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Metaphorical Language in Engineering Texts: English for Specific Purposes in STEM Context

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Abstract

In engineering degrees, functional language courses are generally taught in simple language. Despite universities' ongoing efforts to prepare ESP learners for effective communication which is a need of the workplace, they are rarely taught practically how to craft lay-friendly explanations through metaphorical language. However, recent research claims that metaphorical language would be more effective if it is infused with language teaching as it helps to connect new concepts with base engineering knowledge. In this regard, the exposure to metaphorical language was given to engineer students under the treatment group through reading comprehension-based activities, while the control group learned the same activities without metaphorical awareness the quantitative results were obtained by comparing the posttest of the control group and treatment group in which positive association was achieved between scientific text and language learning. This study provides an opportunity for improving the pedagogical ways by giving metaphorical awareness to students in teaching language ESP context.

Keywords: Metaphor, Scientific Text, Metaphorical Awareness, Language Teaching. ESP

Introduction

It is hard to overstate the significance of metaphorical language in human thought, language, and their related experiences of life. Over centuries, particularly in the last four decades with intense focus, the metaphor has been defined, theorized, and applied to different fields and sometimes in an unusual way. Nonetheless, a substantial agreement is built that metaphorical language bridges two different entities, so that we can think, experience, and communicate in different terms also. As we commonly hear, inanimate objects are associated with human qualities such as intelligent machines, mind as machines, or emotions as external forces. This mechanism of thinking stretches our ability to feel, reason, and broaden our horizon of communication in versatile ways that are characteristically human (Liu et al., 2018).

Generating and interpreting metaphorical language either through related or unrelated objects, attributes, people, ideas, and phenomena remain the center of human communication in different contexts including education. As educators, much of our instruction relies on explaining ideas, theories, facts, and experiences to our students. Particularly in technical or scientific courses, instructors usually need to explain abstract concepts and theories. Mostly, these abstract concepts are explained with concrete ideas and objects in the form of metaphors, analogies, and metonymies-like devices to connect new ideas with the existing knowledge of the students. This pedagogical approach is found to be useful in different fields including the field of engineering (Nilsson et al., 2014). However, while learners may acquire technical or scientific knowledge based on metaphorical language explanations and they might be influenced by the subsequent use of these metaphors in scientific curricular text (Sergio de, 2014], they are hardly taught how to formulate their own creative scientific explanations. Darling and Deanna (2003) pointed out that generally, this type of explicit teaching occurs mostly in university-requirement (UR) writing courses rather than in technical courses, yet the latter may need to explain complex scientific ideas that require the translation of engineering concepts, data, and developments using rhetorical situations. Contrary to that, the other claim rejects the use of metaphorical language in teaching and learning scientific ideas as it may cause problems, ambiguity, and mislead original scientific ideas. (Cameron, 2003). To extend this view further, Littlemore (2005) observed that although the use of metaphor is rarely observed by ESP learners, evidence shows that with intense training in using metaphorical language, intermediate students can employ it proficiently in their academic debate. In this regard, this study aims to find the comprehension ability of scientific curricular text through metaphorical awareness. Moreover, it also explores how effective metaphors are used by the students in writing activities based on given scientific curricular text.

Literature Review

Metaphorical language is considered as unambiguous communication and creates ease in language learning for ESP students. In some cases, several notable linguistic features are considered exemplary in the discourse of civil engineering. Although taught with plain text, students acquiring technical education have trouble conceptualizing the content. Studies (e.g., Janus & Bever, 1985; Liu, 2012) claim that this skill is absent because literal language is primarily used in teaching/communication in the belief that doing so is necessary to explain concepts and eliminate any space for uncertainty, thus enhancing scientific learning. Contrary to this view, it has been suggested that because metaphorical language requires greater creative and cognitive involvement, the use of metaphorical language, which may seem challenging to understand by students, actually plays a vital role in the development of science and critical thinking (Janus & Bever, 1985). Therefore, the controversy remains unsettled about whether metaphorical language promotes the scientific conception of learners in comprehending the English language.

Usually, for engineering education, metaphorical approaches can play a vital role. For example, engineers are concerned with avoiding transport barriers, such as a river, creating an effective bridge, or connecting two distant towns through a highway. The bridge's structure must satisfy standard requirements and technical specifications, such as the ability to combat opposing forces and hold different loads across its deck. On the other hand, any bridge is located in a particular location and surrounded by a unique setting. How do undergraduate engineering students at the university level deliberately use metaphorical language in learning English to play a role in their success in innovative science tasks, and students taught in the experimental community perceive the contribution of the use of metaphorical language to the growth of their scientific comprehension of ideas (Liu, 2012)?

According to the pragmatic interaction approach, metaphorical language is a matter of contact among language users (Adams, 2002). Metaphors are related indirectly to the related parallels between the two things, phenomena, etc. Moreover, it acts as an aid to the imagination of scientists. For instance, virtually at all levels of physics, the metaphor works. Essentially, it is used as a linguistic tool by implementing the word for one item to another, giving relevance between both versions. This didactic method is often carried out on a one-word framework, restoring the widely recognized word physicists usually describe as the model to a comparatively unknown word. This replacement refers to the conceptualizing metaphor of Aristotle's intuition. One of his suggested meanings was that a metaphor is a transposition of an "alien" term, which is a name that belongs to “something else”. Taking the notion of transpositional motions occurring in modern physics, “Transposing the Unseen: The Metaphors of Modern Physics” (Fitje) commonly refers to these transpositions as metaphors. Not just linguistic or perceptible maneuvers, he finds such substitutions as a venture of imagination or inventions of mind that take their flight. The one-word metaphor in physics today is no longer part of the alien concept but belongs to the familiar one (Gerring, 1999).

The replacement venture now takes on the unfamiliar notion and replaces it with an older, familiar, and more developed one to generally discuss increasingly theoretical scientific ideas. The metaphor of one word works as a reduction, distinguishing the divergence between foreign and familiar concepts from each other. However, modern physics often has a metaphoric character that is more active than a direct comparative quality: an evocation of the interconnection between objects, knowledge of duality, and a semblance of two distinct senses as one. In these terms, the metaphor may be regarded as the very creation of things, blurring the gap between them and their names (Schön, 1979). More generally, the metaphorical vocabulary used in the field of physics refers not only to linguistics but may also affect the process of scientific thinking. At best, it reflects mental fertility, an imaginative ability to recreate an old concept in the light of something new. In explaining modern scientific terminology, it has been expressly noted in the book *The Language of Modern Physics* that scientists need a metaphor: Metaphors are used to give our terms a more concise meaning or to add a significant nuance when words generally used in a given context seem to fail, we seek support with words that usually belong to another context. In this way, the use of our usual expressions is extended; this is important if we want to build up a scientific vocabulary to explain an artificially generated experiment in the laboratory (Hutten & Hutten, 1956; Redman & Maples, 2017). We talk of the field of force in physics, the movement of heat, and so on. Indeed, without metaphorical words, technical discourse cannot do so.

Science learning can be characterized as exchanging prior knowledge, concurrent experiences, and information accessed from print and other sources in a particular social context based on meaning development. By alternating between text-based (print, chart, and image) and similar experiences (specific questions, conversations, and thinking), readers process information interactively and associate information and experiences with their knowledge (topic, domain, scientific enterprise, textual, strategic). To establish practical explications (models) of the short-term memory scenario, personal information is collected from the long term. It can be either derived from text, other people, and parallel experiences and then assimilated into information structures acquired from long-term episodic and semantical memories or accommodated by reorganizing their knowledge structures as they are tracked and planned strategically (Pears et al., 2007). Cognition, therefore, is an interactive constructive process, and metacognition is an awareness and regulation of this generative process, leading to information being managed, organized, and re-conceptualized into functional knowledge networks.

English as a Second Language (ESL) students pursuing any degree in science-related fields are expected to pursue a severe system of academic reading (Hesse, 2020) of scientific texts in the English language with comprehensibility, irrespective of the extent of the material and linguistic difficulties. Dense and lengthy textbook chapters and complex prose of additional reading assignments are common and involve complex reading processes. Unfortunately, the critical challenge ESL readers face seems to be difficulty understanding authentic scientific, academic texts, as they are mostly informatively thick, syntactically complex, and linguistically and conceptually domain-specific.

Reading is as much about interpreting the language representations of the written text as it is about the involvement of the thoughts of the writer and reader. This is because as the reader decodes the white page linguistic prints (Holliday et al., 1994), they begin to create the context intended by the writer at the same time by combining knowledge with what they know about the subject in the text and thereby creating a situation model based on the text material content. The method of the reader's reconstruction of meaning is very complicated and incredibly complex. As the eyes of the reader fall on the printed words, multiple sources of knowledge will function simultaneously presented by the text, such as feature extraction, orthographic knowledge, lexical knowledge, syntactic knowledge, and semantic knowledge (Adamuti-Trache & Sweet, 2014) and prior knowledge.

Research on reading (e.g., Hamid & Samuel, 2011; Kim et al., 2018) has addressed what techniques for L2 readers work or do not work. Lower L2 readers have been found to use more bottom-up processing or lower cognitive strategies, whereas experienced L2 readers have used top-down or higher cognitive strategies. Reading for global understanding also leads to good reading, while reading for local understanding does not. L2 reading technique guidance for academic purposes in English has also promoted the use of higher cognitive techniques such as inference (Storch & Whitehurst, 2002) recognizing the structure of the text, and triggering prior awareness. It is stated that the empirical method is "a more productive learning approach to improve the learning outcomes of students; learners are an active learning subject or learners are the subject of the learning process. To support the demand of the learning process in this curriculum, (Stanovich, 2000) notes that five stages of learning activity must be carried out in the learning process:

1. Empirical study
2. Analytical curiosity creation through questioning
3. Critical thinking building
4. Exploration
5. Communication

Therefore, the 2013 Curriculum of Indonesia emphasizes the modern pedagogical dimension of learning using a scientific method (Hosenfeld, 1977), the scientific approach is emphasized in the 2013 Curriculum as one of the leading learning approaches. In the 2013 curriculum sense, learning in the scientific method is usually divided into five main phases. They observe, inquire, experiment, interact, and communicate with others. Reading and writing are crucial for a good learning process for college students. Therefore, as writing expresses knowledge in print, students must have information to share before writing (Horiba, 1990). Topp et al., (1980) discuss that by learning, we do not learn to write but rather by reading. It implies that both simultaneously and longitudinally, reading and writing are substantially related. Writing, by its meaning, is the creation of correspondence, the linking of ideas, and the development of knowledge or the giving of arguments to a single reader or a community of readers. This description means that writing is the development of the written form of the ideas conveyed. The reader and writer need to obtain and process information as much as possible before the writing is done. This assumption is in line with the ideas of Kellogg that reading and writing a significant cognitive task since it is a memory, vocabulary, and reasoning skill test at once (Vogelstein et al., 1989). In particular, Abidin (2014) discusses that academic reading and writing is a course intended for college students to learn effectively as they have to do tests, coursework, thesis, or final project report college assignments.

The reading process is a collective event that is affected by context, requires internal control, and uses higher-order thought (Krashen, 2016; Suskie, 2018). As a consequence of their interaction with each other, social constructivism focuses on the creation of cognitive processes that exist within individuals. This implies that reading-related cognitive processes no longer exist solely in the person; instead, they are seen as being pushed out of the privacy of one's head and into contact. Kellogg (2018) suggested that the active position of readers uses print clues to create a sense model of the text (Redman & Wendy, 2017).

Material and Methods

As this study deals with language learning issues in ESP classrooms for engineers, mixed methods were used with a pragmatic worldview. This quasi-experimental study was conducted to compare the results between the control group and the treatment group. In this regard, the treatment group was given metaphorical exposure to reading and writing activities while the control group was taught without metaphorical awareness in plain reading and writing activities. The intervention plan set of five different activities was designed based on reading passages and writing activities. Later the posttest was conducted to compare the results with the control group who were also taught a set of these activities with traditional methods based on plain language teaching. The material was selected from engineering curricular books having the contents of Vector Calculus, Physics, and Thermodynamics. Different reading passages were selected and based on that different comprehension exercises were developed. They were designed to check the understanding level of both groups. Fifty students were selected from each group of engineering classes at the undergraduate level from an autonomous engineering university. After quantifying the results, the qualitative analysis was drawn with former studies.

Results and Discussion

Table 1
Summary of Treatment Group

R	R^2	Adjusted R^2	F Change	Significance Value (p)
158	.025	.18	3.796	.043

Table 2
Summary of the Control group

R	R^2	Adjusted R^2	F Change	Significance Value (p)
.170	.029	.22	4.417	.067

The regression test was applied where students' performance was tested after the intervention plan. It was separated into two groups, a control group and a treatment group. Language instruction was given to the control group without considering metaphorical awareness.

The result of alpha predicts that there is no relationship between the metaphorical text as the dependent variable and language learning as an independent variable because the value of significance is higher than 0.05 as it lies up to 0.067 in the control group and 0.043 in the treatment group, which shows that there is a positive relationship between language learning and scientific text. The tables estimated through SPSS show that although the significance value was achieved the effect of beta values is inverse. The Beta value in the Coefficient of the post-test predicted negative value lies in the figure of -0. These negative signs predict that results drawn on the scientific text (DV) did not rely on language learning (IV). The result shows that proficiency in comprehending text would also enable the students to comprehend scientific text effectively even without metaphorical awareness. In comparison, those who could not comprehend general reading could also not comprehend the ESL/ESP text.

Analysis

Use of Metaphor in Scientific Discourse

For centuries, philosophers of science and scientists have challenged the use of metaphor in scientific discourse. However, a close look at this discourse shows metaphor as a critical and essential instrument in forming scientific terminologies and hypotheses. It is an implied comparison of two things that are different. These two are referred to as the tenor, the primary subject or the object being mentioned, and the vehicle which is the secondary subject or what the primary subject is contrasted to. For example, the moon is the tenor (primary subject) in the metaphor the moon is a pumpkin, and the pumpkin is the vehicle (secondary subject). A detailed discussion of a subject is presented by knowledge discourse. Exploratory dialogue discusses a problem and tentative ideas or problems involved in a topic and alternative beliefs. Scientific discourse posits and supports a hypothesis about a subject, either inductively or deductively. The focus is on scientific writing, while insightful and exploratory discourse can also be extended to consider.

Each kind of referential discourse has its own style, but there are apparent similarities in the stylistic features of science, informative, and exploratory discourse. Objectivity is the great virtue of the scientific style. Most of this style's semantic and grammatical characteristics derive from science's objectivity, the effort to replicate truth as accurately as possible. Referential discourse as a whole is dominated by reality. It has a style of simple. However, metaphor has historically been related to being defined as the literary target through which language draws attention to itself, an objective that is opposed to that of referential discourse. Since the scientific researcher aims to approach reality by creating precise hypotheses and verifiable findings in terms of empirical reality, the terminology used in science must be straightforward and simple to understand (Celce-Murcia & McIntosh, 1991). Therefore, many philosophers of science have eschewed imagery, including metaphor, in theory, even though scientists frequently use metaphors in their writing. Aristotle deplored figurative language as excessive and in contrast to objectivity, stating that a metaphor is one of the marketplace illusions. Ultimately, despite the accusations against figurative language, in performing three tasks, metaphor is useful, often essential: constructing terminologies, explaining abstract ideas, and developing hypotheses.

Metaphorical Language Competence Development in Scientific Texts

Metaphors are a resource type based on analogy reasoning, which assumes that it is characteristic of removing an explicitly comparative particle. The main objective of this article is to contribute to a broader understanding of pedagogical issues focused on making the reasoning structure used in the classroom well-known to science students. The study focuses on SET for the improvement and usefulness of writing and reading based on STEM teachers (Flower, 1989). It is a case study focused on the use of metaphors in a specific course that seeks to investigate the method and efficacy of using metaphors as interpretive and explanatory models of scientific phenomena in teaching and learning processes. Recent developments in cognitive linguistics have emphasized the significance of metaphor in language and its ubiquity.

In particular, research into forms and structural characteristics of metaphor has come a very long way in the last thirty years, and this problem has been discussed among scholars effectively. In particular, while ESL learners seek to navigate and understand scientific curriculum texts in a language other than their mother tongue, the aim of technical communication and English courses for learners is not to develop their understanding of the metaphorical language in scientific discourse. Instead, students are taught using the plain text approach that impedes their ability to understand their curricular texts in science subjects and their ability to write in their disciplines effectively. In this sense of understanding, the spirit of the time for the metaphor to make significant progress in mainstream pedagogical practice (Yager, 1983) and the design of teaching materials in the classroom to make students understand science.

Metaphors Usage in Scientific and Engineering Education

As discussed earlier, English is an important language treated with attention in all institutions, just as metaphors play a crucial role in scientific thought and communication. The metaphor refers to an attempt to construct a language, particularly a metaphysical one, which necessarily involves having a certain amount of data for which a language is constructed-expressed or unexpressed. If this data set is expressed, it may be in the form of an informal language of common sense (Boyd, 1979) or, if it is not expressed, a meaning or remembrance or any other entity. However, the general structure of languages is possible without first taking the object domain to be used as an area for interpretation. There are already several languages for special object domains, such as Euclidean geometry, mathematical physics, etc., and we can compare them to see the existing uniformities. Research on metaphor forms, structures, and functions (e.g., Richards, 2008) has taken a lot over the last three decades. Several writers argued that many research findings had severe implications for second language teaching and learning. However, it took a long time for a metaphor to move significantly toward mainstream education practice and material design for teaching. Even now, few commercial second-language courses are available that teach the metaphor of colorful phrases as anything but the foundation.

The metaphor is prevalent in everyday communication. It is known for helping individuals to understand complex problems, communicate effectively, and influence others. The usefulness of the metaphor is reviewed in the study, and significant findings and disputes are described while recent experimental and theoretical developments are emphasized. Metaphors reflect fundamental conceptual representations and processing, a vision connected to Layoff and Johnson's ground-breaking conceptual metaphor theory. Recent research examines whether and how metaphor shapes attitudes and thinking and outlines specific cognitive, emotional, and social forces that moderate the effectiveness of metaphorical decision-making. Metaphoric language and imagery often occur in systems of conventionalized metaphors (Osborne et al., 2004). For instance, time, love, change, etc., refer to physical motion in space in some way. However, metaphors are sometimes generated without a clear link with the existing metaphor systems.

To preserve the currency and quality of degrees, it is essential to review and improve engineering curricula continually. There are numerous drivers, including the need to keep pace with rapid technological development to review and update the curriculum. Ultimately, changes in social expectations aligned with legislative changes and regulations on engineering. In engineering, technological innovations mean that monetary policy and the link between the engineering curriculum and the technology of industry require constant attention. As a fundamental concept, engineering is relatively stable (e.g., energy conservation, chemical corrosion, and fluid mechanics). However, technological innovation means that in the field of technological examples (Gruenewald, 2003) such as Nano-technology-based solar photovoltaic cells, the corrosion characteristics of new alloys, and the reverse-osmotic-water treatment behavior, we must keep pace with current professional practice applications. The need to keep engineering curricula up to date with social and political pressures, which are increasingly influencing the daily work of engineers, is a second element of the currency. Moreover, growing community concerns about sustainability issues have led modern engineers to consider the broader impact of technical decisions (e.g., life cycle analysis, environmental footprints, triple accounting) and to mobilize and solve problems in a broader range of actors (e.g., community consultation, deliberative demo works). Social and political pressures are emerging and mean that specific tools and attributes must now be included in the curriculum for engineering to enable graduates to properly apply their technological knowledge in socio-political contexts (Liu & Singh, 2004).

Discussion

The study was dedicated to understanding and using metaphorical language by the STEM students. The integration of the language form with the metaphoric context and meaning has been achieved through metaphoric expression teaching in conjunction with conceptual metaphor awareness-raising activities. According to Boers (2004), these characteristics aid learners in realizing how broad metaphors in ordinary language help them become more conscious of the systematic use of linguistic metaphors. It also introduced conceptual metaphors, especially in the source domain. These include encouraging metaphoric expression and increasing the learner's awareness of the possibilities. According to Boers (2004), metaphoric notions should be organized into a vocabulary group based on general metaphoric themes. Thematic lesson preparation for conceptual metaphor awareness can provide a broad framework for integrating metaphoric expression into conceptual metaphoric themes.

The assessment was used to judge students' performance using metaphorical devices. Metaphors try to make the unexpected familiar and the unusual approachable by generating concrete example that connects with an audience in accessible, memorable ways. Although teachers frequently utilize metaphors, most students need formal instruction on communicating technical concepts to a wide range of audiences. The ability of L2 learners to analyze metaphors is substantially based on five psychological mechanisms, according to Littlemore and Low (2006a). Activation of source domain knowledge, noticing, analogical reasoning, associative fluency, and image formation are all part of these activities. According to them, these strategies should help learners focus more on the relationship between the target domains and the source, allowing them to understand better how metaphors work. During the research, it was observed that students used metaphor, primarily analogy, metaphors, and similes in an organic way to educate their audience and achieve lofty goals in the presentations evaluated in this study. They used metaphorical techniques in their technical writing, demonstrating an effective effort by the students to modify their communication to explain technical concepts to their target audience clearly. Most students have implied the idea of source and target domain and successfully used them to create meaningful writing. In their writing, metaphorical devices were spontaneously produced, and all of them were well-worn. However, fewer students used the techniques of metonymy and synecdoche in their writing, which showed they were less valuable than the other techniques in conveying their ideas in scientific writing.

Conclusion

To conclude it can be said that linguistic studies have shown that using metaphorical terms in natural language across many different fields of discourse, including academic discourse, is common. Overall, the study seeks to narrow the distance between the expectations of effective conceptualization and teaching patterns in Applied Linguistics by emphasizing the importance of relational properties to metaphor in science learning. Focusing on metaphors in science and relating them to metaphors in art also opens up new avenues of thinking about creativity in science. During this study, it was observed that metaphorical language positively impacts scientific writing. Levy and Godfrey-Smith (2020) suggest that science is "both a creative endeavor and a highly regimented one." Metaphors can also be a significant feature of innovative science at the level of science as a collection of socio-political institutions. Metaphors can appeal to the eye in various ways and help the unfamiliar feel familiar.

It has been argued that using metaphorical language in teaching and general communication will better achieve curriculum learning objectives. This practice is beneficial for all stakeholders on one hand, while on the other hand, it allows the professional development of teachers to improve their language teaching methods by using metaphorical language and making the language learning process successful and exciting for students of science and technical subjects.

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