passive vs. active structure.
- **CLO #3:** know how to parse sentences into sentence constituents (individual words) that are ordered, arranged, and labeled using tree diagrams.
- **CLO #4:** understand the discrepancy (and resultant inequities and social injustices) between what is grammatically correct/acceptable from the points of view of descriptive grammar (grammar as defined/infused by how people speak the language) versus that of prescriptive grammar (grammar as defined/imposed by how people within academe, institutions, and the high-social-economic subculture write formal/professional English).
- **CLO #5:** have examined an overview of the history of the English language.
- **CLO #6:** are familiar with the fundamentals of language science, that is, linguistics, and this discipline’s various schools of thought.
I also observed that standard sections of 106 typically used grammar textbooks as chief references. These textbooks’ contemporary approach to the subject centered around the generative grammar system combined with traditional grammar where the authors deemed it relevant. Two frequently used titles were Max Morenberg’s *Doing Grammar*\(^8\) and Noel Burton-Roberts *Analysing Sentences: an Introduction to English Syntax*\(^1\).

*New Version:* Because 106 STEM was a special section of an existing course, the experimental version had to be cross-listed among three departments. So I prepared the following course description for ENL/LIN/UWP 106 STEM to be posted by the registrar during spring quarter enrollment and by departments on their web sites:

> “This survey of present-day English grammar uses a new methodology to examine the architecture of sentences through the lens of math. Intended for students majoring in Science, Technology, Engineering, and Math (STEM), the course offers both alternative and complement to the study of grammar and style as informed by contemporary linguistic theories...”

Unfortunately, some miscommunications occurred, and the STEM tag and revised description did not appear on the student interface for online enrollment. Instead, the course appeared as *106: special section.* Thus, many of my students enrolled without clear understanding that what distinguished the special section from the regular version was that it featured an experimental (and radically different) math-based approach.

*Course Syllabus & Trial Delivery*

For instructional method text, I used the Sentence Algebra section from my book manuscript for *A Math-Based Writing System for Engineers: Sentence Algebra & Document Algorithms*. Still in draft form, I distributed relevant excerpts to students as a series of free PDF files. Again, my objective was for 106 STEM to address the same six common Course Learning Outcomes (listed above) covered by standard 106 sections. The main difference was that I intended to teach the subject matter “through the lens of math,” and also to create lectures, in-class exercises, homework problems, tests, and projects incorporating engineering/science, rather than literary, context and diction wherever possible.

Figure 1 below shows a snapshot syllabus of how, more specifically, I delivered the course over a 10-week academic quarter. The 4-unit class consisted of 2 1/2 hours of lecture and 1 hour of discussion section each week. The snapshot syllabus shows topics covered week-by-week, and
how and when the six key CLOs were fulfilled. For CLOs #1, #2, and #3, the only math-based adaptation was that Sentence Algebra variables described the Parts of Speech (“N”, “V,” “Mn,” etc.) rather than word labels, and that basic and advanced sentences were parsed into functional units (words or word groups) described by variables and equations, rather than into word-level constituents ordered and arranged on tree diagrams. Most units of instructions on Sentence Algebra were taught using a combination of lectures and slides, in-class and out-of-class exercises, group work, and discussion sections.

I used an active-learning (collective, student-centered/instructor-facilitated activity-based) approach to deliver the instructional units associated with CLO #4 – grammar and dialects, and what is correct/appropriate depending on point of view, CLO #5 – history of English grammar, and CLO #6 – introduction to language science, or linguistics, and its guiding theories. This approach manifested a mock linguistics conference in which student teams investigated topics related to CLO #4, #5, and #6 and reported their findings to the class as team-delivered oral presentations. As a follow-on, the students also prepared team-written mini-conference papers.

Because the course was an open/nonexclusive listing, and because it was inconsistently advertised, 24 out of the 58 students total who enrolled and attended the first class were non-STEM majors. The other 34 were STEMs.
Observations by Instructor

Overall, my observation was that the trial delivery of 106 STEM using the Sentence Algebra Method was a successful field-test type experiment and that the prototype class delivered useful and positively received educational outcomes for students. This is not to say that the class’ rollout was entirely smooth and optimal in execution. The first couple of class meetings were plagued with complaints from students who felt the class had been unclearly advertised and had recruited them into the wrong version (106 STEM) instead of the course’s regular version (106 standard), which they had originally wanted or needed to take. I empathized with the students who were grousing. It was true their misplacement was the institution’s fault not theirs.

Yet there was little I could do about it. Relocating the students from my class into another 106 wasn’t an option. No other 106 sections of any kind were offered that quarter. My advice to disgruntled students was for them to either drop my class and find an alternate G.E. course to cover 4 units, or to prepare themselves for studying grammar using a radically new approach.
What immediately ensued was a large-scale exodus. My 106 STEM grammar class’ first-day roster listed 58 students—of which 34 were STEM majors and 24 were non-STEM majors. Thereafter, during the first two weeks of the quarter, while I proceeded to introduce and begin teaching Sentence Algebra, 28 students dropped—of which 12 were non-STEM majors and, interesting enough, 16 were STEM majors.

I was surprised at the high percentage of STEM drops. Yet I was even more surprised with the class’ final line-up 30 students—18 STEM majors (an even mix of undergraduate engineers and scientists, and one mathematician) and 12 non-STEM majors (representing the disciplines of Art Studio, English, Economics, Film Studies, Linguistics, International Relations, Theatre and Dance, Textiles and Clothing, and Sociology). No further attrition occurred from week three onward.

For several years prior to this, I had been testing pieces of my Sentence Algebra system on students in my engineering and science writing classes, and I had also taught the system all-the-way through to a number of individual students—engineering writing interns who held positions on my system development team. The interns seemed to learn the system rapidly as they progressed through early drafts of my textbook. When I presented portions of the system in small, selective increments to engineering and science writing students, my observation was that they reacted to math-based grammar training with enthusiasm. However, my attempts at teaching students bootstrap lessons on Sentence Algebra variables and basic equations in just one or two class sessions were not highly effective. When I tested them with basic system application exercises such as sentence coding (going from text to equation) and sentence cooking (going from equation and pre-defined variable set to text), these students struggled.

Therefore, when I developed my STEM grammar class syllabus, I designed it to focus the first five of ten weeks of study on learning basic core skills progressively, one basic skill at a time, and proceeding not too rapidly. This way, I thought students could adequately and confidently develop sufficient baseline competency, so that during the second half of the quarter, they could engage in learning advanced sentence-algebra theory and applications. Most of the students in my spring 2015 STEM grammar class, however, learned the basics about twice as fast as I had originally anticipated. Most were ready for advanced studies by week three or four rather than week six.
Another thing I hadn’t anticipated was that both the STEM students and non-STEM students seemed to progress in skill building at the same rate. In fact, several students who were English majors were among the best coders and cookers in the class. (For examples of advance sentence coding and sentence cooking, see the appendix.) In addition, though the students complained that the midterms were too difficult, on the whole, the students’ work on them was impressive to me.

The course culminated with the mock linguistics conference. Although I was not surprised that the students greatly enjoyed the academic freedom afforded by this activity, I was surprised by the great creativity and intellectual depth that students brought to their mock linguistics conference projects. The titles of the presentations listed below reveal some of this penetration:

- “Subculture Dialects: Re-appropriation of Language [as] Urban English”
- “Poverty of Stimulus [a term coined by Noam Chomsky as it relates to linguistic nativism]”
- “Psycholinguists [an introduction]”
- “Banned Grammar [a historical perspective, from 1500 to now]”
- “Banned Grammar: Don’t Use Contractions”
- “Dialect: Black Vernacular Speech”
- “The Grammar Behind Different Types of Writing [as shown by sentence-algebra coding]”
- “Computational Linguistics [an introduction]”
- “The History of the English Language: Grammaticalization”
- “The History of the English Language: the Great Vowel Shift [seven vowels reduced to five]”

During the conference presentations, the students and I had the opportunity to examine and learn about a broad span of interesting material on the history of English as well as on scholarship in linguistics. The students’ mini-conference papers, which we also shared at the class level, provided a finer layer of intriguing details.

By the end of the class, it appeared to me as if the 106 STEM class’ math-based grammar approach not only advanced the students’ understanding of grammar for both STEM and humanities/social sciences students alike, but also engaged students’ interest in applying their learning toward the study of language beyond grammar. On the other hand, my trial class also
revealed that, for some students (those who dropped the class during weeks one and two), the prospect and very nature of studying grammar through the lens of math was immediately off-putting—to the extent that these students opted not to try it and to study grammar more conventionally or not at all.

Feedback from Students, Start to Finish

When I launched the class on the first day, along with addressing the students’ confusion about class focus and matters of enrollment, I distributed 3x5 notecards and asked the students to do two things—on one side of the card jot down briefly why the students wanted to take a college grammar course, in general; and on the other side of the card, list three favorite nouns (persons, places, or things). I asked question one to get a better sense of my audience and to make sure the syllabus of activities I had planned would be sufficient for the group. I asked question two as an icebreaker and fun factor.

Out of the 58 students initially present, 23 indicated they were there to take a grammar course to learn grammar theory; 22 indicated they were there principally to learn applied grammar, that is, common grammar mistakes and how to spot them and fix them in documents; and 3 students indicated they wanted to learn more about the history of English grammar. The responses for the other questions, the icebreaker, ranged from to “Beyonce” to “Hawaii” to “my iPhone.” Informed by the cards, at the next class session I discussed how the students’ learning needs might be met—that the class would cover grammar theory and practical applications, and that we would have a chance to discuss the history of English grammar during our mock linguistics conference.

At two points during the quarter, weeks four and week eight, I distributed 3x5 cards again and this time asked the students to do a “3-minute essay.” Specifically, my 3-minute essay instructions were for students to respond to the fill-in-the-blank-type prompts, “I like _____, I like _____, and I like _____” on one side of the card; and to do the same with “I don’t like _____, I don’t like _____, I don’t like _____” on the card’s other side. I have used the “3-minute essay” assessment instrument in a lot of my classes and find it provides easy-to-collect input on class-level trends on how students are experiencing the class in-progress as well as on how my instruction is working.
Figure 2 (see below) displays the 3x5 card data (which, I grant, is soft and non-statistically significant). Review of the anecdotal feedback revealed eight common themes for sourcing positive versus negative input. Both the week four and week eight card results indicated that students tended to like the lectures and slides (row 1), the classroom dynamic and various modes of interaction (row 2), the class’ activities, exercises, and workload (row 4); and the sentence algebra method (row 5).

A majority of responses indicated students liked the class’ pace (row 3) the first four weeks but did not like it at the week eight checkpoint. This in most cases was because students didn’t think the advanced grammar part of the course moved fast enough and covered enough ground, because we had spent too much time covering the basics during the first five weeks. Conversely, the students did not like the sentence algebra application unit (sentence coding and cooking) (row 4) during the first four weeks, and yet grew to like it by week eight. Students consistently rated the class organization/polish low (row 7) and consistently did not like the midterms at both the week four and eight check points (row 8). Figure 2 notes a few miscellaneous themes (row 9) that I chose to acknowledge, but not classify, because I deemed them irrelevant attributes regarding the class’ success or non-success.

<table>
<thead>
<tr>
<th>Course Attributes</th>
<th>Week 4 of 10 Survey n=24</th>
<th>Week 8 of 10 Survey n=23</th>
</tr>
</thead>
<tbody>
<tr>
<td>lectures &amp; lecture slides</td>
<td>I like ... (effective)</td>
<td>I don’t like ... (ineffective)</td>
</tr>
<tr>
<td>classroom dynamic (individual &amp; team interaction)</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>pace &amp; structure</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>exercises, activities, &amp; workload</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>sentence algebra method (theory/concept)</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>sentence algebra application (coding &amp; decoding sentences)</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>class organization/polish</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>midterms</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>other</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 2–Student Feedback Themes from 3-minute Essays, Week #4 and #8
As with all classes at my university, the students were required to complete a generic course evaluation on the final day of class. The appendix contains a summary sheet of the evaluation responses. The survey consisted of seventeen Likert 1- to 5-scale questions. The questions ranged from “1. The instructor made the course objective clear” to “17. Please indicate the overall teaching effectiveness of the instructor.” Response rate was 67%, 20 out of 30 students on the final roster. Fifteen of the scaled questions scored between 4 and 5 (that is, “agree” and “strongly agree”). Two of seventeen questions (twelve and thirteen) scored less than 4 at 3.6. Both of these questions had to do with paper grading—“12. helpfulness of instructor comments on papers” and “13. promptness of the instructor in returning papers.”

A few of the individual response sheets for end-of-class evaluation had comments written on the back. The comments were brief yet uniformly positive, and generally indicated that the students who wrote comments found the class and the sentence algebra method to be useful. I was particularly pleased that one student wrote, “This class will be useful to students in any major.”

*Precedents/Contextualization in the Literature*

Though sometimes not widely adapted, educators have been exploring non-traditional methods for teaching grammar for many years, and some of these undertakings have used math as a touchstone. For example, in 1930, Clough developed and published a technique called “Algebraic Grammar,” which makes use of math metaphors and capital and lower-case letters to engage students. A simple representation of this technique would be SV: a subject-verb sentence, such as “the dog barked.” Clough considered symbols and formulas to have “an obvious advantage” over purely verbal (words to describe words) systems. Furthermore, beyond Clough’s “Algebraic Grammar,” it is not farfetched to view both the traditional Reed-Kellogg diagramming system and the contemporary tree diagramming system as graphic languages that express how sentences dissect and parse.

In recent decades, other methods have focused on developing students’ grammar skills by showcasing and explaining grammar rules as patterns revealed in written examples. Cismas’ paper on engineering writing reinforces these concepts through the “student-centered approach” and hands-on group work. Similar to the 106 STEM mock linguistics conference project, Cismas assumes that when students learn different aspects of grammar while collaborating on projects, the process enriches the knowledge of the whole group. Gattegno’s “The Silent Way” is a technique that teaches English word pronunciation and grammar to non-native speakers of
English using wooden building blocks (square rods of various lengths and colors). Neither mathematical, graphical, nor team-driven, the Gattegno method intersects language and physical geometry. Hart’s engineering writing textbook teaches grammar using real-world examples from actual research papers. A different facet of grammar usage and report writing is covered in each Hart chapter.

Educators have been using technology to quickly impart grammar knowledge onto students. Monash University in Australia has created an Engineering Grammar website which can be accessed at any time. Each online unit, in a similar style to the chapters in Hart’s text, contains an explanation of grammar theory, examples pertaining to engineering subjects, and worksheet exercises. Another innovative self-paced, online source of grammar education that teaches practical grammar in the context of engineering examples is Core Grammar of Engineers. This soon-to-be-released online product leverages the programming style of Core Grammar for Lawyers, an online resource that has already been widely adapted by and integrated into hundreds of law school curriculums.

Conclusion & Path Forward

The final, bottom-line conclusion I can extrapolate from this reflection on my and my students’ experience testing the experimental 106 STEM grammar class, spring 2015, is quite simply that the initial field test went well enough to merit running a revised, more refined, more rigorously assessed version of the class, a revision b, sometime soon in the future. Even better would be a trial of several sections of a revision b—one predominantly populated by STEM majors, one populated, once again, with a mixture of STEM and non-STEM majors, and additionally, a section designed predominantly for non-STEM majors who are curious about trying a course about word-based language taught using the language of math.

To move beyond informal perceptual measures like “3-minute” essays and end-of-class surveys, we will further need to develop pre- and post-class grammar skill tests, and new ways to study how something like Sentence Algebra training impacts the quality of engineering reports written by student engineers in design classes. After establishing new assessment plans and tools to collect more precise and more extensive data, it might also be useful to simultaneously offer two sections of 106, where one class is the standard version (control) and one class is 106 STEM (test).
Moreover, using an experimental versus control paradigm, a more specific scenario for comparing and contrasting grammar education type and grammar education effectiveness might be to pair a class of non-STEM students taking standard grammar versus a class of STEM students taking STEM grammar. Or, another scenario could be STEM students in a standard grammar class versus STEM students in a STEM grammar classes. Ultimately, I would hope for large-scale, grant-supported, longitudinal studies.

At my university, the next hurdle will be working with the several academic departments that offer standard versions of our existing grammar class, ENL/LIN/UWP 106, in order to get clearance to run another experimental trial of the 106 STEM grammar class during the 2016-2017 academic year. Along with enrollment problems, another administrative problem associated with the Spring Quarter 2015 STEM grammar class was that it raised a nagging question: Where should a university situate a STEM grammar class built around a math-based method that has no clear attachment to an existing academic department or program? Unfortunately, this debate, as yet unresolved, disallowed me from gaining approval to schedule a second trial of 106 STEM during the 2015-2016 school year.

Since the Sentence Algebra method was developed by a mechanical engineer with a masters degree in creative writing (someone who has found an intersection between these two fields that fosters a unique space for teaching engineering writing creatively to engineers), the math-based grammar method exists without a clearly defined and vetted scholarly pedigree. The rogue nature of Sentence Algebra is something that, in and by itself, also invites debate.

Nevertheless, I remain optimistic about both Sentence Algebra and STEM grammar courses finding a home in academe. There is always resistance to new ideas, and ironically, often it comes from seasoned practitioners of methodology that was once revolutionary, but now the norm. Yet in institutions of research and higher learning, there are also many teachers and scholars with pioneering spirit, who believe the best way forward following a positive yet still inconclusive trial is to continue onward, to gather further evidence by repeating the experiment with an improved prototype and improved experimental design.
References


Acknowledgements

I would like to thank Ms. Katelyn Cooper, a junior-level B.S. in Chemical Engineering student at University of California, Davis, for her topnotch research assistance in preparing the Precedents/Contextualization in the Literature section of this paper. She and talented other undergraduates like her, who serve now, and have served in the past, on my engineering writing internship team, are an essential and indispensible source of inspiration, insight, and creative energy for me.
The first person who could really be identified as an engineer was Imhotep, a great physician, architect, and statesman of ancient Egypt. He built the first known pyramid at Saqqara about 2650 B.C. as a tomb for King Zoser. Built in a series of steps, it is known as the Step Pyramid and marked the first recorded use of hewn stone for any structure. Over the next 150 years, many other pyramids were built—undoubtedly our first civil works, built with the manual labor of thousands of people [many of whom, regrettably, were slaves]. These feats were truly remarkable, but for engineering they also marked the first application of arithmetic, geometry, and a smattering of empirical data to solve problems.

[120 words]

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**Sample Represented as a Sentence Chain:**

\[ S^1 \rightarrow S^2 \rightarrow S^3 \rightarrow S^4 \rightarrow S^5 \]

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**Sentence Coding:**

*Parsing into Bn, 1/Bn, and A sentence equations*

(1) *The first person who could really be identified as an engineer was Imhotep, a great physician, architect, and statesman of ancient Egypt.*

\[ S^1 = B_3 = (M_{n1} * N_a * RC(M_{n2})) + V_1 + \{N_p \text{ or } [M_{n3} * (N_{a1} | N_{a2} | (N_{a3} * LP(M_{n4})))]} \]
(2) He built the first known pyramid at Saqqara about 2650 B.C. as a tomb for King Zoser.

\[ S^2 = B_2 \]
\[ = X_s + V_t + (M_{n_1} * M_{n_2} * N_o) \ldots [LP(M_v) * LP(M_v) * LP(M_v)]^E \]

(3) Built in a series of steps, it is known as the Step Pyramid and it marked the first recorded use of hewn stone for any structure.3

\[ S^3 = A \]
\[ = B_{2 \text{ pass}} | B_{5 \text{ pass}} \]
\[ = (VP(M_{n_1}) * (X_o)_s) + V_{t \text{ pass}} * LP(M_n) | [(X_o)_s] + [(V_{aux} * V_t)_{\text{pass}} + (M_v * VP(N_c))] \]

(4) Over the next 150 years, many other pyramids were built—undoubtedly our first civil works, built with the manual labor of thousands of people [many of whom, regrettably, were slaves].

\[ S_4 = B_{2 \text{ pass}} \]
\[ = [LP(M_v)]^F \ldots M_{n_1} * M_{n_2} * (N_o)_s + V_{t \text{ pass}} ... [M_v * X' - M_{n_3} * N_a]^E * VP(M_v)]^E \]
\[ = B_2 \]
\[ = [LP(M_v)]^F \ldots ((M_{n_1} * M_{n_2} * ((N_o)_s) or [M_v * X' - M_{n_3} * N_a]) + (V_{t \text{ pass}} * VP(M_v))) \]
\[ = Over the next 150 years, many other pyramids—undoubtedly our first civil works—were built, built with the manual labor of thousands of people [many of whom, regrettably, were slaves]. \]

(5) These feats were truly remarkable, but for engineering they also marked the first application of arithmetic, geometry, and a smattering of empirical data to solve problems.5

\[ S_5 = A \]
\[ = B_3 | B_2 \]
\[ = (M_{n_1} * N_o) + V_1 + (M_v * M_p) | [(LP(M_v)^F ... X_s + (M_v * V_i) + (M_{n_2} * N_o * LP(M_{n_3})) \]

***
Appendix B: Sentence Cooking Example

Sentence Cooking Example

<table>
<thead>
<tr>
<th>Ingredients</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (nouns)</td>
</tr>
<tr>
<td>rotors</td>
</tr>
<tr>
<td>welder</td>
</tr>
<tr>
<td>truss</td>
</tr>
<tr>
<td>aerospace engineer expert</td>
</tr>
</tbody>
</table>

Recipes

Basic Core Sentence One (B_1)

\[ B_1 = N_s + V_i \]

example: Rotors turn.

explanation: a subject noun (N_s) partners with an intransitive verb (V_i) expressing independent action.

Basic Core Sentence Two (B_2) with one M_v (adverb) and one M_n (adjective)

\[ B_2 = N_s + (M_v * V_i) + (M_n * N_o) \]

example: The welder skillfully mended a broken truss.

explanation: a subject noun (N_s) partners with a transitive verb (V_i) expressing action that transfers onto a noun object (N_o). An adverb modifies the verb, and an adjective modifies the noun object.

Basic Core Sentence Three (B_3) with one M_n (adjective) word group

\[ B_3 = N_s + V_i + (N_p * M_n) \]

example: The aerospace engineer was an expert in fatigue failure analysis.

explanation: a subject noun (N_s) partners with a linking verb (V_i) that links the subject noun (on the left) with a predicate noun (N_p) (on the right) that renames the subject noun. *Here, “in fatigue failure analysis” is a word group functioning as an adjective modifying “an expert” (specifying type of expertise).
**Appendix C: Summary Sheet for End-of-quarter Student Evaluations, 106 STEM**

<table>
<thead>
<tr>
<th>Henderson, Brad FAC</th>
<th>UNIVERSITY OF CALIFORNIA - DAVIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>UWP 106 A01-A04</td>
<td>Student Evaluation of Teaching</td>
</tr>
<tr>
<td>SPRING 2015</td>
<td></td>
</tr>
</tbody>
</table>

**Enrollment**

<table>
<thead>
<tr>
<th>% responding</th>
<th>67%</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Statement</th>
<th>strongly agree</th>
<th>agree</th>
<th>uncertain</th>
<th>disagree</th>
<th>strongly disagree</th>
<th>x</th>
<th>SD</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The instructor made the course objectives clear.</td>
<td>10 30%</td>
<td>10</td>
<td>20%</td>
<td>0</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>2. Discussion was clearly related to course goals.</td>
<td>10 30%</td>
<td>10</td>
<td>20%</td>
<td>2</td>
<td>30%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>3. The instructor encouraged class participation.</td>
<td>13 35%</td>
<td>4</td>
<td>20%</td>
<td>1</td>
<td>30%</td>
<td>2</td>
<td>10%</td>
<td>20</td>
</tr>
<tr>
<td>4. The instructor treated successes with exuberance.</td>
<td>14 35%</td>
<td>7</td>
<td>20%</td>
<td>3</td>
<td>30%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>5. The instructor provided helpful examples to clarify points.</td>
<td>10 30%</td>
<td>5</td>
<td>30%</td>
<td>4</td>
<td>20%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>6. Paper topics were generally challenging.</td>
<td>10 30%</td>
<td>5</td>
<td>30%</td>
<td>4</td>
<td>20%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>7. Paper assignments were clear.</td>
<td>10 30%</td>
<td>5</td>
<td>30%</td>
<td>4</td>
<td>20%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>8. The instructor clearly explained the grading standards for written work.</td>
<td>10 30%</td>
<td>5</td>
<td>30%</td>
<td>0</td>
<td>5%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>9. The instructor graded the written work according to the stated standards.</td>
<td>10 30%</td>
<td>4</td>
<td>20%</td>
<td>1</td>
<td>30%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>10. The instructor encouraged students to take advantage of office hours.</td>
<td>10 30%</td>
<td>5</td>
<td>30%</td>
<td>4</td>
<td>20%</td>
<td>0</td>
<td>0%</td>
<td>20</td>
</tr>
<tr>
<td>11. The course was intellectually stimulating.</td>
<td>10 30%</td>
<td>7</td>
<td>35%</td>
<td>1</td>
<td>30%</td>
<td>2</td>
<td>10%</td>
<td>20</td>
</tr>
<tr>
<td>12. The instructor's comments on my papers helped me understand how to improve.</td>
<td>5 17%</td>
<td>7</td>
<td>20%</td>
<td>4</td>
<td>20%</td>
<td>2</td>
<td>12%</td>
<td>18</td>
</tr>
<tr>
<td>13. The instructor returned papers quickly enough for me to benefit.</td>
<td>5 20%</td>
<td>6</td>
<td>30%</td>
<td>6</td>
<td>30%</td>
<td>0</td>
<td>0%</td>
<td>18</td>
</tr>
<tr>
<td>14. I would recommend this instructor to other students.</td>
<td>10 30%</td>
<td>7</td>
<td>35%</td>
<td>3</td>
<td>30%</td>
<td>2</td>
<td>10%</td>
<td>20</td>
</tr>
<tr>
<td>15. This course gave me a greater understanding of what effective writing is.</td>
<td>9 47%</td>
<td>8</td>
<td>32%</td>
<td>3</td>
<td>19%</td>
<td>1</td>
<td>5%</td>
<td>19</td>
</tr>
<tr>
<td>16. Please indicate the overall educational value of the course.</td>
<td>8 47%</td>
<td>8</td>
<td>47%</td>
<td>0</td>
<td>0%</td>
<td>1</td>
<td>6%</td>
<td>17</td>
</tr>
<tr>
<td>17. Please indicate the overall teaching effectiveness of the instructor.</td>
<td>8 47%</td>
<td>8</td>
<td>47%</td>
<td>0</td>
<td>0%</td>
<td>1</td>
<td>6%</td>
<td>17</td>
</tr>
</tbody>
</table>

*Summarized by the Teaching Resources Center*