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Tagmemics: Using a Communication Heuristic to Teach Problem Solving

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Engineering design is an important skill that is taught at many different levels within an engineering curriculum. ABET defines engineering design as [1]:

> The process of devising a system, component, or process to meet desired needs. It is a decision-making process (often iterative), in which the basic sciences, mathematics, and the engineering sciences are applied to convert resources optimally to meet these stated needs.

Many different versions of the design process exist, but all have problem definition in some form as an early and important step. George Dieter in *Engineering Design* writes [2]:

> Probably the most critical step in the design process is the definition of the problem. The true problem is not always what it seems at first glance. Because this step requires such a small part of the total time to create the final design, its importance is often overlooked.

Engineering students, especially first-year students, often overlook the importance of truly understanding the actual problem that needs to be solved. Cursory attention to problem definition is even more likely if students are already familiar with the problem or it seems straightforward to them upon their initial examination. Yet, as this paper will show, moving past the problem-definition stage prematurely can have serious consequences. One way to help students slow down and focus attention on this critical step of problem definition may be to employ a system developed for problem solving in linguistics, called “tagmemics.”

Tagmemics is a truly multidisciplinary approach to organizing thought. Although it is a subfield of linguistics, tagmemics was originally derived from early twentieth-century theoretical physics. And the man who developed tagmemics, Kenneth Pike, was himself a multidisciplinary man, both a linguist and an anthropologist. His scholarship during the 1960s focused primarily on linguistic application of his new theory, but in 1970 he and co-authors Richard Young and Alton Becker published a widely influential textbook, *Rhetoric: Discovery and Change* that brought tagmemics to the field of writing instruction [3]. Today, 45 years after its publication, *Rhetoric: Discovery and Change* is still cited as a foundational work in the scholarship of rhetoric and composition studies.

The authors of this paper, who represent both engineering and humanities/communication disciplines, are intrigued by the potential of tagmemics for systematically categorizing and ordering phenomena in order to view a problem from many different perspectives and dimensions. There are many examples of designs that did not address the real underlying need and therefore were considered to be unsuccessful, and the issue was not the actual design, but the problem definition. The real value of tagmemics in an engineering context is its contribution to a more thorough approach to problem definition. This paper explains the concept of tagmemics and demonstrates its application in solving an engineering problem (the creation of a better crash test due to deaths and injuries caused by air-bag trauma in front-end crashes) through comprehensive tagmemic analysis.

Background on Tagmemics Theory and Methodology

The beauty of tagmemics for engineering educators is both its simplicity and its complexity. The methodology provides a framework for classifying phenomena but is far more than a mere taxonomizing device. Within the intersections of the grid (**Table 1**) are contained all the static and dynamic relationships among various states of existence and experience. Tagmemics introduces students to a straightforward process for conceptualizing reality and discovering meaning in chaotic, ambiguous environments.

Kenneth Pike (1912–2000) worked in the field of linguistic anthropology. In addition to inventing the tagmemic grid, Pike is credited with originating the terms "emic" and etic" to describe language from both "insider" and "outsider" perspectives. These terms remain well known today in social science fields like anthropology, sociology, and psychology.

An "**etic**" model is based on an "outside" perspective, taking a scientific approach that disregards culture-specific data and instead seeks universal characteristics. Studying language from an etic perspective would emphasize quantitative, empirical research methods characterized by taxonomies that allow data units to be classified and organized into hierarchical frameworks.

An "**emic**" model of language is based on an "inside" perspective, taking into account the unique characteristics of a specific culture. Studying language from an emic perspective would emphasize qualitative research methods like ethnography, an approach employed by anthropologists and other social scientists in which the researcher assumes the roles of participant and observer simultaneously, immersing himself in the society he is studying in order to understand cultural phenomena from the point of view of the subject.

Tagmemics, then, is a methodology that fuses the quantitative/qualitative, outside/inside dichotomy by prompting consideration of both form and function. "Form" is an **etic** perspective that involves classification of units by type and partition of units into their constituent parts. Distance from the subject matter is required to perform this type of "scientific" exercise, and the subject matter itself is treated as static data. "Function" is an **emic** perspective that involves identifying dynamic relationships among units. Close identification with the subject, trying to observe from the perspective of a cultural insider, allows the researcher to collect "rich" data that is deeply contextual in nature.

In some ways the etic–emic divide echoes the cognitive divide found by linguistic anthropologists who study the literacy–orality divide. In general, literate cultures tend toward "higher-level" thought processes, as shown by the ability to understand complex, abstract relationships through taxonomizing strategies like classification. Oral cultures, on the other hand tend toward more simplistic, associational thought processes. In a famous study of oral and literate subjects in Uzbekistan and Kirghizia in the early 1930s, psychologist Alexander Luria discovered that people who live in oral cultures (that is, cultures in which almost no one is literate) recognize "function" more readily than "form." When asked to select three words that went together from the following list—"hammer, log, saw, hatchet"—people from an oral culture did not recognize the obvious choice (to people from a literate culture) that "log" did not belong in a list of tools. Instead they focused on the fact that without the log, the other items had no use. [4]

Cognitive thought processes of non-literate people within a non-literate, oral culture are “emic” and “function” oriented. In contrast, the cognitive thought processes of literate people within a literate culture tend to be more “etic” and form oriented. Engineering students, with their immersion in STEM subjects, have an even greater tendency toward “etic” abstraction and complexity than the general population. Just as people from an oral culture tend not to recognize that “log” does not belong in a list of tools because they think in terms of “emic” function rather than “etic” form (classification), so do engineering students generally tend not to recognize “emic” associations because they think in terms of “etic” abstractions.

It is therefore not surprising that most engineering students enter the design process with an unconscious bias in favor of an etic, form-centric, scientific-distance, quantitative approach to observation and problem definition. For students to view a design problem as part of a larger system—or even multiple systems—requires an ability to morph perspectives, to develop an insider’s “feel” for the context while maintaining an outsider’s detachment.

Tagmemics provides a heuristic framework for capturing data from both etic and emic perspectives. Teaching students to perform a tagmemic analysis may lead to improved engineering design skills—especially because the variety of contexts and perspectives captured increase the likelihood of better problem definition in the first place.

The tables below illustrate the concept of tagmemics in a progression from pure definition (**Table 1**), to a more detailed definition (**Table 2**), to a simple application (**Table 3**).

Table 1
Tagmemics Heuristic Procedure
(adapted from *Rhetoric: Discovery and Change*)

Etic → Emic ↓	**Contrast (1)** identifying features that distinguish it from similar things	**Variation (2)** how much it can change without becoming something else	**Distribution (3)** where it belongs (where it can be found, where it fits into the larger context)
Particle (A) isolated, static	(A1) an entity	(A2) an instance, a specific variant form of the concept	(A3) an element of a larger context
Wave (B) dynamic	(B1) an event	(B2) a dynamic process	(B3) part of a larger, dynamic process
Field (C) relational (views the "whole" as the sum of its "parts"; classifies the type of organizational relationship the component parts have with each other)	(C1) a system	(C2) a multi-dimensional system, containing multiple subsystems and engaged in relationships with other systems	(C3) a system within a larger system

Table 2
Definition of Tagmemics, from *Rhetoric: Discovery and Change*, by Richard E. Young, Alton L. Becker, and Kenneth L. Pike, 1970

Etic → Emic ↓	**Contrast (1)** identifying features that distinguish it from similar things	**Variation (2)** how much it can change without becoming something else	**Distribution (3)** where it belongs (where it can be found, where it fits into the larger context)
Particle (A) isolated, static	(A1) View the unit as an isolated, static entity. What are its contrastive features, i.e., the features that differentiate it from similar things and serve to identify it?	(A2) View the unit as a specific variant form of the concept, i.e., as one among a group of instances that illustrate the concept. What is the range of physical variation of the concept, i.e., how can instances vary without becoming something else?	(A3) View the unit as part of a larger context. How is it appropriately or typically classified? What is its typical position in a temporal sequence? In space, i.e., in a scene or geographical array. In a system of classes?
Wave (B) dynamic	(B1) View the unit as a dynamic object or event. What physical features distinguish it from similar objects or events? In particular, what is its nucleus?	(B2) View the unit as a dynamic process. How is it changing?	(B3) View the unit as a part of a larger, dynamic context. How does it interact with and merge into its environment? Are its borders clear-cut or indeterminate?
Field (C) Relational (views the "whole" as the sum of its "parts"; classifies the type of organizational relationship the component parts have with each other)	(C1) View the unit as an abstract, multidimensional system. How are components organized in relation to one another? More specifically, how are they related by class, in class systems, in temporal sequence, and in space?	(C2) View the unit as a multidimensional physical system. How do particular instances of the system vary?	(C3) View the unit as an abstract system within a larger system. What is its position in the larger system? What systemic features and components make it a part of the larger system?

Table 3
"The Pencil" Defined by Tagmemics

Etic → Emic ↓	**Contrast (1)**	**Variation (2)**	**Distribution (3)**
Particle (A)	The pencil is a writing/drawing instrument with a graphite/lead core. Usually about ¼" in diameter and less than 12" long.	A pencil can vary in the color of graphite/lead. It can be a "mechanical" pencil, with individual graphite sticks that are inserted into the plastic or metal core and advanced by twisting or pumping motions	The pencil is part of a class of handheld writing/ drawing implements such as, pens, crayons, styluses, markers, charcoal sticks, pastel chalks, etc. The pencil assumed its commonly recognized form in the late 16^{th} century, following the discovery of graphite.
Wave (B)	The pencil is held in the fingers and its graphite point is pressed and dragged/pushed across a surface, usually paper, leaving marks. These marks are semi-permanent; they will last indefinitely but can be erased.	The lead wears down as it is used to write and transfers to the writing surface. Either the wood surrounding the graphite core is then sharpened to expose more graphite OR the graphite stick is advanced beyond the tip of a mechanical pencil. Erasers also wear down as they are used.	The No.2 pencil is used by people when taking many important standardized tests, such as the ACT or SAT. This pencil's soft lead creates a mark inside the circle next to the answer selected that is then read by a scoring device.
Field (C)	The pencil is composed of an outer shell surrounding a core of graphite. At one end (the end used for writing) the graphite tip is exposed. At the other end there is usually an eraser. The pencil casing can be hexagonal, cylindrical, or rectangular.	A mechanical pencil incorporates a system for advancing fresh lead as the exposed tip wears away. A mechanical pencil's casing may contain space for storing extra leads and erasers to replace worn components. The "wear" rate varies with pressure applied to the writing surface and the speed with which the user writes.	The pencil is an essential part of formal education, used in standardized tests and essay exams. In an age when a student typing an essay exam on a computer might cheat by cutting and pasting text from the internet or receiving text via email, having students write their essay with a pencil safeguards the exam's integrity.

In summary, tagmemics is a systematic approach that can be used to describe and understand phenomena. In linguistics it is used to describe and categorize words. In the field of rhetoric and composition studies (writing instruction), it is used as an invention heuristic to generate content for essays. In engineering the approach can help students explore a potential problem in order to understand what is really needed in the solution to ensure that the true problem is addressed.

Using Tagmemics for Better Problem Definition in Engineering Design

In teaching the importance of problem definition in a freshman engineering design class, one example that clearly demonstrates the consequences resulting from inadequate problem definition is the history of air-bag issues in motor vehicles in the United States.

By 1995 it had become apparent that something was going terribly wrong in the deployment of air bags in motor vehicles. A significant number of deaths (284 as of January 1, 2008) and severe injuries had been suffered by children and small-statured adults when air bags deployed during front-end crashes—sometimes during minor collisions at low vehicle speeds, when injury might not have occurred in the absence of air bags [5], [6], [7]. In particular the at-risk population was found primarily to be [7]:

- Infants in rear-facing child restraints
- Short-statured and older adult drivers (mainly women) sitting too close to the steering-wheel air bag
- Right-front passengers (particularly unrestrained children) out-of-position due to pre-impact braking

Initial responses to the deaths and injuries included extensive educational efforts about seatbelt use, seating distance from the steering wheel, and placement of child safety seats in the rear—in other words steps aimed at preventing the situations in which they tended to occur. States passed mandatory seatbelt laws and stepped up enforcement. Additional warning labels about the dangers of air bags were installed in vehicles. Aftermarket installation of "on–off" switches was allowed for any owner who submitted a request form to and was granted approval by the National Highway Traffic Safety Administration (NHTSA). Finally, NHTSA made a commitment to improve the testing of air bags and crash protection for children and other small-statured occupants [7].

One reason for the unusually high number of deaths and injuries among these populations with the "First Generation" air bags was that the problem to be solved was defined in terms of protecting unbelted, larger-statured adults in a front-end crash traveling at a high rate of speed. Federal Motor Vehicle Safety Standard No. 208 Occupant Crash Protection (FMVSS No. 208) required air bags to protect a 50th percentile adult male dummy, unbelted, in a head-on crash at 30 miles per hour, at all angles between perpendicular and 30 degrees to either side [6]. Air bags had to deploy with adequate force to meet that design specification.

Yet the specific components of the NHTSA test requirement were not intuitively and universally appealing to the agency's counterparts in Europe, Canada, Australia, and Japan—which developed their own specifications and procedures that simulated the dynamic conditions of frontal car-to-car crashes, which are commonly "offset" rather than squarely head-on and which involve two deformable objects rather than the rigid block used in the American test. The European procedure tested for results at 60 kph (37 mph) or greater. Additionally, the European tests did not involve unrestrained dummies, as seat belt usage in European nations was 95%. And finally, the European tests' injury criteria included a "lower limb response," which the U.S. FMVSS No. 208 did not [8].

The point of all this background information is to focus attention on the commonsense proposition that one problem may prompt several different understandings of how that problem should be *defined*. Sometimes inadequate problem definition arises from limited data; sometimes, from an impoverished worldview and knowledge base. Sometimes cultural values shape the problem's appearance: for example, in industry the field of "knowledge management" is viewed variously as an IT problem, a human resources problem, a library-science problem, or an interpersonal/organizational communication problem depending on the domain of the person trying to describe it. A human resources approach to defining a knowledge-management problem will be very different from that of an IT professional.

To solve a problem, therefore, the first requirement is to define that problem as accurately and precisely as possible—because only then can there be reasonable certainty that the correct problem is being solved. Solving the wrong problem can usually be corrected; after all, trial-and-error and multiple iterations are fundamental problem-solving techniques. But in a case where the stakes are high—life-and-death, in the instance of air bag testing regulations—relying on a more thorough, comprehensive problem definition in the first place is a moral imperative.

Tagmemics may be one approach to expanding engineering students' view of the complexities of problem definition. Its greatest strength is that its grid-like model provides both a closed and an open universe. It guides users through a systematic inquiry of the subject, forcing examination of the topic from many angles. Yet, it does not limit the amount of information in any area of the grid or automatically favor any one perspective. What tagmemics does is this:

1) Draws out existing knowledge on the subject, from both "emic" and "etic" perspectives
2) Identifies areas in which more information or exploration is needed
3) Organizes many disparate bits of data and information into a logical framework

The following table (**Table 4**) is an example of the types of questions that could be raised and the further inquiry needed to describe/define a problem statement for the design of an improved crash test.

Table 4
"Frontal Impact Crash" Defined

Etic → Emic ↓	**Contrast (1)**	**Variation (2)**	**Distribution (3)**
Particle (A)	A front-end collision (or, crash) occurs when a vehicle collides with another object head on. Any living entities involved, including people and animals, are considered part of the front-end collision event. The event is distinct from crashes involving other modes of transportation (motorcycles, bicycles, mass-transit vehicles, even human-centric modes like walking, rollerblading, or Segway riding). (A1) Viewed as an isolated, static entity	A front-end collision is not one universal type of experience. Specific instances of a front-end crash will vary from one another depending upon factors like materials, design, systems (air bags, restraints, braking), road conditions, tires, and human factors. Recently front-*angle* collisions, which are not directly head-on, are becoming considered as falling under the definition of a "front-end" collision? (A2) Viewed as a specific variant form	A front-end collision is one type of crash involving a motor vehicle. Other types are rear-end crashes, rollover accidents, right-angle/T-bone collisions. (A3) Viewed as part of the larger context
Wave (B)	In a front-end crash, a vehicle and/or one (or more) other vehicle(s) or object(s) collide. A front-end crash begins at the moment of contact between the vehicle and other object(s); it ends when all energy transfer has been completed. (B1) Viewed as an event	The front-end collision has changed over time as vehicle design and materials have changed, tire design has changed, safety restraints and other safety features (e.g., safety glass) have changed. Also, changes in road design, speed limits, and traffic laws have altered the nature of a front-end collision. (B2) Viewed as a dynamic process	A front-end collision occurs within the larger system of vehicle operation: design of roads; speed limits; design of guardrails, road signs, light poles; design of parking lots and ramps/ structures. (B3) Viewed as part of a larger, dynamic context

Field (C)	In a front-end crash, there are several different components and forces at work and interacting with one another. The most significant is energy transfer, but mechanics components such as deceleration and crumple are also important. Human factors should also be considered in this system of interactions. (C1) Viewed as a system	Each component and force mentioned in C1 is a system unto itself. The state of each system can vary according to temperature and weather conditions, failure of a single sub-component, wear, speed, and varying human factors. (C2) Viewed as a system containing subsystems	The front-end collision belongs to a class of systems (accidents/ crashes) in the larger class of auto/vehicle safety, which in turn belongs to an even larger class of transportation safety. (C3) Viewed as a system within a larger system

In the process of using the matrix, important questions can be raised that encourage the exploration and inquiry of additional information that allows the problem/need to be understood and defined correctly. The problem/need can be viewed not only as an entity (particle), process (wave) and part of a system (field) but also within the framework of "how it is different" (contrast), "how it can vary and still remain what it is" (variation) and "how it fits within its context" (distribution). The above example is a thought exercise and just represents the starting point. One could envision a number of different problem statements with very different criteria and constraints depending on how the questions raised are answered.

Conclusion

The authors believe that tagmemics, which has its roots in linguistics, has the potential to assist engineering students in describing and understanding complex problems. The authors plan on using the technique in the 2015/2016 academic year with first year engineering students in both the beginning engineering design course and in first-year general studies courses (a sequence combining study of humanities/social-science topics with communication skills).

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