Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6, 7300-7309
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i6.3583

Enhancing students' comprehension of metaphoric terms in physics

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Abstract: This paper aims to dwell on students' perceptions and attitudes towards metaphoric terms and some approaches that contribute to the comprehension and acquisition of basic physics metaphoric terminology for 1st-year undergraduate engineering students. Physics English terminology comprehension and acquisition is of great importance when it comes to these students. Being the *lingua franca* of today, mastering the basic terminology of the respective field of interest in English is demanding for everyone who aspires to have a deep understanding of their field of interest and a prosperous career in the future. To have an effective input and output in the teaching/learning process a collaboration among professionals of STEM (science, technology, engineering, and mathematics) and ESP (English for Specific Purposes) is necessitated. Physics is fundamentally dependent on abstract notions that frequently lack tangible counterparts, such as in these metaphoric terms "*tunneling effect*" or "*black hole*". Concepts expressed through such metaphoric terms assist students to envision, conceive, and acquire the latter, but can also hinder their understanding of concepts. To conduct this research, a semi–structured questionnaire was handed to 100 students of Polytechnic University of Tirana to investigate their beliefs towards these terms and to determine different approaches that will contribute to their understanding of the above-mentioned terms. The results concluded that students face challenges in comprehending a metaphoric unknown term. Nevertheless, the results indicated that the most used and preferred approaches to learning these terms are related to the professor's assistance with explanation, analogy with everyday experiences, and visual aids, videos mainly. This study highlights the importance of collaboration between STEM and ESP in combining the linguistic-semantic nature of terms and their practical application in the function of students' terminology acquisition.
Keywords: *Comprehension, Engineering, Metaphoric term, Physics.*

1. Introduction

In an increasingly globalized world, English has established its role as the universal language, especially in fields related to science, technology, engineering, and mathematics (STEM). For students in engineering disciplines, mastering English terminology, particularly in physics, being one of the pillars of their academic formation, is essential to participating meaningfully in their future work environment. This terminology deals with fundamental concepts related to engineering. Acquisition and comprehension of this terminology is somehow mandatory and a crucial educational goal for students of most engineering fields.

Physics terminology relies on abstract and complex concepts that in most of the cases lack physical counterparts. This fact paves the way of a challenging path in understanding the concepts and acquiring their respective terms. Many basic physics phrases are provided figuratively through metaphors in order to bridge this chasm, encapsulating intricate ideas within recognizable linguistic structures. In particular, metaphoric phrases like "black hole" are classic examples of how metaphors are used in physics; they use language that envisages common images to help students mentally comprehend and understand abstract concepts.

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However, the mastery of such metaphorical terminology stands in need of more than just recollection. It demands a strategic approach that fosters deep conceptual understanding and perpetual retention. Based on our experience in defining the challenges first-year engineering students come across in gaining an understanding of these terms and acquiring them, we believe that a collaboration between STEM and ESP specialists is fundamental.

This interdisciplinary approach implemented in this paper can foster teaching methods that facilitate the acquisition of terminology, therefore impacting the enhancement of students' ability to acquire, conceptualize, and apply complex physics ideas. Metaphorical terms in physics and pedagogical approaches used for understanding and acquiring this terminology are the main object of this paper. Specifically, it presents findings from a survey conducted among students at the Polytechnic University of Tirana, which sheds light on students' perception of metaphorical terms, most used and implemented methods for learning this physics terminology,

2. Related Work

Being the universal language of science and technology, English proficiency is indispensable for engineering students, due to its presence in academic literature, various guidelines and manuals and its importance as a tool for intercultural communication. Hutchinson and Waters assert that having a robust vocabulary in English for Specific Purposes (ESP) enhances students' ability to engage with discipline-specific content and then contributes to their career advancement (Hutchinson & Waters, 1987, cf. Flowerdew & Peacock, 2001) [1]. For non-native English speakers, such as Albanian, in our case, the acquisition of this vocabulary can be challenging. It often requires specific strategies that go beyond commonly language acquisition methods in order to fulfill students' linguistic needs concerning their field of interest.

Respectively, physics terminology is characterized by a metaphoric nature of language employed to represent abstract scientific concepts and theories. Appertaining to metaphors, Lakoff and Johnson have highlighted the importance of metaphor in helping learners "internalize" or "absorb" concepts that are else ways difficult to fathom (Lakoff & Johnson, 1980 cf. Amin, 2015) [2]. This statement is particularly present in physics terminology. It is noticed that by making use of metaphoric terms, complex notions such as "naked singularity" or "quantum entanglement", enable students to visualize and relate these ideas to tangible experiences or simpler concepts. Metaphors in language serve as an approach to use previous linguistic patterns to construct new patterns. By "translating" structures from one conceptual field to another, metaphor makes it possible to understand a term (in most cases abstract, especially in physics terminology) using a term from another field (which in most cases is concrete). This procedure is particularly important for the creation of terminological metaphors. Research on terminological metaphor, which mostly focuses on conceptual metaphor, is not yet fully embraced by linguists, terminologists or scientific researchers. Nonetheless, it should be emphasized that the last decade has shown a tremendous growth of studies in this aspect.

We can bring up here works by Temmerman, 2000 [3]; Fuertes-Olivera, P.A. & I. Pizarro-Sánçez 2002 [4]; Dias J.G, 2004 [5]; Finatto.M.J. 2010 [6]; Riejos & Mansilla 2006 [7]; etc,.

Pertaining to metaphors in physics education, one should acknowledge the fact that they play a prominent role by bridging the gap between abstract theories and concrete understanding of the main concepts. In his study on the origin of energy concerning mostly on metaphors and manifestations as resources for conceptualizing and measuring the invisible, imponderable, Harrer dwells on some specific aspects of physics and the role of metaphors in expressing them by stating as follows (Harrer B. 2017) [8]:

"*In particular, the use of substance metaphors has permeated the history of the developing energy concept. Planck, for example, pointed out that drawing analogical parallels between energy and matter was helpful in establishing acceptance of the energy concept among scientists of the 19th century. He also strongly suggested that a substance-like conception of energy, in addition to adding clarity to the abstract concept, would inspire progress in the development of energy theory that goes beyond mere quantitative considerations.*"

Pursuant to conceptual metaphor theory founded by Lakoff and Johnson, metaphors allow individuals and students in particular to map familiar cognitive structures onto unfamiliar or complex

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ideas (Lakoff & Johnson, 1980) [9]. In physics, where many principles lack direct visual and tangible representations, metaphors facilitate cognitive accessibility for phenomena and concepts which possess a difficulty in visualizing them, facilitating students' engagement with the material (Niebert, Marsch, & Treagust, 2012) [10]. Moreover, metaphors as Isaeva says points out in her paper, possess a cognitive potential in terminology which lies in its ability to model the content and structure new scientific concepts by analogy with familiar concepts from other knowledge domains or everyday (Isaeva, 2019)[11].

It should be emphasized the fact that when referring to the educational perspective of metaphor-based theory in physics, the challenges students encounter while trying to understand and learn these terms are underrated. Moreover, the process gets tougher especially when their native language and cultural frameworks do not align with the nature on English metaphors (Brookes & Etkina, 2007 cf. Amin, 2015) . In light of this scenario, students often rely upon learning techniques and tools such visual aids, analogies, and real-world examples in order to concretize abstract terms (Treagust & Duit, 2008) [12]. Furthermore, research indicates that terms originating from metaphors can sometimes lead to misconceptions if students interpret them too literally, highlighting the need for strategies that emphasize correct interpretation and contextual usage (Treagust, Duit, & Fischer, 2017) [13]. However, on the other hand, students can "exploit" metaphoric terms such as "caloric metaphors", which are widely used in this terminology, in order to tangibly envision different caloric concepts, such as "heat transfer" (Brookes, David & Etkina, Eugenia.,2015) [14].

Teaching methodology regarding the acquisition and mastery of metaphor-based physical terms comprises various strategies and techniques. In a study on concept development and transfer in context-based science education, the use of terms within relevant settings has been shown to significantly improve comprehension and retention of complex scientific vocabulary (Gilbert, Bulte, & Pilot, 2011) [15]. In addition, visual aids such as diagrams, simulations, and infographics are widely acknowledged for their role in enhancing understanding, particularly for abstract physics concepts (Mayer, 2001) [16]. Ainsworth in her article on A conceptual framework for learning with multiple representations states that combining various representations for a specific content, for example, visual elements with metaphorical language, can improve conceptual understanding by providing students with multiple channels for encoding information (Ainsworth, 2006) [17].

According to Flowerdew and Peacock, an interdisciplinary collaboration among ESP and STEM professionals have a substantial effect in the enhancement of terminology acquisition from students. In particular, for engineering students, this approach can create a more cohesive learning experience where language and content are taught simultaneously, enhancing both language skills and subject comprehension. Such collaborative efforts pave the way for the development of specific strategies which are tailored to the specific linguistic and conceptual needs of engineering students.).

3. Material and Method

3.1. Data Collection

Physics terminology for students of engineering fields serves as the building blocks of their academic development as future engineers. Our experience as professors of physics and ESP has shown us that students face some difficulties when dealing with metaphoric terms and their acquisition. Therefore, we decided on conducting a study which main objective is to investigate the features of these metaphoric terms and to define most effective approaches which serve students' comprehension and acquisition of this specific terminology according to students' perceptions.

So, The Research Questions of This Study Are:

1. What are students' perceptions on metaphorical terms?
2. Which are students' most and at least implemented techniques in the acquisition of metaphoric terms?
3. Which are their most endorsed techniques to comprehend and acquire metaphoric terms?

This study was implemented with students of Polytechnic University of Tirana. Students from different faculties and study programs participated voluntarily in this study. Most precisely, students were part of these faculties and respective study programs:

1. Students from Faculty of Civil Engineering:
   a. Hydrotechnical engineering
   b. Geodetic engineering
   c. Construction engineering
2. Students for Faculty of Mechanical Engineering
   a. Mechanical Engineering
3. Students from Faculty of Electrical Engineering
   a. Electrical Engineering
4. Students from Faculty of Mathematics Engineering and Physics Engineering
   a. Students of Physics Engineering

A total number of 120 students were asked to fill a questionnaire via google Form but only 100 were able to complete and submit the questionnaire. The sample was not randomly chosen. These study programs were purposefully chosen considering the importance of physics basic concepts and terminology in their engineering fields The students were encouraged to participate in the study and were explained that their sincere answers to the questions would be very important to figure out which are the most used and preferred techniques of students in order to comprehend and acquire the metaphoric terms.

The questionnaire was composed of 16 questions related to demographic data and background information concerning English physics, their perception and interpretation of specific metaphoric terms and their most used and preferred techniques to comprehend and acquire the terms. Students' answers were analyzed manually and are presented through different charts from Excel. The choice was due to the presence of several open-ended questions, which need a thorough analysis.

3.2. Research Design

This study employs a mixed-methods descriptive approach to explore students' conceptualization of metaphorical physics terms.

The semi - structured questionnaire, provided numerical data on students' preferences for various learning techniques. Statistical analysis was applied to determine and assess the frequency and effectiveness of these techniques.

Open-ended questions allowed for thematic analysis, offering deeper insights into students' interpretative strategies and challenges when encountering metaphorical terms. This integrative approach ensures a comprehensive understanding of how engineering students comprehend and acquire metaphorical physics terminology, aligning with the study's objectives.

4. Data Analysis

The questionnaire started with demographic data related to gender. The results were not surprising considering that not only in Albania but worldwide based on a recent study[1], engineering fields attract mostly women. 97% of the respondents are male, and only 3% are females. This disparity of results channels the results into showing us a male perspective of the study case.

For more on the study see here: https://www.fictiv.com/articles/women-in-engineering-statistics-32-notable-facts[1]

ISSN: 2576-8484
Vol. 8, No. 6: 7300-7309, 2024
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Figure 1.
Students' gender.

Second question was in respect to students' study programs. The engineering fields were chosen by purpose and their expansion due to the enrollment of students in specific study programs is not even. However, the highest representation was in mechanical and hydrotechnical engineering. On the ground that each field has a considerable focus on physics, students' familiarity with physics terminology is expected but there is variation among fields.

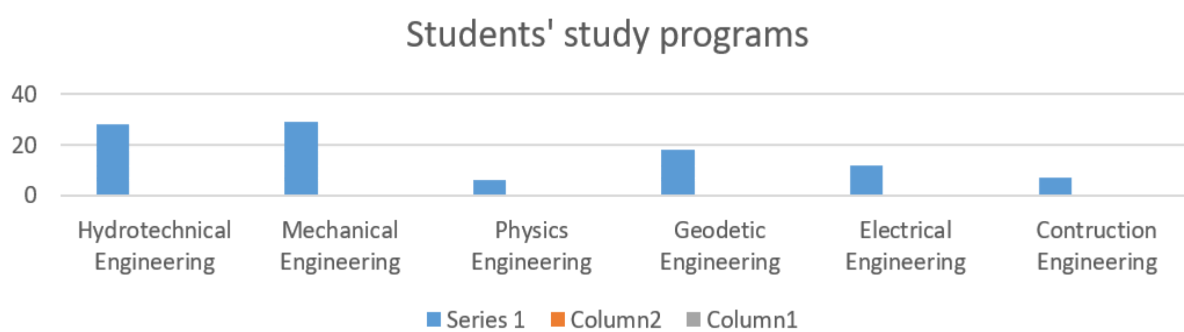

Figure 2.
Students' study programs.

Regarding background information, students were asked if they dealt with advanced physics subject in high school, were 61 % said yes and 39 % had not advanced physics as a subject in high school. These results influence their ability to comprehend certain physics concepts.

In the framework of certain projects in Albanian, several high schools have physics taught to students in different languages, but mostly in English. Additionally, some schools such as "Harry Fultz", deal with English subjects. On that account students were asked if they had English physics as a subject in high school. Only 12 out of 100 said they studied physics in English. This may imply that a lack of familiarity with the English physics terminology could hinder students' comprehension and acquisition of terms. The hurdle becomes more evident when encountering metaphoric terms which on the other hand can be less intuitive to students.

Further on, students were required to *make a self - evaluation of their lexicon* in physics terminology. Starting from rich to not very rich and not rich at all the answers varied. 54 % considered their technical vocabulary of physics not very rich, 13 not reach at all, while only 2 considered their physics

terminology stock rich. These results pinpoint that lion's share of students don't consider their physics terminology rich, indicating in this way a problem in this respect.
The next section of questions treated students perceptions on various aspects of metaphoric terms.

Firstly, they were asked to determine the frequency of encountering metaphoric terms. As seen in Figure 3, the answered varied; 12 % chose very often, 40 % sometimes, 43 % rarely and only 5 % stated they never encountered metaphoric terms.

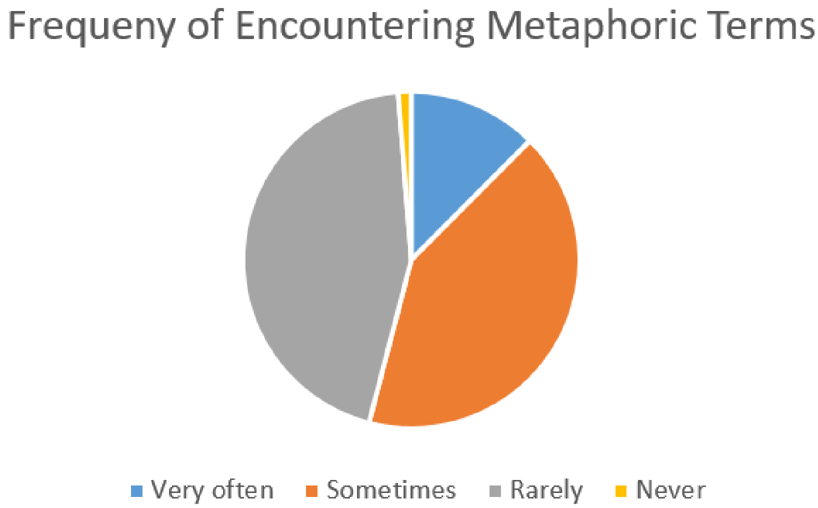

Figure 3.
Frequency of encountering metaphoric terms.

Questionees were then asked if they could recall any metaphoric term, concerning physics terminology. Half of the respondents could not recall any term, while the other 50 % mentioned common physics terms such *as "black hole", "big bang", "left hand's rule", "wave – particle duality", "naked singularity", acceleration", "dark matter", "entropy".*

These results reveal a considerable degree of unfamiliarity with current terminology. Conversely, the examples provided by the other half of questionees are considered as the most common metaphoric terms in physics implying that students may have it difficult to recall less-known terms.

Another question asked to students was as follows: "Do you think the literal interpretation of the term helps or interferes in the understanding of the terms?" 72 % said it helps, while the other 28 % said it actually interferes in the understanding.

When asked if the metaphors change their perception of physics, their answers were diverse. The most common elaborated answers were: *"metaphors make it much more interesting", " "… make physics concepts more tangible for us", " … make physics more complicated", " …simplify physics for us", " don't affect the way I perceive physics", "… foster imagination and curiosity on the subject".* While there were approximately 40 % just answering *"Yes"* or *"No"*.

The other section of questions focused on the comprehension of metaphoric terms in order to gather more data in respect to students' interpretation and understanding of metaphoric terms. While asked if they base on the literal interpretation of terms to figure out their meaning or rely on the context, the answers varied: 11% said they don't rely on the literal meaning of the term, 12 % said they rely on the literal meaning and 66 % said they rely on the context. This considerable reliance on the context implies a strategic choice of the approach of students, autonomously chosen in order to comprehend unfamiliar concepts and terms.

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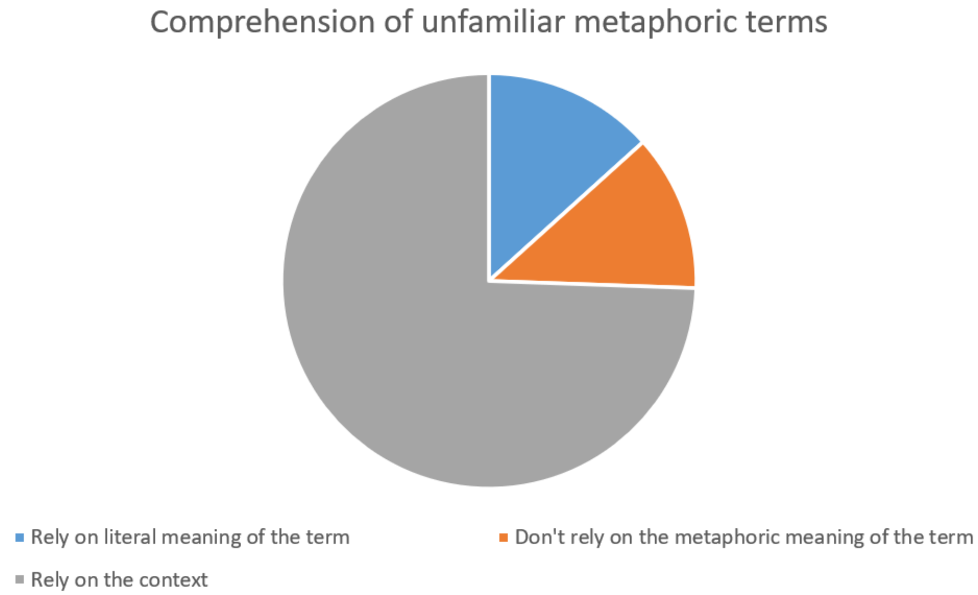

Figure 4.
Comprehension of unfamiliar metaphoric terms.

Subsequently, specific questions on specific terms were addressed in order to get concrete evidence on students' interpretation and comprehension of unknown terms. One of the terms was "tunneling effect", which is not very common for first year undergraduate students. 16 students answered "I don't know", indicating their lack of presumption on a specific explanation on the term. However, others provided answers in the form of definitions indicating the term was not unfamiliar to them but some independent research has been part of their learning process. The remaining of the interpretations were miscellaneous. Hereby we cite some of their common responses: *"something related to a closed, tunnel-like area"*, *"an effect same as the effect of the passing of a car through a tunnel"*, *"direct movement in a specific space"*, *" movement effect"* etc. These answers reveal how students may interpret this unfamiliar metaphoric term by using general language and spatial analogies, considering space as the main concept. By associating the term with familiar visuals, these interpretations pave the way toward a better understanding of the term.

This section of questions comprised the last part of this semi - structured questionnaire. It covers the methodology students implement in order to comprehend and acquire metaphoric terms and their preferred technique in order to figure out and learn the metaphoric term. The first question gathered the following answers: 35% used visualization of terms but referring to their prior knowledge of physics, 24 % looked for definitions in books and on-line, 20 % made use of simple visuals such as pictures, infographics, diagrams, and other visual aids and 15 % considered AI as a tool to ascertain the semantic content of the term, while the other part left, 6 % do not provide a specific method or tool.

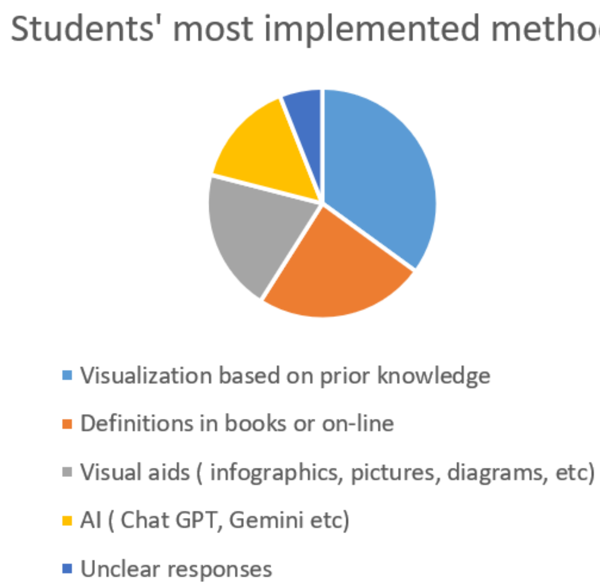

Figure 5.
Students' most implemented methods.

The last question's type was a ranking one, for students to determine the effectiveness of the most common methods used to best comprehend metaphoric terms from 1 (not effective at all) to 5 (very effective). Most of the rankings were foreseen based on the previous answers of the questionnaire. While throughout the questionnaire, based on the responses, context was seen as a very important source for "deciphering" the meaning of the metaphor in technical text, in this question only 35 % of the respondents consider it a very effective tool, while more than 30 rank it as not an effective one.

Foreseeable was the ranking regarding the effectiveness of videos where more than half ranked it as very effective and only 14 % considered it not effective at all.

The consideration and reliance on professors and maybe "dependence" on them was witnessed with more than 56% considering "definition and explanation from professors" very effective. Other visual aids were also ranked as effective, while analogy between the term and real - world matters was classified as one of the most effective tools based on more than 55 % of the respondents' answers and only 8 % defined it as not effective at all.

5. Discussion

The data obtained from the questionnaire indicate that overall, there are some difficulties regarding the comprehension of metaphoric terminology of physics for various engineering students. Factors related to limited vocabulary, varied familiarity with English terminology, and reliance on literal interpretations hinder the process of metaphoric term comprehension and acquisition in English. Students' answers shed light on a problematic matter referring to students' hesitation to provide an answer regarding their own interpretations for specific terms. A considerable percentage of students didn't manage to provide an answer, mainly due to the lack of familiarity with general English physics terminology, reflected in their responses. However, students' overall perception on metaphors in physics terminology was positive, while many considering it has an imaginative role and an enactive role as well. These results go hand in hand with several studies on metaphors in physics which point out the following roles: imaginative role: metaphors as aids to imagination 2) embodied role: metaphors as conceptual mechanisms of knowledge transfer 3) enactive role: metaphors as figures of action (Kersting, M., Sampieri-Cábal, R. 2024) [18].

The presence of IA as a tool in facilitating term comprehension, based its role and popularity nowadays was expected to be higher in students' responses. Because of the fact that it has been considered these last years as an emerging tool in ESP and STEM education and due to the personalized learning by adapting to students' individual learning typologies, paces and needs (Hwang, Xie, Wah, & Gasevic, 2020) [19]., its effectiveness is somehow but not fully recognized by our students. Therefore, an approach based on making the most out of IA should be considered in the teaching/learning process in order to accomplish the goal of metaphoric term comprehension.

Students' answers proofed that there was a tendency towards blending literal and figurative interpretation of the terms, which contributes in enhancing students' apprehension of terms. Multimedia and visual techniques comprised of pictures, diagrams, graphics and infographics and mainly videos reflected a multimodal approach for different learners, but without backlisting at all professor's role as a guide and a facilitator throughout the learning process. The role of the professor, especially for 1st year undergraduate students of engineering, based on the theoretical nature of the subject, is principal. The interlocking of these techniques reduces cognitive load and increases learning. On the other hand, analogies to real-world phenomena make metaphorical terms relatable, enabling students to connect technical meanings with everyday experiences.

6. Conclusion

In conclusion, this research sheds light on the enhancement of engineering students' comprehension of metaphorical terms in English within physics. Through a questionnaire where detailed data regarding students' self – evaluation regarding their familiarity with metaphoric physics terminology, their overall and specific perception on these terms, frequency of metaphoric terms encountered, preferred and implemented methods to comprehend this terminology this paper accentuates prime techniques necessitated to enhance and support students' comprehension of metaphoric terms. The results of the findings produced evidence that tools such as analogies with everyday life, teacher – led explanations, multimedia, visual aids and blended elucidation by combining both scientific explanation and literal meaning of the term by having a fluid handling with abstract principles, constructively contribute to increasing student's ability to comprehend and retain these terms.

Moreover, this research emphasized the importance of context and visual aspect filling the gap that exists between the metaphoric terms and their discernible and tangible understanding from students.

These insights align well with the objectives of the paper to explore strategic approaches for improving metaphor comprehension among first-year physics engineering students.

6.1. Limitations and Future Research

One of the paper's limitations concerns the dearth of studies on this specific subject in the global context of the topic but especially in the Albanian context. There may be really few papers which discuss approaches students employ to acquire metaphoric terms in physics, while in Albania based on our research there are studies at all on this matter. In this regard, it is challenging to draw any analogies or generalizations.

The study's narrow emphasis on a specific demographic — 98 % of male students and only 2% females circumscribe the results of the study to only male's points of view. Moreover, future studies could build on this same work by examining how metaphors are learned in other engineering fields except the ones part of this study. In order to meet the varied demands of students, more research might also look into the efficient integration of AI tools and multimodal resources into educational settings, being the subject of today's educational world.

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