Genre Theories and Their Potential for Studying Proof

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In this theoretical report, we outline several major traditions of genre theory, argue that proof qualifies as a genre as defined by these traditions, and propose how genre analyses could be used to further our field's understanding of proof.

Keywords: genre, genre theory, proof, move analysis, critical genre analysis

Mathematics education researchers have engaged intensively with proof and the learning and teaching thereof, but rarely have they drawn on genre theories in this pursuit. In this theoretical report, we outline several major traditions of genre theory, argue that in line with these traditions proof is a genre, and propose how genre analyses could be used to further our field's understanding of proof.

A Brief Overview of Genre Theories

Since the 1980s, "genre" has received significant attention in the Anglophone world of applied linguistics from scholars of three research areas: English for Specific Purposes (ESP), Rhetorical Genre Studies (RGS) (sometimes referred to as "New Rhetoric" studies), and Systemic Functional Linguistics (SFL) (sometimes referred to as the "Sydney School") (Hyon, 1996, 2018b; Swales, 2012). All three traditions are united in viewing genre as a social practice (Tardy, 2012): ESP scholars define genre as communicative events (within discourse communities) with shared communicative purpose(s) (Swales, 1990), RGS scholars define genre in terms of the "action it is used to accomplish" (Miller, 1984, p. 151), and SFL scholars define genre as "a staged, goal oriented social process" (Martin et al., 1987, p. 59). As Tardy (2011) summarized:

> [The three traditions] agree on several general characteristics of genre as a category of discourse:
> - Genres are primarily a rhetorical category
> - Genres are socially situated
> - Genres are intertextual, not isolated
> - Genres are carried out in multiple—and often mixed—modes of communication
> - Genres reflect and enforce existing structures of power. (p. 55)

That said, the three traditions continue to differ, for example, in terms of: (a) the genres studied, (b) the attention paid to linguistic features, (c) the attention paid to institutional contexts, and (d) methods employed (Hyon, 1996, 2018b).

In addition to the three aforementioned traditions for studying genre (i.e., ESP, RGS, SFL), Swales (2012)—father of ESP genre theory—noted that there also exist "[t]he Brazilian approach to genre (Vian, 2012) and the Academic Literacies movement, sometimes known as the 'New London School'" (p. 113). Although it is incorrect to think of the Brazilian tradition as a monolith (Vian, 2012), it is correct to note that genre research in Brazil has been heavily influenced by Bakhtin's (1986b) work on genre (Gomes-Santos, 2003) and, albeit it to a lesser extent, socio-discursive interactionism (Bronckart, 1997). The Academic Literacies movement finds the ESP tradition too textual and pushes for a greater focus on academic practices (Swales, 2012). For discussion of further traditions of genre theory, see Vian (2012).

The Genre of Proof

In this section, we argue that proof satisfies Tardy's (2011) five characteristics of genre. We thereby wish to justify applying genre theories (particularly ESP, RGS, and SFL) and genre analyses to the genre of proof.

Proof Is Primarily a Rhetorical Category

By being "primarily a rhetorical category," Tardy (2011) meant that "what makes a text a genre is not its linguistic form but the rhetorical action that it carries out in response to the dynamics of a social context" (p. 55). As Hanna (2000) listed, proofs can be used to, for example, verify, explain, systematize, discover, communicate, construct, explore, and incorporate.[1] And, Hanna (1989) argued, some of these functions (i.e., rhetorical actions) may be more appropriate in certain social contexts—"proofs that explain should be favored in mathematics education over those that merely prove" (p. 45). That dynamics of different social contexts can lead to different rhetorical actions was also demonstrated by Schifter (2009): In one elementary school classroom, students used a proof as an aid to understanding; in the other, students used a proof to convince. In short, we argue that proofs serve a set of communicative purposes that depend on the discourse community in question, that is, as primarily a rhetorical category.

Proof Are Socially Situated

To assert that proofs are "socially situated" according to Tardy (2011), we should be able to observe that conventionalized forms of proof are tied to their socio-rhetorical context (e.g., a class of 4th graders and their teacher, Poisson geometers). Stylianides's (2007) frequently cited definition of proof acknowledges this centrality of the socio-rhetorical context by qualifying that accepted forms of statements, modes of argumentation, and modes of argument representation used in proofs are only "accepted" in that they are endorsed *by the classroom community*—or, as we would amend using ESP terminology, a given discourse community.

To underline that proofs are socially situated and that their form is tied to their socio-rhetorical context, consider the following three examples: (a) a two-column proof in a high school geometry classroom, (b) a proof by Gauß in *Disquisitiones Arithmeticae*, and (c) a proof told as a first-person singular narrative (e.g., "First, I noticed that if you take …") in an elementary school classroom. All three proofs vary significantly in form but, assuming their veracity, are valid forms of proof within their socio-rhetorical contexts.

Proof Are Intertextual, Not Isolated

"[T]he communicative work that genres do is almost never carried out by isolated, single texts. Rather genres work in coordination to accomplish complex tasks and social goals" (Tardy, 2011, p. 58). Below, we outline two ways in which proofs are intertextual.

First, proofs often explicitly reference previously proven statements (e.g., "By Proposition 4.2, …"). Thus, deliberate connections are made in proofs to other texts. All such intertextual references in proofs must be carefully organized so as to avoid circular reasoning. More generally, all proofs implicitly reference axioms and/or previously proven statements due to how mathematical theories are logically organized as inverted pyramids.[2]

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[1] We acknowledge that although "verifying" is not the only communicative purpose of the genre of proof, it is a central one, and it is hard to make sense of proof without thinking about proving that a statement is true or false.

[2] In this analogy, the point of the inverted pyramid is axioms, upon which a progressively broader set of theorems is built.

Second, proofs are intertextual in that they work in coordination with other genres, such as definitions, theorems, and remarks. (Mariotti, 2006, argued that proofs must be understood as a triad of proof, statement, and background theory.) Often, a definition is followed by the statement of a theorem (or proposition or lemma) about the just-defined object or property, which is then proven. After the proof, an author may make a remark, which offers, for instance, observations about the just-finished proof. (For a genre analysis of remarks that illustrates different communicative purposes of remarks, see Küchle, 2023.) Sequences of definitions, theorems, proofs, remarks, and other mathematical genres (e.g., examples, exposition) can combine to form larger narratives (e.g., a sequence culminating in Lagrange's Theorem)—narratives that university instructors can backwards engineer.

Proofs Are Carried Out in Multiple—and Often Mixed—Modes of Communication

As O'Halloran (2015) noted, mathematics is multimodal: Mathematics uses linguistic, symbolic, and visual forms of representation. We assert that proof is also multimodal: Proofs consist of words, symbols, and images (e.g., graphs, diagrams). Yet, we acknowledge that although the value of images during proof-production has been suggested (e.g., Alcock & Weber, 2008; Weber & Alcock, 2004), the question remains to what extent a valid proof may be visual. Larvor (2019) addressed this question by showing that although not all types of diagrammatic inferences are typically allowed in proofs, there is a class of such inferences that are often allowed. In addition to satisfying certain diagram characteristics (Larvor, 2019), we believe that a proof's socio-rhetorical context—context that includes level and subdiscipline of mathematics—contributes to the permissibility of images in proof.

Proofs Reflect and Enforce Existing Structures of Power

As Dawkins and Weber (2017) noted, there are values and norms at play in proof-writing. Further, where there are values and norms at play, power dynamics emerge. Thus, Tardy (2011) deduced, "[genres] must be viewed as not just a reflection but also a reinforcement of the power structures that exist in the community within which they are used" (p. 60). Indeed:

> Genres are forms of "symbolic power" (Bourdieu, 1991, p. 163) and could be forms of "symbolic violence" (Bourdieu, 1991, p. 139) if they create time/spaces that work against their users' best interests and their users perceive them as naturalized or "just the way we do things around here." (Schryer, 2002, p. 76)

Thinking about the educational setting, Tardy (2011) observed: "School genres […] inherently situate students in low-power positions, subject to the evaluation and preferences of teachers, who serve as gatekeepers" (p. 60).

Tardy's (2011) observation about school genres also holds for proofs in educational settings. Even proofs written by research mathematicians for publication are subject to a power difference between the authors in low-power positions and the editors and reviewers as gatekeepers. In educational and academic settings, the person(s) in high-power positions uses their set of values and norms to evaluate the proof of the person(s) in low-power positions (see Tanswell & Rittberg, 2020). For instance, a proof may be considered "too verbose" or "make too many omissions." That these types of critiques are subject to bias and can (re)enforce existing structures of power—in our case, white supremacist capitalist patriarchy (hooks, 2015)—can be seen by considering the example of Su's (2020) student Akemi, whose proofs stopped receiving full marks once the teaching assistant found out Akemi was a woman.

To see how proofs may reflect existing structures of power, consider the language in which they are written:

> [T]he mode in which mathematic is usually written and spoken is one of advocacy, of claims and assertions, one which generally ignores its audience. It is a language which I feel is more easily adopted by men than women, if we can believe what we are told about women using fewer declarative sentences in conversation. And it is a language, which particularly, when spoken, is frequently abused with impatience, frustration, and defensiveness. (Keith, 1988, p. 8)

Thus, proofs—and the language they are written in—may reflect stereotypical traits of masculinity (Hottinger, 2016; Weber & Melhuish, 2022).

Summary

We contend that proof satisfies Tardy's (2011) list of five genre characteristics on which the three central Anglophone traditions of genre theory can agree. Thus, we feel justified in applying these theories' genre analysis tools to the genre of proof.

Analysis Possibilities

In this section, we explore two types of genre analysis from the three traditions and see how they could be applied to the genre of proof.

Move Analysis

In the ESP tradition, a genre is often studied by conducting a move analysis, which focuses on moves, "those textual segments that make up a genre's organizational structure and help the genre achieve its purposes" (Hyon, 2018a, p. 27). They are functional units (i.e., they are not about what a text is saying but about what the text is doing) and can be thought of as mini communicative purposes (Hyon, 2018a). For example, a common move in research article introductions is "establishing a niche," which can be realized by, for instance, indicating a gap in research (Swales, 1990). As Bhatia (1993) noted, moves need not occur linearly; they can also be interactive (e.g., in legislative texts, legislating and specifying can be thought of as a two-part interactive move).

A common goal of performing a move analysis is to determine a move structure that can be shared with students to aid their learning (Hyon, 2018a). To this end, mathematics education researchers could use, for example, Hyon's (2018a) stages of a move analysis—based on Biber et al.'s (2007) and Upton and Cohen's (2009) approaches. A move such an analysis might yield is *indicating deduction*, which authors realize in many ways (e.g., "[X]. Thus/hence/therefore, [Y]", "Since/Because [X], (it follows that) [Y]", "If [X], then [Y]", "From [X], we get that [Y]", or "[X] implies that [Y]"). This move can serve several common communicative purposes of proof: by *indicating deduction*, the author is able to more easily *convince* the reader since the text has been *systematized* and aids the reader's *verifying*. Other example moves might include setting a goal or initiating a proof technique.

A move analysis may also shed light on cross-cultural differences, be they differences between, what Holliday (1999) termed, "large cultures" (e.g., proofs in Germany versus those in the U.S.A) or "small cultures" (e.g., proofs by undergraduates in an introduction to proof [ITP] course versus those by research mathematicians) (Hyon, 2018a).

To illustrate what a cross-cultural difference might look like, consider our following informal observation. While skim-reading proofs in research papers and in first-year lecture notes, we noticed that mathematicians-as-teachers frequently *(re)express the statement to be proved*—a move seen but once in the research papers. Consider the following examples from Linear Algebra, Abstract Algebra, and an ITP course:

Proposition 5.3. Let $T : U \rightarrow V$ be a linear map. Then:
(i) im(T) is a subspace of V;
(ii) ker(T) is a subspace of U.
Proof. For (i), we must show that im(T) is closed under addition and scalar multiplication. […]

Theorem VI.6. *Let G be a group and a, b* $\in G$. *Then* $(ab)^{-1} = b^{-1}a^{-1}$.
[…]
PROOF. We're being asked to prove that $b^{-1}a^{-1}$ is the inverse of ab. So we want to show that $(b^{-1}a^{-1})(ab) = 1 = (ab)(b^{-1}a^{-1})$. […]

Example 8.11. State whether the following sets are bounded or unbounded and prove your answer. […]
(b) $B = (-\infty, \sqrt{2})$. […]
Solution: […]
(b) $B = (-\infty, \sqrt{2})$ is unbounded. We will prove this by showing that for all $M \in \mathbb{R}$ we can find $x_0 \in B$ such that $|x_0| > M$. […]

(Re)expressing the statement to be proved seems pedagogical in nature as it breaks down what needs to be shown. Although this move may seem innocuous, we would like to point out its potential for "deceiving" the student into thinking that nothing has happened. Yet, (re)expressing, or "unpacking," what needs to be shown is often a key step in first-year proofs, which frequently amount to rewriting/seeing something in a new way. Therefore, this move can significantly simplify the proof. Although the move might be thought of as the instructor modeling "good" proof behavior, it also removes the opportunity for students to do this work themselves. The study of e-Proofs suggests that in the interplay between work done for the student reader by the author and work done by the student reader to make sense of the proof, sometimes learning is supported better when the student reader's work is not co-opted by the text (Alcock et al., 2015).

In short, given differences in intended audience and discourse community, proofs written by mathematicians-as-researchers and mathematicians-as-teachers will serve slightly different communicative purposes—recall Hanna (1989) asserting that "proofs that explain should be favored in mathematics education over those that merely prove" (p. 45). Differences in communicative purposes entail differences in moves (i.e., mini communicative purposes), and we posit that the field of mathematics education may benefit from studying mathematicians-as-teachers' proof moves and the extent to which these indeed facilitate student learning.

Critical Genre Analysis

As argued above, the genre of proof reflects and enforces existing structures of power. To study how genres do so, some genre researchers have performed critical genre analyses (e.g., Hyatt, 2005; Levina & Orlikowski, 2009). Rather than being a singular type of analysis, critical genre analyses differ in their methodologies but are connected by their focus on power structures, relations, and imbalances. For example:

- Hyatt (2005) performed a corpus analysis of tutor feedback (and noted the potential for a critical discourse analysis [Fairclough, 2003] to complement the analysis);

- Levina and Orlikowski (2009) performed a qualitative study, as part of which they identified genres in the management consulting field and then "examin[ed] how control over genre enactment was exercised […], as well as who had competence in and participated in the various genre enactments, and how." (p. 678); and
- Schryer (2002) combined a rhetorical analysis with a critical discourse analysis (Hodge & Kress, 1993) to create a chronotopic (Bakhtin, 1981) analysis of "bad news" letters by an insurance company.[3]

Below, we discuss bias and author–reader–proof-text relations[4], before offering our thoughts on what a critical genre analysis of proof could look like.

First, consider that different readers receive a text differently, that is, a text is not reader-independent. A reader's past experiences with a genre shape their expectations for contemporary realizations of the genre. More broadly, discourse communities have and use their own genres, which are understood against a horizon of expectations that has developed over time (Swales, 2016). In addition to a reader's past experiences with a genre, Akemi's example from before suggests that the reader–author relation (shaped by the reader's context and biases) also affects the reader's reading of text. Given how heavily U.S. mathematics departments lean non-Hispanic White (77%) and male (70%) (Blair et al., 2018)[5], women and people of color are most likely to be targeted by readers' implicit and explicit biases.[6]

"Properties" of proof—like *convincing*, *transparent*, or *perspicuous* (Czocher & Weber, 2020)—are not so much properties as they are author–reader–text relations. They can be used to weave a set of contradictions that will always ensure that a proof is not good enough for a biased reader. The reader might claim the proof was unconvincing because it was too short or that the proof—perhaps amended and increased in length—is not perspicuous and untransparent. Minoritized students receiving negative (and possibly contradictory) feedback is concerning as it can lead to a loss of confidence and contribute to an unsupportive culture—reasons identified as leading to undergraduate and graduate students leaving STEM, particularly minoritized students (Herzig, 2004; Thiry et al., 2019).

Second, note that an author's awareness of the (hypothetical) reader(s) shapes their writing. SFL scholars would observe that proofs do not merely serve an ideational function but also an *interpersonal* function (and a textual function). ESP scholars would note that a communicative purpose is shaped by *discourse community* and *intended audience*. RGS scholars would point to genre being a *social* action. Finally, Bakhtinian scholars would point to the importance of an utterance's *addressivity*. For example: An author of a journal article will be trying to convince the reader that the proof is novel, important, and gives due credit to prior work, whereas a student seeks not only to convince the instructor of the veracity of their proof, but also of their knowledge. In short, regardless of how much proof genre conventions suppress agency, a proof is not author-independent, and the author's shaping of the text is affected by their awareness of the (hypothetical) reader(s). (Whether the shaping achieves the author's goals is a different matter.)

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[3] Although Schryer (2002) did not label her work a critical genre analysis, she termed it a "critical approach to genre theory" (p. 76) and a way to "address the issue of genre and power" (p. 76).
[4] The triangle of author–reader–text relations (within contexts) is sometimes referred to as the rhetorical triangle.
[5] Percentages refer to full-time faculty in mathematics departments of four-year colleges and universities in fall 2015.
[6] Proof readers' bias is not just concerning with regard to university students, but also with regard to researchers. Single-blind journals are prevalent in mathematics alongside a culture of publishing preprints on arXiv. As a research mathematician friend of ours remarked, "I've never reviewed a paper I didn't know the author of."

Combining our observations about readers' biases and authors' awareness of their (hypothetical) reader(s), we note that an author's awareness may also include an awareness of their (hypothetical) reader(s)'s biases. For example: A friend of ours vividly remembers changing a proof to include more "powerful" mathematical ideas ("sledgehammers") to make her proof more convincing and beyond (anticipated) reproach.

Given the breadth of what constitutes a critical genre analysis, there are many possible avenues to pursue with the goal of studying power structures, relations, and imbalances as they pertain to the genre of proof. Drawing on our above observations and the view that criteria such as "convincing," "perspicuous," and "transparent" are prone to biased application, we believe it might be fruitful to ask: "What criteria do readers of proof apply when evaluating proofs, and how do they apply these in biased ways?" By studying the feedback that proof readers give—and to whom they give it—awareness can be fostered for the subjective nature of proof evaluation criteria. Further, revealing how biases interact with the application of proof evaluation criteria can provide a starting point for raising awareness of this problem within the discourse community of (research) mathematicians.

Finally, as aforementioned, proofs may reflect existing structures of power and stereotypical traits of, among others, masculinity (Hottinger, 2016; Weber & Melhuish, 2022). This observation raises the question of how proofs can be reenvisioned and rehumanized (Gutiérrez, 2018). For some examples thereof, consider Harron (2016), Sinclair (2005), Leron (1985), and Tymoczko (1993). A critical genre analysis could be used to identify the (invisible) constraints of the genre of proof (which hinder reenvisioning and rehumanizing proof) and how they reflect and enforce existing structures of power (e.g., Bowers & Küchle, 2020).

Conclusion

In this theoretical report, we hope to have given the reader a brief overview of contemporary genre theories, argued that proof is a genre for the purposes of (at least) three major genre theories, and outlined the potential of move analyses and critical genre analyses for advancing the field of mathematics education. But there are many more types of genre analysis mathematics educators could pursue, such as:

- a rhetorical appeals analysis (i.e., appeals to logos, pathos, and ethos);
- a lexico-grammatical analysis (e.g., of frame markers, attitude markers, hedges, and boosters) (SFL, in particular, offers a plethora of lexico-grammatical analysis tools);
- a historical or diachronic study of genre to understand the evolution of a genre;
- an ethnography to learn about the relevant discourse community;
- a genre systems analysis (or genre network analysis) to learn about the relationship among genres (and the relationship between genres and community);
- an intertextual analysis to, for example, understand references to other texts;
- a multimodal genre analysis. (Tardy, 2011)

Further, Bakhtin (1981, 1986a) has served as inspiration to genre theorists—particularly of the Brazilian tradition—and offered a whole set of possibly useful concepts, such as, carnivalesque, chronotope, dialogism, heteroglossia, and polyphony. In short, genre theories offer a whole host of analytic tools that, we argue, may be applied to the genre of proof to advance our field.

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