Communicative Awareness is the Key: Using The Rhetorical Triangle for Improving STEM Graduate Academic Writing

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Abstract

The ability to carefully craft writing for an intended audience is crucial in creating persuasive rhetorical arguments. Learning to do so requires knowledge beyond IMRaD (Introduction, Methods, Results, Discussion). Many graduate students learn by mimicking this structure, yet lack audience awareness and overuse jargon, producing low-readability texts. What is more, they increasingly rely on AI-based writing tools that mimic the same structures that are already often poorly written. The results are too often uncommunicative articles that fail to persuade the intended audience. Therefore, we suggest writing pedagogy includes a deeper understanding of effective written science communication using the rhetorical triangle. As graduate students most readily understand the importance of logos, i.e., the scientific content, our job as writing instructors should be to emphasize the role a carefully aimed pathos and ethos plays in producing highly readable, persuasive, publishable articles. To this end, this paper first presents a brief background on the IMRaD structure before outlining the much-overlooked role of the rhetorical triangle in scientific writing. Specifically, we offer a detailed table for graduate students to use in science, technology, engineering and mathematics (STEM).

Introduction

The academic publishing system is overburdened with scholars and graduate students competing to publish (Arsenault et al., 2021). Yet, studies have shown that few scholars manage to publish every year, especially in top-tier journals (Dhammi & Rehan-Ul-Haq, 2018), and numbers indicate that manuscripts are rejected over 60% percent of the time when they are first sent out (Hall & Wilcox, 2007; Hesterman et al., 2018). Already stressed, editors deal not only with an ever-growing number of articles but also with less well-written ones. Academic writers are gravitating to heavy use of jargon and to longer, subsequently harder to follow sentences (Plavén-Sigray et al., 2017; Song et al., 2023). Left with little choice, editors reject potentially fruitful research for its dense, uncommunicative writing or repetitive nature (Bolton & Rowland, 2014; Milton, 2022). Moreover, for many science, technology, engineering and mathematics (STEM) graduate students and early career scientists, English is a foreign language, an added obstacle (Bennett, 2014; Morton et al., 2015; Rakedzon & Baram-Tsabari, 2017).

Artificial intelligence (AI) tools, though used increasingly in academic writing, have proven highly limited in supporting writing that is persuasive, clear and engaging (Barrot, 2023; Kumar, 2023). Now more than ever, students require training in what AI lacks: an encompassing understanding of communication that will allow them to meet each writing challenge. AI tools have strength in speed and grammatical correctness but lack the complexity of human thought and research (Kumar, 2023). But again, arriving faster at grammatical correctness does not

imply a better rhetorical appeal. In cases of truly weak writers, both L1 and L2, who may depend on ChatGPT to compensate for slow writing speed and sentence structure issues, students must still be able to make sure their AI-generated text uses the persuasive language needed to appeal to the target audience (Barrot, 2023).

One effective starting point for proper organization of academic writing is based on the IMRaD moves (Introduction, Method, Results and Discussion) (Devitt, 2015; Juergensmeyer, 2022; Swales, 1990; Swales & Feak, 2012). Done well, the IMRaD produces organized and engaging communications. Yet, more is required beyond IMRaD and genre awareness for effective writing. As such, IMRaD and genre awareness should be complemented by other tools. For example, scientific writing can be improved using visualizations such as 'disciplinary reasoning diagrams' which help integrate knowledge from STEM by scaffolding the composing process while developing students' genre awareness (Lane et al., 2022).

Here, we show that studying the rhetorical triangle, specifically for STEM graduate students, can boost persuasiveness. The triangle crystalizes the relations between logos (the internal logic of the message, to connect to the audience), pathos (appeals to emotion as well as shared beliefs and knowledge, and to the credibility of the researcher), and ethos (the resulting trust of the writer based on their perceived authority and professionalism) (Aberšek & Aberšek, 2010; Caplan & Johns, 2022; Van de Ven & Schomaker, 2002). The triangle helps match the audience's expectations regarding format, language, sentence structure, and rhetorical moves into a most convincing argument. The more surprising or controversial an argument, the greater the need to apply the triangle's principles.

Our goal is to emphasize to early career scientists that scientific writing is an endeavor requiring style as well as carefully crafted appeal to the audience, i.e., to contribute to the idea that "to present a scientific subject in an attractive and stimulating manner is an artistic task, similar to that of a novelist or even a dramatic writer" (Born, 1968). In this paper, therefore, we will argue that while outlining IMRaD and stressing grammatical issues for L1 and L2 users of English are useful in guiding these writers' academic writing, teachers of writing should expand and explain the importance of effective, engaging written communication. To do so we should use tools that emphasize persuasive writing, such as the rhetorical triangle, which can be easily implemented alongside other tools, including the new AI-based tools such as ChatGPT. Our jobs should be to demonstrate that a well-honed, well-aimed pathos and ethos will produce highly readable, persuasive, publishable articles.

Background

The evolving IMRaD structure and scientific publication
Recently, the nonlinear nature of the online environment has both changed – and not changed – IMRaD structure. Journals are increasingly utilizing links or hypertext insertions, for example. Prestigious publications, such as the well-established British Medical Journal (BMJ), have expanded their online presence by adding an app, for example. Others exist only online, and others still as open-source rather than tightly controlled peer-reviewed formats (Casper, 2009; Pérez-Llantada, 2022). Many link separately to the methods section. Even beyond the methods, there are suggestions for dealing with additional data and methodological information like including links to video files and PowerPoint slides (Cerqueira et al., 2017; Luzón & Pérez-Llantada, 2022). Another example is post-publication peer reviews in the format of online comments and forums, such as in Science and PLOSone (Casper, 2009; Yeo-Teh & Tang, 2023). Other options that have been proposed include data comics that encourage telling your story through visualization and animated figures that are brief videos integrated into a PDF (Bach et al., 2017; Grossman et al., 2015)

Researchers have looked closely at the implications of digital changes and reached a similar conclusion: the online presence of articles is less about the genre transforming and more about an innovative communication approach made possible by online modes. In other words, research now suggests the differences are found not in the structure, but in the flexibility that digitalization allows (Autry, 2013; Luzón & Pérez-Llantada, 2022). Learning how to utilize this flexibility best to maximize rhetorical appeal, then, should be the order of the day.

Early career scientists will benefit from understanding, for example, a reader is likely to open an article online, looking at the abstract first (Groves & Abbasi, 2004; Kelly et al., 2014; Subramanyam, 2013), and, at a glance, jump into other links. The stress, therefore, should shift to include ways of drawing the reader in, both visually and rhetorically.

The role of rhetoric in scientific writing

The use of rhetoric in scientific writing in genres is not new. Some students are introduced to the rhetorical triangle when entering college as part of undergraduate teaching textbooks, but mostly in English-speaking countries (Bunchasansiri et al., 2021). Yet, the Aristotelian classic formulation aimed at appealing to audiences all but disappears for graduate learning. Moreover, a quick search on Google Scholar and other databases reveals how little attention it receives in scientific communication; in one of the few examples, Segal supports the use of the triangle to communicate health issues on the internet better (Segal, 2009). Another blog suggests its implementation in communicating data science (Rakedzon and Rabkin, 2022). Other articles recommend it, and report graduate students respond to it favorably (Aberšek & Aberšek, 2010).

The importance of rhetoric in scientific writing is echoed by Fahnestock (1986) in her seminal paper, detailing the significant shift in rhetorical style in writing for various audiences. She discusses academic science writing full of hedging (language of uncertainty) and jargon, and how these aspects are greatly diminished when scientists write for the public and decision-makers (Fahnestock, 1986). That rhetoric can speak to science writing has also been polemically argued by Alan Gross (Harris, 2006), who posited that even science writers cannot escape the need to submit to linguistic social realities.

There has not always been a polite conversation between rhetoric and science (Harris, 2006). Harris (2006) stresses that the goal of rhetoric is not to "reduce" the sciences or to lure them away from objective knowledge building. Rather, it is about recognizing that language creates science writing, and is, therefore, subject to the social construction inherent in it. Latour (1987) writes of the need for supporting texts and the 'enrolment of many other people'; if not, the rhetoric of science is powerless, losing readers because of a lack of interest or indifference. On a more positive note, as Ceccarelli (2010) argues that the conversation between rhetoric and science is about recognizing that scientists can be most effective when they internalize their responsibility for convincing their readers, i.e., for "advocating" for their arguments.

Teaching early career scientists to navigate rhetorical persuasion while relying on specific communicating principles reflects advice from writing books and experienced editors regarding how the quality of writing affects readers. Glasman-Deal (2010) and Borja (2014) argue that abstracts, for example, should be easy to understand, avoiding overly complex jargon as much as possible. Both scholars stress the importance of first impressions when dealing with readers opening databases. With hundreds of hits sometimes, how can a single title or abstract stand out? The answer is that an abstract appealing to its readers will draw a reader more than a dense, badly written one (Kelly et al., 2014). The classic model for writing an abstract has not changed. Wise writing choices based on understanding how to appeal to the modern reader who searches on a database will make the difference.

The good news is that there is no need to completely reconstruct teaching or learning writing. We propose, rather, adding to the pedagogy the rhetorical triangle as a specific lens through which to consider all the above. The triangle helps highlight to students that there is a clear correlation between writing in a manner that narrates to the audience and higher impact results (Ellederová, 2023; Hillier et al., 2016).

Whether students write the texts themselves and use AI to improve their writing, or, in some extreme cases, use AI to write a complete draft, in the end, students and researchers must have tools that help them judge, monitor and modify texts to suit their scientific goals as well help writers identify to whom they are "telling their story."

Later in this paper, we offer students a practical table aimed at deepening their focus on the IMRaD structure using the triangle's principles (see Table 1). The table guides writers to focus

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on what and why they are communicating, an interrogation that will result in increased readability and clarity. The table will help writers make decisions regarding language and content in a way that will improve their argument, allowing them to appeal to different readers, for example, another scientist who is sometimes a colleague and sometimes from another discipline.

How to use the rhetorical triangle to improve scientific writing

What do we mean by the rhetorical triangle's logos, pathos, and ethos, and how can these help early career scientists (as well as more experienced ones) become more effective writers? The primary expectation of STEM readers is that writers base their knowledge on logic, or logos. A scientist's focus on logos begins as early as planning the research, through the construction of solid experiments and the collection of facts. Considering their professional training, students understand this concept readily and quickly. In fact, they seem to take logos for granted. Therefore, we name it, assuring students that, indeed, readers of science articles will first and foremost look for strong logos. If the logos of the article is poor, the article will be dismissed. The IMRaD structure is highly logical but is at its best when it aims to make science products for a specific audience.

Aiming the logos requires a well-thought-out pathos. Moving from logos to pathos will not necessarily be easy and, from our experiences, may be met with initial skepticism. Traditionally, pathos is identified as the "emotional appeal" of the argument. It represents those parts of the argument that appeal to the readers' emotions as a way of convincing them. For scientific purposes, pathos' deeper meaning matters: pathos also means appealing to shared beliefs or ideals common to the discourse community (Knoblauch, 2011; Lunsford et al., 2010). One example of pathos in IMRaD can be found in the introduction. In an introduction, a writer can importantly emphasize the appeal of a shared value as it relates to the paper's central problem. For example, in the medical field, it could be healing, making sure people are healthy, reducing pain, and more; in more theoretical work, it could refer to problem-solving. In methods sections, pathos arrives in the shape of stressing care, which is taken to avoid contaminating samples, for example.

Pathos, in addition, is the rationale behind moves in articles, moves that are not always obvious. Many examples can be found in the authors' combined decades of teaching writing: one classic question from students is why bother with all the introductions? Why do we need the "niceties" such as "it has been established"? Students ask, if we have the numbers and the science is solid (logos), why rewrite an introduction to the topic? Why not only write the methods and results with some conclusions but also copy the introduction from a similar paper and be done?

Students can get frustrated, especially if they discover that the introduction they write is like many other articles that have already been written (hence the impulse just to copy and be done). The answer is that communication conventions are not strictly about numbers but also about an article, which is a stand-alone piece of communication. The audience expects that the writer takes time to appeal to them, to give context, to explain which conversations the writer connects to, and to demonstrate loyalty to the shared values (i.e., healing or solving the problem). It is almost as if readers expect to be courted with proper manners. When you walk into a formal situation, you shake hands and introduce yourself in the same way over and over. These "manners" are part of pathos, and they dictate that you appeal to your readers.

The final stage of the rhetorical triangle is ethos. The ethos is produced as a result of solid science presented (logos) in a way that considers moves the discourse community expects with stresses on shared values (pathos). During a conversation, people form an opinion of the speaker based on additional aspects of the spoken message itself. We watch the way a person stands (confident? or arrogant?), the way they address us (respectful?), and we listen to the way they express themselves (political correctness, knowing the correct jargon that we share in the discourse community). As readers, we similarly reflexively react to the writer, forming an opinion of whether they seem trustworthy. Ethos could be the citations the author has chosen to include or the reputation of the publication in which they publish. Sharing our values, detailing our specific brand of logical progression, word choices, jargon usage (its particular use or

sometimes its avoidance), and much more shows respect to our readers (Lunsford et al., 2010). Ethos, simply put then, is created due to the confidence the readers have in the author based on the complex relationship between logos and pathos.

The elements of the rhetorical triangle (logos, pathos, and ethos) turn a writer's attention to the connective nature of the story one is telling. It causes a writer to focus on communicating effectively using everything from their hard work in the lab to asking themselves which background work they should be quoting in their initial introduction. Attention to the triangle's elements helps answer such questions as which background information will best help a specific type of reader understand the logos. Checklists for writers are useful in this context because they cover what writers should be looking for to ensure their work is well-written. Aberšek and Aberšek (2010) developed such a checklist for their engineering students, a list that takes them through the three parts of the triangle. The table we offer in this paper offers an extensive "checklist" for writers that take this idea further. The table leads writers, even those with little or no experience with the triangle, through the three parts while detailing its implication for writing each IMRaD section. Nevertheless, the table will work best when a writer first learns the basics of the triangle, along with what it teaches regarding the basics of communication with audience awareness as a primary goal.

Guidelines for implementing the rhetorical triangle

What makes a reader click on an article? Several anecdotes often come up in writing courses. For example, an ecstatic student who finally published an article, only to realize a general title has left it virtually lost and unread. In such a case, the writer failed to stress keywords readers would be searching for on databases. In other cases, PhD students with supervisors have received rejections from peer reviewers because the novelty of the work was not clear. In another typical story, a student presented groundbreaking research about enzymes "walking" on genes at an international conference. When colleagues commented that he should publish his work, he repeated that he had already published it, but that no one was reading it. In class, he concluded that the published article used overly complex jargon and sentences. He realized that while attempting to use impressive language, he confused his readers and produced a low-readability text. We assert that rhetorical awareness using the rhetorical triangle could aid in such situations.

To implement the triangle, our table emphasizes the triangle's application. After briefly defining each term, the table presents an overview intersecting the triangle with each of IMRaD's sections. This way, a specific triangle aspect (e.g., pathos) can be intersected with a specific IMRaD portion (for example, the results section). Or, alternatively, a writer can choose a specific intersection of the triangle and IMRaD they need to review as they work.

The table can be used in several ways, both inside and outside the classroom. For example, it can be used in class to ask students to reverse engineer articles published in high-impact journals to help them develop the rhetorical awareness of the triangle's three sides of persuasion. In addition, the table can accompany students throughout the semester. As they write assignments, they can be asked to reflect on their progress using different parts of the table. For example, when working on methods, students can be required to review the table and refer to it in their reflection. They can be asked to write in a few sentences about the ways in which they took the triangle into account as they worked on preparing their method assignment.

Moreover, the table can be expanded when preparing other high-stakes writing such as grants or scholarship thank you letters. In grant writing, pathos and ethos may play an even stronger role. For example, many grants ask for sections that include the leading researcher's CV and credentials for carrying out the proposed research (credibility – ethos); they often also include a section on the relevance of the research to a broader audience of peer review (shared values – pathos).

Table 1: Guide for writers to implement the rhetorical triangle in an IMRaD research article

	LOGOS 'Facts, statistics, evidence'	**PATHOS** 'Values, emotional impact, personal connection with the audience'	**ETHOS** 'Trust, credibility, ethics, tone/style of the writer'
General Principles	Collect and include all the facts and evidence, i.e., all of the science, before writing: (1) acquire and document the knowledge required in your field of work (report protocols and statistics); (2) learn and use the appropriate jargon; and (3) find relevant and up-to-date published articles relevant for your work. Tip: Use up-to-date as well as seminal articles in the field, especially from prestigious peer-reviewed journals. Make sure arguments are presented logically.	Show awareness of the reader by appealing to shared ideas and beliefs. This is about establishing the importance of the issue to convince your readers and gain the readers' trust. Start each section of the article with a small introduction that uses the language/conventions/ appropriate literature. Tip: Stress the motivation of the paper and use relevant examples, analogies, or images to engage the reader.	A strong ethos is a by-product/result of well-executed logos and pathos. Writing is not just reporting facts. For example, justify the choice of methodology. Tip: Choose several respected sources to show you are familiar with primary past research; write the text professionally and correctly for your intended audience.
Abstract	This is an efficient summary of what your article does for your reader. Tip: Logically organize the summary of the research, outlining all parts of IMRaD. Use keywords.	This is an "advertisement" for your work: stress the positive and your contribution, upfront. Tip: Make sure your abstract emphasizes the novel aspects of your work and choose language for the widest possible audience.	In a digital environment, with so many choices, this is the first impression of your article. Stress the take-home message and relevance to your community. Tips: The work should be well-written, grammatically clear, enticing, and professionally written. The reader should want to open the article.
Introduction	The introduction serves to create an article that is self-contained and stand-alone by including up-to-date, relevant background. Tip: Add to the conversation scientifically by sharing the appropriate level of background, including up-to-date research, and explanation for your audience.	Here, connect to the larger conversation by citing supporting work, establishing importance, and including background knowledge. Tip: Stress the "so what" of your research. What are the shared values that can be stressed? Is it healing, problem-solving, or pure science?	The introduction needs to be well-written. In citing relevant and peer-reviewed background research, show you are part of the conversation. Tip: Sometimes, an important part of ethos is about quoting all the right names; the reader needs to be able to trust you from the beginning.

	LOGOS 'Facts, statistics, evidence'	**PATHOS** 'Values, emotional impact, personal connection with the audience'	**ETHOS** 'Trust, credibility, ethics, tone/style of the writer'
Methods	The method allows others to replicate the protocol, explaining modifications or new methods in detail. Tip: Present sufficient details.	Here is also your chance to demonstrate precision and professionalism. Tip: What did you do to make sure you are trustworthy? What can you stress to help your readers trust your results? You can stress you took care with your process, used industrial kits, followed ethical protocols, and more.	Readers will follow your methods on a logos level and see that you took care and that you are a professional. Your ethos will be strong. Tip: Present the justifications for your choice of methods, and how the research is replicable.
Results	Organize the results logically and objectively. The charts and graphs clearly represent the data. Tip: Choose an appropriate graphical form to present your results. Also choose signal words that most accurately describe the results (e.g. often, repeatedly, regularly).	Here, stress what is surprising and what is strong. Tip: Present the results in an organized fashion that suits your story.	Show the connection between your results and previous work, how it expands on previous research, supports it, and even contradicts it. Tip: Stress the potential and significance within the limitations, and how previous work supports the findings.
Discussion/ Conclusion	Here, compare results to previous literature. Show your contribution to the field's knowledge base. Tip: Clearly explain, interpret, and present implications for the future of your field. Ensure interpretations are supported by previous work and knowledge.	Here, carefully choose the best possible language to stress achievement. Tip: Use hedging to indicate awareness of uncertainty (e.g., possibly, indicate).	Make specific connections that create a clear, bigger picture based on support and evidence from the field. Tip: The bottom line/novelty is made clear, and precisely summarized at the end of the article.

Conclusion

In the end, the continual discussion of writing abilities and the importance of writing in academia, not to mention in science and the workplace in general, has produced a plethora of books and articles aiming to help young career scientists (e.g., graduate students and young scholars) at various levels improve their writing and communication capabilities. Moreover, the abundance of online and AI-based tools provides students with writing support, even shortening the writing process. Such guidelines, best practices, and tools are useful at various levels – and combined can help a writer progress significantly. At the end of the day, writing should be clear, concise and mechanically and grammatically correct – but it is so much more than that.

This article examined the bigger picture – encouraging academic writers to step back – both before, during, and after the writing process – alongside the AI-based tools many use today. We believe the rhetorical triangle is ideal to help guide writers make their texts communicable, publishable, and readable moments that readers will understand and use in their research. Importantly, the rhetorical triangle directs writers to look at what they need to do before the writing process, i.e., realize that it begins at the stage of knowledge and actual work in the laboratory. Next, notes from editors, advisors, or peer readers can and should be passed

through the triangle's filter. The tool will help writers identify better which, if any, of the stages suffers from interrupted or weakened ethos because they fail to connect with a specific audience. Writers then can go back and improve the appeal of flawed parts. Finally, at the post-writing stage, the writer can look back at their work and see if the metrics have strengthened what they thought was a "successful" text – if it is published, read, used and cited.

Once a writer understands the triangle, the IMRaD becomes more than a lengthy logos-based list. It becomes a communication narrated for the reader with clarity and purpose. Scientific articles build strong ethos by combining logos (the knowledge built in the research) with a story that follows the rules and values the specific community expects (pathos). When done successfully, the result is published work woven into the scientific conversation and community.

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