INVESTIGATING MULTIMODAL SCIENTIFIC COMMUNICATION: AN ANALYSIS OF COMMUNICATIVE MODES IN BIOLOGY AND ENGINEERING RESEARCH ARTICLES*

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Abstract

The dissemination of knowledge in science and technology relies on efficient communication, with a noticeable shift towards multimodal communication. This research explores the subtle patterns of multimodal scientific communication to comprehend how several modes work together to enhance discourse quality. Twenty research articles, ten from the field of Engineering and ten from Biology, written over the previous three years by researchers of the University of El Oued, Algeria were collected from credible journals and then examined using a qualitative content analysis. The findings demonstrated that the authors used a multimodal approach in their research articles, presenting their research outcomes through a combination of textual explanations and visual components including graphs, tables, images, and diagrams. The study's findings highlighted the interdependent nature of text and images and their importance in communicating scientific discourse. Furthermore, the data displays differences in the modes selected by these researchers, which reflects the specificities and particular needs of each discipline in choosing the modes. The study suggests that researchers' active participation in workshops and training sessions can improve their proficiency in multimodal scientific communication. Moreover, it recommends additional research to broaden the area of enquiry and improve knowledge of multimodal communication in scientific discourse.

Key words: *Biology, Engineering, Modes, Multimodal communication, Scientific discourse.*

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1. Introduction

To efficiently capitalize on the evolutions in science and technology research, it is essential that these fields' research results are comprehensibly presented and successfully communicated to both professionals in the field and the broader audience (Kress *et al.*, 2006). Consequently, the validity and accuracy of results are not the only factors that determine the effective communication of scientific and technological findings, researchers should also carefully consider how best to synthesize their findings using both text and visual aids.

In the quickly developing domains of science and technology, the modes of information transfer are experiencing evolution, necessitating an understanding of the dynamics at work (O'Halloran, 2011). The traditional text-based scientific communication paradigm is changing dramatically to become multimodal and include visual elements such as graphs, tables, images, and diagrams (Hyland, 2009). O'Halloran makes a notable assertion concerning the gradual change of communicating research findings. It is crucial to acknowledge that, as scientific fields diversify and grow more specialized, researchers' preferences for communication become increasingly apparent. This is especially true in fields like Biology and Engineering, underscoring the crucial role of multimodal communication. However, while some studies have examined modes of communication in scientific discourse, the interconnectedness of text and visual elements like images, graphs, tables, and diagrams and how they differ in several scientific disciplines, mainly Biology and Engineering, remains limited to date, particularly in the Algerian Higher Education context, despite their significant roles in knowledge dissemination.

This research aims at identifying the prevalent modes (text and visual elements) of scientific communication and highlighting the synergistic relations among these modes, specifically how they cooperate to communicate the scientific information. Additionally, the study intends to explore various practices across Biology and Engineering disciplines, aiming to comprehend how researchers in the University of El Oued, Algeria prioritize and utilize several modes in presenting their research findings within the results and discussion sections of their articles in these respective fields.

Addressing this gap is vital for understanding the developing dynamics of scientific communication, thereby providing useful insights to improve scholarly discourse. It also contributes to enhancing the researchers' communicative skills by making them aware of the fundamental role of multimodal communication for an effective knowledge dissemination.

2. Literature Review

2.1. An Overview of Multimodality and Multimodal Discourse Analysis

2.1.1. Multimodality

Within the realm of semiotics, multimodality is the process of communicating with others by using different meaningful modes. Jewitt (2009) defined multimodality as "approaches that understand communication and representation to

be more than about language, and which attend to the full range of communicational forms people use like images, gestures, graphs, poster, and so on, and the relationship between them" (p. 14). In the same regard, Granström *et al.* (2002) defined it as "the use of two or more of the five senses for the exchange of information" (p. 1). According to these definitions, multimodality refers to the various ways in which people communicate and share information, including verbal, visual, and graphic forms. More specifically, it is a theoretical framework intended to clarify and understand human communication across many contexts. This framework goes beyond the confines of a singular mode, like verbal language, and seeks to understand communication through various forms of expression.

2.1.2. Multimodal Discourse Analysis

Multimodal Discourse Analysis (MDA) stems from Halliday's social semiotic approach to language. It sees language as just one of many semiotic tools or modes that people employ to construct meaning and communicate along with posters, images, graphs, tables, sounds etc. MDA goes further by exploring the interplay and combinations of these various modes to generate meaning within social contexts. In essence, MDA studies the ways in which words are amalgamated with images, videos, graphs to create comprehensible meanings. In the same vein, O'Halloran (2011) claimed that "MDA is an emerging paradigm in discourse studies which extends the study of language in combination with other resources, such as images, scientific symbolism, gestures, music, and sound" (p. 1).

Within MDA, the examination of language, speech, and writing is integral. While acknowledging that language does not function in a vacuum, MDA seeks to understand how different modes interact with speech and writing in discourse (Kress, 2011). Rooted in Halliday's theory, MDA adopts three metafunctions related to language: the ideational metafunction (concerned with the content of a text), the interpersonal metafunction (addressing the relationship between participants), and the textual metafunction (focusing on how the message is structured).

2.2. Multimodality in Academic Scientific and Technological Discourse

Discourse, according to many linguists, encompasses all significant semiotic actions and goes beyond language forms of representation alone. The representation system has witnessed a radical change in the last few years, shifting from a mostly verbal to a visual focus in a variety of genres, such as research, education, the media, and ads. Visuals are often just as important as verbal components in academic and educational situations (Tang *et al.*, 2019). This leads researchers to use multimodal studies to provide a comprehensive view of these shifts. By using this method, researchers examine how several modes organize the world and draw attention to changes in authority, significance, and how people interact with their social and natural environment (Kress, 2011).

At its core, multimodal analyses concerned with defining the inherent capacities and constraints associated with various modes of communication. Examining the realm of writing, Kress (2011) argued that writing and imagery follow different logics. Writing operates within the dimension of time, while imagery is determined by spatial factors. In written communication, significance is frequently

associated with appearance order, highlighting the importance of being first in a statement. On the other hand, in visual communication, element location is crucial; anything placed in the center will convey a different meaning than something placed at the perimeter, and an element placed above may imply superiority over something below (Kress, 2011). Essentially, by taking advantage of their unique affordances, new technologies like digital portfolios, PowerPoint, and e-journals are spreading throughout academic and educational settings, speeding up and magnifying a variety of potentials for representation, engagement, notions' simplification and communication (Danielsson & Selander, 2021).

Academic writing has integrated several forms of communication, particularly in scientific fields. However, there has been a noticeable increase in the influence of visual design in textbooks and articles (Hyland, 2009). Unlike in the past, visuals now serve a more significant purpose than just providing an illustration or enhancing textual content. In modern academic writing, figures, tables, and pictures can make up as half of the text, especially in scientific research publications. Consequently, Hyland (2009) contended that it is pivotal to recognize that comprehending academic discourse entails more than just reading and analysing textual materials. Proficiency in both reading and deciphering visual elements has become a central skill of mastering scientific and technical discourse.

O'Halloran (2011) asserted a paradigm shift in the development of scientific written discourse by challenging the conventional perspective that has traditionally treated scientific language in isolation, neglecting its status as a semiotic resource shaped by the incorporation of symbolism and visual representation. The trajectory of scientific language, according to O'Halloran (2011), has been intricately related to its symbolic and visual roles, resulting in distinct patterns. In the regard, Lemke (2002) posted that science discourse is inherently multi-semiotic and multimodal, with each mode offering unique affordances for meaning making and collaborative efforts between modes helping to contextualize and widen meaning. As a result, it is argued that a scientific text is conceived of as an interconnected system of meaning relationships spanning various modalities within the textual context. This approach aims of bridging the gap between science experts and non-experts, making scientific knowledge accessible to a wider audience (Luzón, 2019).

2.3. Disciplinary Variances in Data Representation

Within the scientific community, discourse often involves intricate elements such as complex shapes, degrees of temperatures etc. which are more aptly described, communicated, and taught through visual modes other than language only (Lemke, 2002; Wanselin *et al.*, 2022; Bursjöö, 2022). While there is a consensus that scientific events involve a variety of visual semiotic modes, it is recognized that specific modes may hold greater value or possess more potential to convey the meaning associated with a particular task in certain communication events or disciplines (Kress *et al*., 2006). Arguing in the same regard, Swales (2004) claimed, "disciplines vary in their use of visual support" (p. 26) depending on the specificities of the discipline itself that determine adopting certain modes rather than others to represent data.

With reference to the fields of this study, in Biology, research data is represented in a variety of ways that are adapted to the complex and dynamic properties of living organisms. According to academics, textual explanations play a crucial part in explaining complex procedures, experimental designs, and nuanced representations of research results.

Regarding the preferred visual representation of research findings in Biology, images of different types, including but not limited to pictures, 3D models, and microscopic images (Garrison *et al*., 2021). The ability to visually explore biological entities and capture minute details is made possible by these kinds of visuals, which also improve the interpretability of the given data (McMillan, 2012). Additionally, to further enhance the clarity of the complex information in Biology, particular types of tables and diagrams are frequently used to demonstrate data. These modes help to clarify complex processes and visualize how biological entities are structured.

In the field of Engineering, the representation of research results is meticulously adapted to the exacting and technical requirements of the discipline. Additionally, this domain relies on in-depth written texts that capture mathematical formulations and procedures, offering a solid foundation for comprehending Engineering research. Furthermore, it has been demonstrated that using graphs and tables to display research data is a significant practice in this field to precisely depict data due to that Engineering is intrinsically defined by numerical values and quantitative data (Beer & McMurrey, 2019). Graphs in this discipline help in time-series analysis and model validation by providing a visual representation of trends, correlations, and dynamic large datasets among other functions (Irish, 2015). They enhance accessibility, make multidimensional representation easier, and play important roles in the rigorous analysis and efficient communication of engineering research data.

2.4. Prior Research Investigations on the Topic

Investigating scientific journal articles done by Lemke (2002) underscored the standard and essential procedure of interpreting verbal text in conjunction with other semiotic systems. Lemke, for instance, noted that many journal publications used tables and graphs to present data, making clear reference to these visual aids in the written text. Scientific papers with graphical modes not only gave background information, but also provided detailed instructions on interpreting graphs through extensive captions. In scientific publications, different modes such as the main text, graphs, and long captions were integrated together, highlighting the need for readers to interpret several semiotic modes in tandem with the written text to fully comprehend scientific concepts.

Subsequent research by Lemke explored the complex mechanisms of scientific meaning generation confirming that meaning in scientific situations usually comes from a combination of words, pictures, formulas in mathematics, and graphical representations. According to Lemke (2002), understanding scientific meaning frequently necessitates engaging two or more semiotic modalities at the same time as they are interacting. They highlighted that although every modality may express a slightly different facet of meaning, the amalgamation of these

meanings adds to the concept's overall comprehension. Therefore, it becomes vital to employ multiple semiotic modalities concurrently in order to properly convey the meanings associated with scientific concepts.

Numerous studies underscored the significance of integrating diverse modes for effective scientific communication. For instance, Oliveira *et al.* (2014) addressed the complex orchestration that goes into teaching science, focusing on the cooperative integration of different modes such as spoken and written language, visuals, and gestures. Patron *et al.* (2017) explored how educators choose and create pedagogic science books using visual representational reasoning. Their research highlighted the need for the subject of study to include three crucial elements for facilitating the process of constructing meaning; (1) the inclusion of disciplinary relevant aspects, (2) insights into critical qualities that may pose challenges to discerning disciplinary aspects, and (3) a semiotic approach, which aligns with the findings of Martin *et al.* (2021). To effectively communicate scientific concepts, it is imperative to integrate several modalities of communication, including language, pictures, gestures, and technology (Hutchison, 2018).

The importance of multimodal communication for improving learning and understanding in different educational contexts is further echoed in several investigations. Lee *et al.* (2019) stressed the critical function of multimodality in scientific communication and the significance of nonlinguistic modalities in communicating disciplinary meaning in science education. According to Grapin (2019), several communication modes provide various advantages and disadvantages, necessitating being cautious in the choices to be used when conveying scientific knowledge. Additionally, research has demonstrated that Multimodal interaction analysis is a potent technique for analyzing students' participation in science activities and it can provide rich insights into how students interact with different modes to comprehend and create meaning in science (Wilmes & Siry, 2021; Smith *et al.*, 2022). Also, it has been discovered that using multimodal texts which incorporate textual explanations, images, video, gestures, and audio is very useful for improving communication and comprehension of scientific knowledge (Cheng *et al.*, 2020; Nielsen *et al.*, 2020). These multimodal teaching strategies not only make learning easier but also give students the chance to interact with science material in a variety of ways, which promotes a deeper comprehension and appreciation of scientific ideas (Wanselin *et al*., 2022).

Moreover, researchers have emphasized the value of multimodal discourse for engaging students with scientific concepts. The discourse in science education is multimodal, meaning that students' interactions with diverse semiotic resources are crucial to their process of making sense of the material (Xu *et al.*, 2021). This emphasizes how crucial it is to take into account a variety of representational styles in science communication in order to enhance students' understanding and interaction with scientific ideas (Bellés-Fortuño, 2018; Jiang & Lim, 2022). In the same regard, it has been determined that a crucial tactic for making scientific concepts understandable and interesting in presentations is the coordination of words, images, and gestures, especially in science popularization efforts (Williams

et al., 2019). In addition to providing all students with worthwhile inquiry opportunities, multimodal teaching approaches also offer a variety of language experiences that help English Language Learners comprehend scientific topics as well as writing about them (Nash, 2018; Arslan, 2020; Varelas *et al.*, 2022; Xie *et al*., 2021). These approaches, when combined with performing arts regardless the language used for knowledge communication, enable students from marginalized backgrounds to take an active role in the generation of knowledge and establish themselves as authorities on science and increasing their motivation in doing so (Akoto, 2021). This illustrates how multimodal communication can support science education that is more engaging and powerful.

The literature conveying findings about multimodal scientific communication, particularly across different scientific disciplines is scarce to the best of the researchers' knowledge. Consequently, further research is required, with a focus on the different communicative modes used to ensure multimodal communication and thereby effectively disseminate research outcomes.

3. Research Methodology

3.1. Research Questions

This study is directed by the subsequent research questions:

1. How do researchers in the University of El Oued use text and visual elements in their research articles' Results and Discussion section within the fields of Biology and Engineering?

2. What is the relationship between textual and visual modes in Biology and Engineering research articles mainly in the Results and Discussion section?

3. How do differences across Biology and Engineering disciplines influence the use and inclination towards specific modes of scientific communication?

3.2. The Research Approach

The researchers adopted a qualitative approach to gain deep insights about the multimodal communication in research articles within biology and engineering domains. This approach commonly centers on the methodical portrayal and thorough examination of the attributes of a phenomenon or subject (Creswell & Creswell, 2017). It enables in-depth exploration of a specific case or carefully selected cases (Gilbert & Stoneman, 2015).

3.3. Data Analysis

The researchers utilized qualitative content analysis to examine the dataset, permitting an "empirical, methodological controlled analysis of texts within their context of communication" (Mayring, 2004, p. 2). The analysis was devoted to the identification of textual and visual elements as well as looking for disciplinary differences, trends, and relationships between modes within the selected research articles.

3.4. The Corpus of the Study

The study's corpus consists of a carefully twenty selected research articles, ten of them focusing on Biology and the remaining ten on Engineering. They were authored by researchers from the University of El Oued, Algeria in the last three years. The selection is exclusive to reputable journals classified as Class B, including

but not limited to Biharean Biologist, Current Trends in Biotechnology and Pharmacy, Frontiers in Biomedical Technologies, Annals of the Romanian Society for Cell Biology, Biomass Conversion and Biorefinery, International Journal of Intelligent Engineering and Systems, and Journal of Materials and Engineering Structures. These journals specifically cover topics in both the biological and engineering domains. Restricting the focus to peer-reviewed research articles that have been published in the last three years guarantees that the analysis encompasses current developments in multimodal communication. In Biology, the corpus includes publications from sub-disciplines such as cellular and molecular biology, biology and plant ecology, and agronomy. In Engineering, the corpus entails articles including but not limited to mechanical engineering, electrical engineering, hydraulics and civil engineering, and process engineering and petrochemistry. This targeted corpus allows for a profound examination of prevailing modes, synergies between them, and disciplinary variances in the mentioned scientific disciplines.

4. Results

4.1. Identification of Prevalent Modes

The analysis of scientific research articles mainly the Results and Discussion section revealed a dynamic spectrum of communication modes that illustrate the nuanced ways in which knowledge is communicated in both Biology and Engineering research.

4.1.1. In Biology Research Articles

Researchers of Biology in the University of El Oued weave a rich web of textual and visual modes to illustrate the intricacies of this ever-evolving field. They used written descriptions as a foundational step to give readers comprehensive details that enable them to grasp the complexities of biological processes. Texts in the corpus used to define biological terminologies, describe the experimental protocols, and most importantly give meaning to results obtained from the conducted research.

They also used vivid images of various types in the Results and Discussion sections to clarify and support their obtained data and facilitate the comprehension of complex knowledge. The corpus displayed researchers' use of various types of images, including

Microscopic images which serve as a crucial element in overcoming the limits of verbal description. The detailed intricacies presented through these images provide a deep visualization, allowing researchers to communicate their findings in a way that surpass the limitations of text alone. It can be challenging for verbal texts to fully capture the complexities of cellular structure. They opted for microscopic images as a bridge by providing a concrete and visually compelling representation of the microscopic world.

A significant utilization of photographs that captured a broad spectrum of biological phenomena with tangible visual impact is included in Biology research articles authored by researchers of the University of El Oued. They used this visual medium to depict the features of certain organs, the behavioural patterns of organisms under investigation. Thus, photographs emerged as a potent tool for

illustrating the dynamic character of living organisms in a researched region and the biodiversity of the investigated area.

Researchers also rely on representing their data using molecular 3D models as adept at depicting intricate molecular structures that can be difficult to fully convey in conventional written language. These models allow the researchers to provide a visual language that goes beyond the constraints of two- dimensional representation, specifically in the field of molecular biology, where the details of biomolecules such as proteins, DNA, and RNA are essential to comprehend biological functions and cellular processes.

In addition to the use of different types of images, two major types of diagrams were found in the corpus are schematic diagrams and anatomical diagrams. They used schematic diagrams to visualize different crucial biological processes. Via this type of diagrams, they communicated complex data and biological information in an understandable and efficient way by simplifying the intricate pathways and molecular interactions. Additionally, they depended on anatomical diagrams to explain effectively structural features and spatial relationships, tissues, and systems under research.

Researchers, also, depended specifically and heavily on the use of comparative tables. It is found that they used this specific type of tables to display the effects of different treatments introduced to experimental groups and compare results with the control group of their studies, providing a holistic synthesis and explanations to the findings of their research.

4.1.2. In Engineering Research Articles

It is necessary to acknowledge that Engineering is a discipline characterized by complex technical terms and jargon, which may be unfamiliar to individuals outside the field. Therefore, researchers of the University of El Oued offered detailed textual explanations to demystify technical words and ensure that readers of all backgrounds can at least have an idea about the complexities of their research data, making engineering research more accessible to a wider range of audience. Moreover, it is observed in the corpus that textual explanations are also attached to different visual representations to ensure a good visualization of the theoretical background and practical implications of conducted research.

In their data representation, they employed graphs and tables as major visual modes:

Data revealed that El Oued Researchers of Engineering utilized three main types of graphs; line graphs, bar graphs, and grouped bar graphs to represent and discuss their obtained results. These visual aids are useful for communicating facts and patterns in a comprehensive way. They have come to favour line graphs as a common medium for displaying continuous data and trends. This type of graphs which featured by the connection of data points with lines, were commonly used to show how variables changed across a continuous range, the relationship between different factors, the effects of varying parameters, and displaying temporal trends in their research. Furthermore, another adopted kind of graphical representation is bar graphs, particularly for discrete or categorical data. They used bar graphs to

present data that could be divided into distinct groups and to compare quantities between various categories or conditions, simplifying visual comparisons. In addition to individual bar graphs, the researchers also employed grouped bar graphs. They depended on this visual medium to compare several variables across various categories simultaneously, facilitating comparisons between their research variables within and between groups.

Additionally, in examining the modes of data representation in the corpus, the Engineering research articles writers opted for data tables and structured parameter tables as visual modes to display raw or processed data, conveying statistical analyses, experimental results, and numerical data. Furthermore, they employed structured parameter tables to organize, compare, and highlight both experimental and numerical data. The use of such tables improved information accessibility and clarity, enabling researchers to successfully convey the convolutions of their research.

5. Discussion

The study's findings advance the current discussion of successful science communication by shedding light on the interaction between text and visual elements. Researchers of Biology and Engineering in the University of El Oued showed their reliance on multimodal communication to depict and communicate their findings. They concur with the claims put forth by McMillan (2012); Nair & Nair (2014) and Richter *et al.* (2021). These previous studies promoted the depiction of Biology research results using a combination of text, tables, diagrams, and images to guarantee multimodal communication and competent data visualization. Furthermore, researchers of Engineering in the University of El Oued displayed that this field benefits from a multimodal representation that includes text, specific types of tables and graphs, supporting the assertions made by O'Halloran (2011) and Irish (2015). This emphasizes the significant importance of multimodal communication to accurately disseminating scientific knowledge. Essentially, the study's results proved that scientific research knowledge representation in the modern era is a fusion with a focus on the collaborative assimilation of multiple modes rather than just relying on textual explanation (Oliviera *et al.*, 2014; Patron *et al.*, 2017).

Examining the interplay between the various modes (text, images, tables, diagrams, and graphs) that are employed, this research spotlighted the collective role that enhances the entire knowledge of research articles, particularly in the Results and Discussion section. In research articles from both disciplines, it is evident how textual and visual components complement and reinforce one another, highlighting their mutual contribution to meaning comprehension (Hyland, 2009). Textual descriptions provide the necessary prior knowledge, context, and in-depth descriptions, while visuals give an obvious portrayal of the topics addressed. This synergy ensures multimodal scientific communication and therefore a thorough transfer of research knowledge.

The study's data accentuated an important fact about how different disciplines involve the use of several visual modes to present and discuss results. The observed disciplinary distinctions underscored how two very distinct scientific disciplines,

Engineering and Biology, embrace different visual representation modes according to the nature of research and the specificities of the discipline (Swales, 2004). Researchers of Biology in the University of El Oued used images, certain types of diagrams, and comparative tables to illustrate the intricacies of this field, while researchers of Engineering depended on specific graphs and tables to convey their numerical data in a streamlined and thorough way.

In the light of the study's results, it is recommended that researchers should participate in training or workshops that supply them with the skills needed to effectively integrate texts and visual modes when communicating their scientific works, ultimately contributing to appropriate scientific knowledge exchange. Additionally, it would be of great benefit to collaborate with researchers in English-speaking environments as it might facilitate their access to valuable sources regarding scientific discourse quality.

6. Conclusion

Since scientific communication is an everlasting change, employing a comprehensive and well-rounded approach to multimodal communication would undoubtedly improve the research quality in the dynamic domains of Biology and Engineering. This study has provided significant insights into the diverse modes of communication that are employed by researchers of the University of El Oued in their research articles, particularly in the Results and Discussion section within the aforementioned disciplines. The intricate interplay between textual explanations and visual elements underscores the need to customize communication modes to the unique requirements and standards of each discipline according to its specificities.

This study has some limitations. First, it focused only on Biology and Engineering domains; hence, its findings cannot be generalized to other scientific disciplines that need to be also researched to gain a holistic picture about the topic. Moreover, although this study covers various sub-disciplines of Biology and Engineering, it does not include the entirety of these fields and variations among less represented disciplines may exist. Therefore, further studies can broaden the investigation to examine a variety of disciplines to improve the multimodal communication in scientific discourse, thereby improving knowledge exchange and readability in the academic landscape.

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