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Finding the Right Angle: Lessons from Mathematics for the Legal Writing Classroom

Maria Termini

FINDING THE RIGHT ANGLE: LESSONS FROM MATHEMATICS FOR THE LEGAL WRITING CLASSROOM

Maria Termini*

Abstract

It is a common belief in the legal profession that many lawyers are not good at math and that math skills are not needed to succeed in the legal field. Many law students are happy to put their days of studying mathematics behind them. It is a mistake, however, for students to ignore their knowledge of mathematics as they take up the study of law and legal reasoning. Despite the aversion many lawyers feel towards math, legal analysis and mathematical analysis are deeply connected: they use many of the same types of reasoning, often have similar purposes, and frequently follow comparable organizational schemes. The author's previous article elaborated on those connections, explained why mathematics and the law are not as different as they may appear, considered possible explanations for the similarities, and drew lessons for legal reasoning based on its similarity to mathematical reasoning. With that theoretical work as background, this Article contributes further to the scholarship by suggesting ways in which the similarities between mathematical reasoning and legal reasoning can inform legal writing pedagogy. This Article argues that legal writing professors can use those connections between the two fields to help their students develop legal reasoning skills. Legal writing professors can show their students how the skills the students learned in their math classes are related to the new skills the students are developing in law school. Further, legal writing professors can borrow techniques from mathematics educators that help students hone their reasoning skills.

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I. Introduction

Antonio and Janel are two new law students in the same small section.[1] They have all their classes together, including their legal writing class. Antonio was an English major in college. He is not sure how he feels about the Socratic method, but he is used to keeping up with a lot of reading and knows he's a good writer. He is confident he will do well in his legal writing class. Janel was a math major. She is nervous about all of her classes, but about the legal writing class in particular. She did not do much writing in college, and, when she did take classes that included essay or research paper assignments, she often struggled to reach the minimum word requirement for an assignment.

When Antonio and Janel receive the feedback on their first memo for their legal writing class, they are each surprised. Antonio's memo had very few grammar and spelling mistakes, but it read more like an essay than like a legal memo. He made his arguments without explicitly connecting them to the rules or the cases. Even though his memo was missing a lot of important information, it was very close to the word limit. Janel's memo, on the other hand, had more grammar and spelling mistakes, but contained a thorough and clear analysis. Her reasoning was easy to follow and laid out in a logical way. She showed how her argument was supported by the case law. Like Antonio's memo, Janel's memo was close to the word limit, but she used the space more effectively, saying just what she needed to say and nothing more.

While students like Janel might worry about legal writing, those students are, in fact, well-prepared for the course. They may have written fewer papers in college than other students, but they had more opportunities to develop their reasoning skills, which are critical to effective legal writing. As I have argued before, mathematical analysis and legal analysis are similar and rely on many of the same types of reasoning.[2] In particular, lawyers and mathematicians both commonly use deductive reasoning,[3] which is reasoning from the

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[1] While these two students are fictional, you might recognize in them characteristics of law students you have known. You might even see something of yourself in one of them.

[2] *See* Maria Termini, *Proving the Point: Connections Between Legal and Mathematical Reasoning*, 52 SUFFOLK U. L. REV. 5, 14-22 (2019); Stephen A. Kenton, *Mathematical Foundations of Constitutional Law*, 52 MATHEMATICS MAGAZINE 223, 224 (1979) (arguing that "[t]he form of the Declaration [of Independence] is Euclidean in nature, starting with a list of axioms and concluding in a proof based on these axioms"; noting that "American law is founded on the form and spirit of mathematics").

[3] *Compare* Mark Graham & Bryan Adamson, *Law Students' Undergraduate Major: Implications for Law School Academic Support Programs (ASPS)*,

general to the specific.[4] In legal writing and analysis, deductive reasoning is often used when applying rules to facts.[5] The rule is general, while the facts of a case are specific.[6] People in both fields also use inductive reasoning,[7] which is reasoning from the specific to the general.[8] In legal writing and analysis, inductive reasoning is often

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69 UMKC L. REV. 533, 533 (2001) (noting that "fundamental reasoning skills that first-year students should be employing as they develop lawyering skills [include] deductive reasoning"), *and* Ruggero J. Aldisert, Stephen Clowney & Jeremy D. Peterson, *Logic for Law Students: How to Think Like a Lawyer*, 69 U. PITT. L. REV. 1, 2 (2007) ("[A]ll prospective lawyers should make themselves intimately familiar with the fundamentals of deductive reasoning. . . . Perhaps 90 percent of legal issues can be resolved by deduction, so the importance of understanding this type of reasoning cannot be overstated.") *with* Andreas J. Stylianides & Gabriel J. Stylianides, *The Mental Models Theory of Deductive Reasoning: Implications for Proof Instruction* (2007), http://lettredelapreuve.org/OldPreuve/CERME5Papers/WG4-Stylianides_Stylianides.pdf [https://perma.cc/2N5H-HAGA] (noting that "successful engagement with [mathematical] proof requires . . . the ability to use deductive reasoning").

[4] *See* Graham & Adamson, *supra* note 3, at 535 ("Deductive reasoning is a cognitive process whereby particular conclusions are reached through the application of general rules."), and Michael Ayalon & Ruhama Even, *Deductive Reasoning: In the Eye of the Beholder*, 69 EDUC. STUD. IN MATHEMATICS 235, 235 (2008) (recognizing "in mathematics, deductive reasoning has a most central role").

[5] *See* Graham & Adamson, *supra* note 3, at 538 ("When students read judicial opinions to determine whether facts set forth warrant the application of a particular legal principle, they employ deductive reasoning skills.").

[6] *See* Aldisert, Clowney & Peterson, *supra* note 3, at 5-6 ("To shape a legal issue in the form of a syllogism, begin by stating the general rule of law or widely-known legal rule that governs your case as your major premise. Then, in your next statement, the minor premise, describe the key facts of the legal problem at hand. Finally, draw your conclusion by examining how the major premise about the law applies to the minor premise about the facts.").

[7] *Compare* Graham & Adamson, *supra* note 3, at 533 (noting that "inductive reasoning" is one of the "fundamental reasoning skills that first-year students should be employing"), *and* Aldisert, Clowney & Peterson, *supra* note 3, at 3 ("reasoning by analogy – a[] form of inductive reasoning – is a powerful tool in a lawyer's arsenal"), *with* George Polya, HOW TO SOLVE IT: A NEW ASPECT OF MATHEMATICAL METHOD 114 (Anchor Books 2d ed. 1985) (explaining the uses of inductive reasoning in mathematics).

[8] *See* Graham & Adamson, *supra* note 3, at 536 ("Inductive reasoning is a cognitive process whereby observations lead the student to a general proposition."); Edwin W. Patterson, *Logic in the Law*, 90 U. PENN L. REV. 875, 884 (1942) ("Reasoning from particular facts or instances to a generalization is commonly known as 'induction.'").

used to synthesize precedent cases and determine a general principle being followed in those cases.[9]

Legal analysis and mathematical analysis are similar in other ways as well, beyond the types of reasoning used in each. They often have similar purposes, including thinking through a problem, convincing readers an analysis is correct, expanding knowledge in the field, and teaching those new to the field.[10] Further, written legal analysis often follows a similar organizational scheme to that of a mathematical proof, which is the way mathematicians establish the truth of a mathematical proposition[11] based on given information and previously known rules.[12] Both types of written reasoning start by laying out the known information and where the writer intends to go, then apply previously established rules to the known information to reach a conclusion.[13]

Despite the connections between law and mathematics, very few entering law students were math majors in college[14] and may not spontaneously see and use those connections as our fictional Janel did. Nonetheless, all law students have experience with mathematical reasoning from their high school days at least. Legal writing

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[9] *See* Graham & Adamson, *supra* note 3, at 542 (describing "the inductive process of developing a legal rule arising out of several authorities"); Aldisert, Clowney & Peterson, *supra* note 3, at 13-14 (noting that the Oklahoma Supreme Court used inductive reasoning when considering an issue for which "the state had no binding case law on point": the court looked at several cases from other states and "[f]rom these individual examples, the Oklahoma Supreme Court inferred the general rule").

[10] *See* Termini, *supra* note 2, at 22-26.

[11] *See* CLAUDI ALSINA & ROGER B. NELSEN, CHARMING PROOFS: A JOURNEY INTO ELEGANT MATHEMATICS, xix (2010) ("[A] proof is an argument to convince the reader that a mathematical statement must be true.").

[12] *See* Eugenia Cheng, *How to write proofs: a quick guide* 3 (October 2004), http://eugeniacheng.com/wp-content/uploads/2017/02/cheng-proofguide.pdf [https://perma.cc/2J7R-2HFB] ("A proof is a series of statements, each of which follows logically from what has gone before. It starts with things we are assuming to be true. It ends with the thing we are trying to prove.").

[13] *See* Termini, *supra* note 2, at 9-14; *infra* Section III.B.

[14] Law School Admissions Council, *Undergraduate Majors of Applicants to ABA-Approved Law Schools*, https://www.yu.edu/sites/default/files/inline-files/applicants-by-major-2018-19%20%283%29.pdf [https://perma.cc/C8M8-2C2F] (indicating .44% of applicants to ABA-accredited law schools for the 2016-2017 academic year were mathematics majors); *cf.* Lisa Milot, *Illuminating Innumeracy,* 63 CASE W. RES. L. REV. 769, 801 (2013) ("[F]ewer than 10% of law school students have more than an insignificant amount of undergraduate training in math, science, or engineering.") (citations omitted).

professors can take advantage of the similarities between legal reasoning and mathematical reasoning by building on students' prior experiences with the skills common to law and mathematics. Further, mathematics educators have experience teaching the types of reasoning skills valued in the law, and legal writing professors can benefit from that experience by using ideas from mathematics pedagogy. This Article explores these possibilities and proceeds as follows. In Part II, this Article describes how law professors can, using ideas related to "transfer of learning," build on law students' prior encounters with mathematical reasoning and logical reasoning. "Transfer of learning" occurs when people build new knowledge by connecting it to their existing knowledge. Professors can help with transfer process by pointing out the connections explicitly. While very few law students will have had experience writing proofs in advanced college mathematics courses, nearly all law students will have had other related experiences, including writing proofs in their high school geometry classes and using reasoning skills in their other K-12 mathematics classes. Law school professors can help students transfer those skills to the legal writing context. In Part III, this Article discusses how legal writing professors can use techniques that mathematics educators have found to be helpful in teaching reasoning skills. Specifically, the Article considers how mathematics educators approach teaching logic and proof writing and draws insights for the legal writing classroom. In Part IV, the Article concludes by suggesting that the ideas of the two previous Parts—activating students' transfer of learning and using pedagogical techniques from other disciplines—could provide future avenues for legal pedagogy scholarship.

II. Teaching Legal Analysis "with" Math: Drawing on Law Students' Existing Knowledge of Mathematics

Many legal writing professors face a dilemma familiar to educators at every level: how to cover the essential material in the limited amount of time available. When there is so much to cover in a legal writing class, discussing mathematics might seem like a waste of that precious time. To the contrary, however, one or two brief discussions of mathematics can be very useful to law students first learning about legal analysis. These discussions can help the students "transfer" what they already know about mathematical reasoning to the legal reasoning they now must do.[15] Specifically, professors can connect legal writing with students' knowledge of proof-writing in

[15] *See infra* Section II.A.

high school geometry[16] and with other skills from mathematics classes.[17]

A. The Pedagogical Value of Referencing Mathematics in the Law School Classroom

As people learn, they build new knowledge on their existing knowledge.[18] In the education field, this is referred to as "transfer"[19] or "transfer of learning."[20] The transfer of existing knowledge to a new area can aid with retention of the new material because "the mechanical underpinnings of long-term memory formation are deeply based on connecting pre-existing neural pathways in new ways."[21]

While transfer can sometimes happen spontaneously, professors can help students with the transfer process.[22] Professors can use "intentional scaffolding" to show students how the things they already know can apply in the new situation.[23] This helps students even

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[16] *See infra* Section II.B.
[17] *See infra* Section II.C.
[18] *See, e.g.*, JOHN D. BRANSFORD ET AL., PEOPLE LEARN: BRAIN, MIND, EXPERIENCE, AND SCHOOL: EXPANDED EDITION 10 (2000) (explaining that "the contemporary view of learning is that people construct new knowledge and understandings based on what they already know and believe").
[19] *See id.* at 39 (stating that transfer is "defined as the ability to extend what has been learned in one context to new contexts") (citations omitted); Linda Darling-Hammond, Kim Austin, Lee Shulman and Daniel Schwartz, *The Learning Classroom Session 11: Lessons for Life: Learning and Transfer*, STANFORD U. SCHOOL OF EDUC. 189, 190 (2003) ("Transfer is the ability to extend what one has learned in one context to new contexts.").
[20] Tonya Kowalski, *True North: Navigating for the Transfer of Learning in Legal Education*, 34 SEATTLE U. L. REV. 51, 53 (2010) ("[A]n entire subfield of education and cognitive psychology called 'transfer of learning' has insights and tools to offer legal education.").
[21] Shaun Archer, et al., *Reaching Backward and Stretching Forward: Teaching for Transfer in Law School Clinics*, 64 J. LEGAL EDUC. 258, 265 (2014).
[22] *See* BRANSFORD ET AL., *supra* note 18, at 54 ("Ideally, an individual spontaneously transfers appropriate knowledge without a need for prompting. Sometimes, however, prompting is necessary. With prompting, transfer can improve quite dramatically").
[23] *See* Archer, et al., *supra* note 21, at 265 (noting "intentional scaffolding can be observed when an instructor builds on an understanding of arithmetic in order to teach Algebra"). An article co-authored by legal writing professor Mary Nicol Bowman and clinical professor Lisa Brodoff shares many useful suggestions for aiding students in the transfer process. *See* Mary Nicol Bowman & Lisa Brodoff, *Cracking Student Silos: Linking Legal Writing and*

when—and perhaps especially when—the comparison is not exact and thus students are less likely to see the connections on their own.[24] Furthermore, discussing the concept of transfer with students can have the side benefit of aiding students in their future learning as well.[25] In the transfer process, professors should be careful to correct any misconceptions students have since "prior knowledge activation can actually impede new learning" when the prior knowledge is incorrect.[26]

Professors can ask students whether they have done this type of task before and, if not, whether they have done something similar.[27] For example, in the context of clinical legal education, scholars have suggested that "when assigning a student to write an advice letter to the client, the supervising attorney can remind her student that . . . the letter calls for the student generally to adapt the same IRAC structure in the paragraphs presenting legal advice as [the student] would in a memo, or a brief."[28]

Clinical Learning Through Transference, 25 CLIN. L. REV. 269, 291-321 (2019).

[24] *See* Ted Becker, *Transferability: Helping Students and Attorneys Apply What They Already Know to New Situations (Part 2)*, 98-MAR. MICH. BAR J. 46, 46 (2019) ("A student who doesn't recognize the overlap between the earlier and current projects may waste time . . . . With explicit guidance regarding how the current task bears similarities to what they've already done, however, students are less likely to flail about and grow frustrated. . . .").

[25] *See* Kowalski, *supra* note 20, at 103 (noting "law schools can motivate students to transfer their learning to new domains by teaching them about transfer").

[26] LINDA CAMPBELL & BRUCE CAMPBELL, MINDFUL LEARNING: 101 PROVEN STRATEGIES FOR STUDENT AND TEACHER SUCCESS 11 (2d ed. 2009). Furthermore, prior knowledge can interfere with students' acquisition of new knowledge when they apply the existing knowledge inappropriately. *See* BRANSFORD ET AL., *supra* note 18, at 58 (noting that students' knowledge of how humans and animals get nutrition led to misconceptions about the photosynthesis process in plants) (citations omitted). Although outside the scope of this Article, professors should be aware of this phenomenon and adjust their instruction to prevent it. For example, in the legal writing classroom, professors should note the differences between legal writing and the other types of writing students may be familiar with in order to ensure that students do not inappropriately apply that existing knowledge about "good writing" in the legal writing context.

[27] *See* CAMPBELL & CAMPBELL, *supra* note 26, at 10 (reporting that meta-analyses have shown that teachers can raise student achievement by "simply asking students what they know about a topic before reading or instruction" or "asking students questions about key concepts and/or clarifying them before teaching the content") (citations omitted).

[28] Archer, et al., *supra* note 21, at 272.

Professors can also use a strategy of guided reflection, asking the students to think for themselves how their existing knowledge might apply in the current situation.[29] For example, when helping law students in a clinic prepare for their first oral argument, the professor could ask the students to think "about previous experiences speaking to authority figures or those with power, or experiences in which students have had to persuade someone to do something for them."[30] The professor can elicit deeper thought and discussion by using follow-up questions about things such as the effectiveness of the students' prior advocacy experiences, the tone used in different situations, the audience reactions and whether the speaker adjusted to those reactions, and the communication of goals.[31]

Transfer of learning is difficult, even in closely related contexts. In law school, students can struggle to use IRAC to answer a law school exam question even after learning about IRAC in the context of writing memos and briefs in their legal writing courses.[32] Similarly, law students and law graduates can struggle to apply their legal writing and analysis skills in a clinical course[33] or in a first job after graduating.[34] If the connection between legal analysis in a legal

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[29] *See* Becker, *supra* note 24, at 47 ("One effective way to speed the transfer of yesterday's knowledge to today's classroom is to ask students to explicitly reflect on specific lessons they learned in the first year that they think will be helpful to their clinic work, and why. This helps students make their own connections between yesterday's and today's knowledge. Professors can strengthen these connections by reminding students down the road about those reflections, reinforcing the lessons students had already started to teach themselves.") (citations omitted); Kowalski, *supra* note 20, at 58 (citations omitted) (Professors can use questions to "cue students to look for useful knowledge from the current module, previous modules, and even prior coursework.").

[30] Archer, et al., *supra* note 21, at 289.

[31] *See id.*

[32] Kowalski, *supra* note 20, at 103 ("IRAC paradigm forms the basis for virtually all traditional legal analysis, whether written or oral, exam or practice, formal or even informal. More experienced law students usually make this connection during the second or third year, typically through a long period of trial and error . . . .").

[33] *See* Bowman & Brodoff, *supra* note 23, at 282-83 (noting that "despite shared syllabi, discussions of common vocabulary, and joint teaching projects, clinicians and legal writing faculty at Seattle University found that our students still struggled to apply their previous legal writing learning to the new context of real client work").

[34] *See* Megan McAlpin, *Transferring Writing Skills from Law School to Law Practice*, 76 OCT OR. ST. B. BULL. 13, 13 (2015) ("When a new lawyer has to take something she used in law school and use it in her law practice, she has to transfer that information or skill to an entirely different context. And that's really hard.").

writing course and legal analysis in other contexts is not always clear to students, the connection between legal analysis and mathematical analysis is probably even less obvious. Therefore, professors should spend time discussing these connections explicitly in order to activate students' prior knowledge in the new context.

While this discussion should focus on the similarities between mathematical analysis and legal analysis to help students with the transfer process, it is also worthwhile to conclude the discussion with an acknowledgement of the differences between law and mathematics. Students should not leave this discussion with the impression that there are definitive answers in the law in the same way there is a definite answer to a problem from a high school geometry or algebra class. In fact, mathematicians have realized that mathematics, at a deep level, does not have as much certainty as we once thought.[35] For purposes of the examples in this article, however, the answers are definitive.

The remaining two Sections in this Part demonstrate how legal writing professors can help students transfer their knowledge of mathematical reasoning to legal reasoning using two tasks the students likely encountered in their mathematics classes: proof writing in geometry and problem solving in algebra. While the specific types of examples discussed below may not be familiar to all law students, they are common in mathematics classrooms in the United States and thus likely are familiar to many law students.[36] Even if students do not have perfect recall of these mathematical tasks, the suggestions below will help professors remind students of their prior knowledge and then connect that knowledge to new ideas.

B. Example: Transferring Geometry Proof-Writing Skills

Most entering law students will have experience with mathematical reasoning from their high school geometry classes, when they had to write proofs[37] that bear many similarities to the

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[35] *See* Termini, *supra* note 2, at 26-31.

[36] Those students who find the examples completely unfamiliar may still benefit from the class discussion since they may remember similar reasoning tasks from their earlier education. Further, the analogy to mathematical reasoning provides a different perspective on legal writing, which students may find helpful even if they do not recall the specific types of mathematical tasks in the examples.

[37] *See* Eric J. Knuth, *Proof as a Tool for Learning Mathematics*, 95 MATHEMATICS TEACHER 486, 486 (2002) (The "role [of proof] in secondary school mathematics has traditionally been peripheral at best; the only substantial treatment of proof is limited to geometry."); Patricio G. Herbst, *Establishing a Custom of Proving in American School Geometry: Evolution*

written legal analyses they are asked to produce in law school.[38] Geometry and proofs have long been linked, starting at least as early as when Euclid used proofs in his exploration of geometry in Elements.[39] In the United States, geometry and proofs began to be part of the high school curriculum in the mid-1800's, when universities began requiring knowledge of geometry for admission.[40] At that time, the most common geometry textbooks used proofs to show that statements about geometry were true but did not require students to write their own proofs; instead, students studied geometry through "reading and reproducing" the proofs in the textbook.[41] As geometry became a more standard part of the high school curriculum, geometry textbooks began to require that students develop their own proofs.[42]

Over the past century, proofs have continued to be an important part of high school geometry classes in the United States.[43] In 2000,

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of the Two-Column Proof in the Early Twentieth Century, 49 EDUC. STUD. MATHEMATICS 283, 283 (2002) ("Having high school students prove geometrical propositions became the norm in the United States with the reforms of the 1890's – when geometry was designated as the place for students to learn the 'art of demonstration.'").

[38] *See* Termini, *supra* note 2, at 14-22.

[39] *See* THE PRINCETON COMPANION TO MATHEMATICS 84 (Timothy Gowers ed., 2010) (describing the structure of Elements, in which Euclid laid out basic definitions and axioms and then "proceed[ed] by purely logical means to deduce theorems from them").

[40] See Patricio G. Herbst, *Establishing a Custom of Proving in American School Geometry: Evolution of the Two-Column Proof in the Early Twentieth Century*, 49 EDUC. STUD. MATHEMATICS 283, 288 (2002) ("American high schools started to offer Geometry courses in the 1840's as universities started to make it a requisite for admission."); *cf.* Bettina Pedemonte, *How Can the Relationship Between Argumentation and Proof Be Analyzed*, 66 EDUC. STUD. IN MATHEMATICS 23, 30 (2007) ("[G]eometry is the domain where proof is traditionally introduced in France and in Italy."). Another source places geometry as a component of university entrance requirements somewhat later, beginning with Yale in 1865. *See* Philip S. Jones, *The History of Mathematical Education*, 74 AM. MATHEMATICAL MONTHLY 38 (1967).

[41] *See* Herbst, *supra* note 40, at 288 ("Texts included neither general descriptions of proof nor methods of proving. . . . The study of geometry was done through reading and reproducing a text . . . .").

[42] *See id.* at 290 ("Geometry textbooks multiplied in numbers as more high schools took charge of the teaching of geometry. . . . In addition to being accountable for replicating the proofs of the propositions in the course of studies, students were given opportunities to craft proofs for 'original' propositions.").

[43] Patricio G. Herbst, *Engaging Students in Proving: A Double Bind on the Teacher*, 33 J. FOR RES. IN MATHEMATICS EDUC. 176, 176 (2002) ("For more

the National Council of Teachers of Mathematics, noting that "[g]eometry has long been regarded as the place in the school mathematics curriculum where students learn to reason and to see the axiomatic structure of mathematics," "include[d] a strong focus on the development of careful reasoning and proof" in its recommended geometry standard.[44]

In the United States today, most high school geometry classes use a particular proof format called a two-column proof.[45] In 1913, a textbook made what was likely the first use of two-column proofs, and two-column proofs then became a common part of the high school geometry curriculum.[46] In a two-column proof, the writer begins by listing "givens," which are the facts that are assumed to be true and form the starting place of the proof. Next, the writer states what the proof will "prove," which is the conclusion the proof will reach. After those preliminary matters comes the body of the proof.

In a two-column proof, the writer starts with the givens and moves step-by-step through the proof, building from each statement to reach a new statement, until the proof reaches its final conclusion. The step-wise statements are numbered and listed in the left-hand column, while the right-hand column contains a justification for each statement.[47] The simplest justification is the word "given," indicating that the corresponding statement in the left-hand column was part of the given information at the beginning of the proof. In order to move beyond the given information, the proof writer must use other justifications such as definitions, corollaries, and theorems. The proof is complete once the final statement in the left-hand column is the same as the statement listed at the beginning of the proof as the thing to be proved.

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than a century, most geometry curricula in the United States have included opportunities for students to understand and do proofs.").

44 NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS, PRINCIPLES AND STANDARDS FOR SCHOOL MATHEMATICS 41 (2000) (indicating that "[g]eometry is a natural place for the development of students' reasoning and justification skills, culminating in work with proof in the secondary grades").

45 *See* Herbst, *supra* note 43, at 177 (noting that geometry curricula customarily has "involved the writing of proofs in two columns of statements and reasons").

46 Herbst, *supra* note 40, at 297 (citing JABIR SHIBLI, RECENT DEVELOPMENTS IN THE TEACHING OF GEOMETRY (1932)).

47 As explained by the textbook authors who likely first used two-column proofs, "[e]very proof consists of a number of statements, each of which is supported by a definite reason. The only admissible reasons are: a previously proved proposition; an axiom; a definition; or the hypothesis." Herbst, *supra* note 40, at 297 (quoting ARTHUR SCHULTZE & F. LOUIS SEVENOAK, PLANE AND SOLID GEOMETRY (rev. ed. 1913)).

By reminding students of their knowledge of two-column proofs,[48] legal writing professors can help students transfer their geometry reasoning skills to the new area of legal reasoning, as Professor Mary Dunnewold has suggested.[49] Many have long recognized that skills from geometry class can provide the basis for the development of reasoning skills in other areas. For decades, many educators identified transfer as an important reason for including geometry instruction in the mathematics curriculum; these advocates argued that students should study geometry, not so much because they would learn the mathematical principles in the course but rather because they would learn reasoning and argumentation skills that could be applied in other fields.[50] With respect to legal reasoning skills specifically, Abraham Lincoln noted the importance of his study of geometry to the development of his lawyering skills.[51]

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[48] The closer analogy is to the paragraph proofs that are often a part of advanced college-level mathematics courses. *See generally* Termini, *supra* note 2, at 11. In light of how few law students have a background in mathematics, however, most law students do not have experience with paragraph proofs and therefore do not have the relevant knowledge to transfer. For those law students who were math majors or took a significant number of proof-heavy mathematics classes in college, the transfer process will likely be even easier. Those students may, without any prompting, see the connections to the type of reasoning and writing they did in college. Even if they do not notice the transfer process, they may intuitively use their existing mathematical reasoning skills as they develop their new legal reasoning skills. If, however, students with backgrounds in mathematics struggle with legal writing, their professors can help them transfer their knowledge by asking about their experience writing proofs.

[49] *See* Mary Dunnewold, *Using the Idea of Mathematical Proof to Teach Argument Structure*, 15(1) PERSP: TEACHING LEGAL RES. & WRITING 50, 50 (2006).

[50] Gloriana González & Patricio G. Herbst, *Competing Arguments for the Geometry Course: Why Were American High School Students Supposed to Study Geometry in the Twentieth Century?*, 1 INT'L J. FOR HIST. OF MATHEMATICS EDUC. 7, 13 (2006) ("The value of studying geometry was located in becoming skilled at building arguments, applying the same reasoning used in the geometry course. Proofs were not important because of the leverage they gave to understand particular mathematical concepts but because of the opportunity they created for students to learn, practice, and apply deduction."). There was not universal agreement that this was the primary reason for geometry instruction but it was one of four main types of arguments in favor of geometry in the curriculum. See id. (identifying the "formal argument" that geometry teaches students to use logical reasoning as one of four "modal arguments for the geometry course").

[51] *See* Interview by John P. Gulliver with Abraham Lincoln, *Mr. Lincoln's Early Life: How He Educated Himself*, N.Y. TIMES, Sept. 4, 1864, at 5.

Professors should be careful to note differences as well as similarities in order to facilitate a smooth transfer of knowledge for the students.[52] Even in the context of mathematics, students familiar with the two-column proofs common in high school geometry can be surprised by the transition to the paragraph proofs[53] more commonly used in college-level mathematics.[54] For legal writing students, the connection between two-column proofs and legal writing might be even harder to see unless the professor explicitly shows the connection.[55]

To help students transfer their knowledge of writing two-column proofs to legal writing, the professor could first show students an example of a two-column proof on a high school geometry topic. The legal writing professor and the class would not need to spend time understanding the geometry since that is not the knowledge that would be useful to transfer in this context. Instead, the class should focus on the reasoning skills in the proof. The professor should ask the students questions that help them remember how two-column proofs are organized and what purpose the proof serves. For example, the professor could ask the students to discuss the purpose of the different parts of the proof in the figure below, using think/pair/share or another technique designed to encourage both individual contemplation and class discussion.[56]

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52 *See supra* Section II.A.

53 Although two-column proofs are common in high school geometry, most mathematicians do not use the two-column form for their proofs, but instead write their proofs out using sentences and paragraphs. *See* Robert R. Reisel, *How to Construct and Analyze Proofs –A Seminar Course*, 89 AM. MATHEMATICAL MONTHLY 490, 491 (1982) (distinguishing the type of proof used in high school from the paragraph style of proof-writing and noting that the paragraph style "is the one used in most mathematical writing"). These paragraph proofs are the type of proof required of students in most advanced college mathematics courses. *Id.* (stating the college "students must adjust" to the paragraph style of proof-writing).

54 Annie Selden & John Selden, *Overcoming Students' Difficulties in Learning to Understand and Construct Proofs*, in MAKING THE CONNECTION: RESEARCH AND TEACHING IN UNDERGRADUATE MATHEMATICS EDUCATION 95, 95 (Chris Rasmussen & Marilyn P. Carlson, eds. 2011) (relating an anecdote in which a student who encountered paragraph proofs in college after being accustomed to two-column proofs in high school said, "You mean proofs can have words!").

55 *See supra* Section II.A.

56 In the think / pair / share technique, the teacher poses a question for students to answer or a problem for them to solve. Debora L. Threedy & Aaron Dewald, *Re-Conceptualizing Doctrinal Teaching: Blending Online Videos with in-Class Problem-Solving*, 64 J. LEGAL EDUC. 605, 621 (2015). For the "think" stage, students think on their own about the question or

Figure 1: Two-Column Proof

Given: Angle *A* and Angle *B* are complementary angles. Angle *B* and Angle *C* are complementary angles.
Prove: The measure of Angle *A* = the measure of Angle *C*.

Statements	Reasons
1. Angle *A* and Angle *B* are complementary angles.	given
2. Angle *B* and Angle *C* are complementary angles.	given
3. The measure of Angle *A* + the measure of Angle *B* = 90 degrees.	Definition of Complementary Angles
4. The measure of Angle *C* + the measure of Angle *B* = 90 degrees.	Definition of Complementary Angles
5. The measure of Angle *A* + the measure of Angle *B* = the measure of Angle *C* + the measure of Angle *B*.	Transitive Property of Equality[57]
6. The measure of Angle *A* = the measure of Angle *C*.	Subtraction Property of Equality[58]

The questions below or questions like them should help elicit a discussion about the proof that will help students begin to make the connections to legal writing.

Questions: What is the information listed after "given"? Why is that information there? Why is it useful to have that information at the beginning? What can we assume about that information? How can we use that information?

Discussion: It is information that we can assume to be true for purposes of the proof. It is the starting point. In a proof, we are trying to use that information and build on it to reach a conclusion. It is helpful to the reader to have that information in the beginning

problem and try to come up with an answer or solution. *Id.* Then for the "pair" stage, students pair up with a neighbor to discuss the problem and solution. *Id.* Finally, for the "share" stage, the whole class discusses the issue, with pairs sharing their thoughts with the class. *Id.*

[57] Under the Transitive Property of Equality, since steps 3 and 4 both contain sums that are equal to 90 degrees, those sums are equal to each other.

[58] Under the Subtraction Property of Equality, "the measure of Angle *B*" can be subtracted from both side of the equation in step 5 and the equation will still be true, i.e., the left side of the equation will still equal the right side of the equation.

because the reader needs to know that the information is true and because the proof will use that information later.

Questions: What is the information listed after "prove"? Why is that information there? Why is it useful to have that information at the beginning? What can we assume about that information? How can we use that information?

Discussion: It is the statement that we are trying to prove. It is the end goal. It is helpful to the reader to have that information in the beginning so that reader knows where the proof is going.

Questions: What is the information in the left-hand column? Why is that information there? How do we figure out what to say at each step in the left-hand column?

Discussion: These are the "statements" of the proof. Each one lists a conclusion we can make based on what has come before and based on the information in the right-hand column. The reader should be able to follow along through the entire proof and thus the statements cannot skip steps. Most of the work of the proof lies in working out how to move through each step from the given information to the thing we are trying to prove. This takes thinking and revising and maybe trial and error before we get the final proof down on paper.

Questions: What is the information in the right-hand column? Why is that information there? How does it relate to the information in the left-hand column?

Discussion: The right-hand column contains justifications, one for each statement in the left-hand column. A justification should show the reader why the statement in the left-hand column must be true. These justifications should convince the reader. For geometry, valid justifications include the fact that something was "given" at the beginning, known definitions, axioms and postulates, and previously-proven theorems.

After this preliminary discussion to remind students about two-column proofs and, in particular, the attributes that are similar to legal writing, the professor can make the connections explicit. The professor should note that, in legal writing as in two-column proofs, we start with the "given" information. In legal writing, these are the facts of the case, which are often summarized at the beginning of a memo or brief. In legal writing, as in two-column proofs, we also tell the reader at the beginning where we want to go. In a two-column proof, this is the statement we are trying to prove. In legal writing, this is the "I" of IRAC or the "C" or CRAC, a statement of the issue or a statement of our conclusion on that issue.

The body of the proof is also similar to what we do in legal writing. Although lawyers do not tend to use a two-column format for memos or briefs, they are (or should be) careful to spell out each step of their reasoning and the justification for each step. Statements are laid out in a logical order – one statement leading to the next – and each statement is sufficiently justified to convince the reader. In legal memos, we can often think of the topic sentence of a paragraph as the left-hand column in a proof, i.e., a statement of the next step in our reasoning, and the remainder of the paragraph as the right-hand column in a proof, i.e., the justifications that will convince the reader that the statement is correct.[59] Many professors use a simple example, such as the classic "no vehicles in the park" hypothetical,[60] early in the course to spur student discussion and introduce students to legal analysis. Professors can use those examples to show students what a legal argument would look like in a two-column proof format and how that would translate to the paragraph format typically used in legal writing.[61] Figures 2 and 3 below show an analysis of facts under the "no vehicles in the park" rule using a two-column format and a more typical paragraph-based structure.

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[59] *Cf.* Tracy Turner, *Flexible IRAC: A Best Practices Guide*, 20 LEGAL WRITING: J. LEGAL WRITING INST. 233, 237 (2015) ("paragraphs should usually begin with a topic sentence that states the point the paragraph will address"); Greg Johnson, Esq., *Assessing the Legal Writing Style of Brett Kavanaugh*, VT. B.J., Fall 2018, at 30, 32 ("The topic sentence expresses the main idea--the point you want to prove--for every paragraph."); Katherine Mikkelson, *Better Legal Writing*, 26 PUB. LAW. 8, 9 (2018) (giving an example of a topic sentence that "illustrates the author's conclusion" and stating that, after the topic sentence, "[t]he rest of the paragraph would describe the reasons why" the conclusion in the topic sentence was correct).

[60] H. L. A. Hart, *Positivism and the Separation of Law and Morals*, 71 HARV. L. REV. 593, 607 (1958).

[61] Professor Mary Dunnewold suggested taking this analogy further by using the two-column structure to help students formulate their legal arguments. *See* Dunnewold, *supra* note 49, at 50.

Figure 2: Two-Column Legal Analysis

Given: Our client Benny McGee received a ticket after a police officer saw him riding a "hoverboard" in the park. The hoverboard uses an electric motor.

Issue: Whether Mr. McGee violated the city ordinance prohibiting vehicles in the park.

Statements	Reasons
1. Vehicles are prohibited in city parks.	City Ordinance 30.945 (2021).
2. Courts have held only motorized forms of transportation are "vehicles" for purposes of the city ordinance prohibiting vehicles in the parks.	In *Dresser*, the court held the defendant had violated the ordinance when she rode an electric bicycle in the park. In contrast, the court in *Ahmed* held the defendant had not violated the ordinance when he rode a skateboard in the park.
3. A court will likely hold that Mr. McGee violated the ordinance because he rode a motorized form of transportation in the park.	Mr. McGee's motorized hoverboard is similar to the defendant's motorized bicycle in *Dresser*, which the court held was a "vehicle" under the ordinance. Although a hoverboard and a skateboard are similar in looks and function, the defendant's skateboard in *Ahmed* was not a motorized vehicle, while Mr. McGee's hoverboard runs on an electric motor.

Figure 3: Legal Analysis

Our client Benny McGee received a ticket after a police officer saw him riding a "hoverboard" in the park. The hoverboard uses an electric motor.

The issue is whether Mr. McGee violated the city ordinance prohibiting vehicles in the park. Vehicles are prohibited in city parks. City Ordinance 30.945 (2021).

Courts have held only motorized forms of transportation are "vehicles" for purposes of the city ordinance prohibiting vehicles in the parks. In *Dresser*, the court held the defendant had violated the ordinance when she rode an electric bicycle in the park. In contrast, the court in *Ahmed* held the defendant had not violated the ordinance when he rode a skateboard in the park.

Mr. McGee rode a motorized form of transportation in the park. Mr. McGee's motorized hoverboard is similar to the defendant's motorized bicycle in *Dresser*, which the court held was a "vehicle" under the ordinance. Although a hoverboard and a skateboard are similar in looks and function, the defendant's skateboard in *Ahmed* was not a motorized vehicle, while Mr. McGee's hoverboard ran on an electric motor.

Therefore, a court will likely hold that Mr. McGee violated the ordinance.

C. Example: Transferring Algebra and Pre-Algebra Skills

While proofs have long been central to the high school geometry curriculum, recent years have seen an increasing emphasis on proof and reasoning skills throughout the mathematics curriculum.[62] In its 2000 Principles and Standards for School Mathematics, the National Council of Teachers of Mathematics opined, "Reasoning and proof are not special activities for special times or special topics in the curriculum but should be a natural, ongoing part of the classroom

[62] Stylianides & Stylianides, *supra* note 3, at 1 (noting, in 2007, there were "increased efforts to make proof central to school mathematics throughout the grades"); Matthew Inglis & Lara Alcock, *Expert and Novice Approaches to Reading Mathematical Proofs*, 43 J. FOR RES. IN MATHEMATICS EDUC. 358, 358 (2012) ("Proof is central to the practice of academic mathematicians and is increasingly seen as essential to a coherent school-level mathematics curriculum.").

discussions, no matter what topic is being studied."[63] For many K-12 students in the United States during the past decade, that emphasis has come as part of the shift to the Common Core mathematics standards, which were released in June 2010.[64] Although states are not required to adopt the standards, more than forty had done so by 2013, and forty-one states currently use the Common Core standards.[65]

Mathematics education under the Common Core is "all about thinking, reasoning, making sense, and communicating."[66] The standards begin with eight broad "Standards for Mathematical Practice," which "describe varieties of expertise that mathematics educators at all levels should seek to develop in their students."[67] As one mathematics educator explained, "The eight practice standards are what we do when we do mathematics, no matter what the math is you're trying to learn."[68] One mathematics educator has noted that two of these standards—(1) constructing viable arguments and critiquing the reasoning of others and (2) attending to precision—are "matters of effective mathematical communication."[69] They also describe matters of effective legal communication.

While the Standards for Mathematical Practice are high level, the Common Core mathematics standards also contain the more-detailed Standards for Mathematical Content.[70] The Standards for Mathematical Content indicate what students should be able to understand and do at each grade level or, for high school, in each

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[63] National Council of Teachers of Mathematics, *supra* note 44, at 342.
[64] Common Core State Standards Initiative, Development Process, http://www.corestandards.org/about-the-standards/development-process/ [https://perma.cc/CQU6-6ST5].
[65] *Id.* According to the Common Core website, this number has gone down slightly from forty-five states in 2013, *id.*, indicating that some states adopted the Common Core standards but then reversed course.
[66] Erich Strom, *How to Do Math Right*, 123 SCHOLASTIC INSTRUCTOR 38 (2013).
[67] Common Core State Standards Initiative, Common Core State Standards for Mathematics 6, http://www.corestandards.org/wp-content/uploads/Math_Standards1.pdf [https://perma.cc/2Z7Q-WJW2].
[68] Strom, *supra* note 66, at 40.
[69] David C. Kamin, *Common Core State Standards for Mathematics and College Readiness*, 25 THE MATHEMATICS EDUCATOR 52, 54-55 (2016). In addition to these two, there are six other Standards for Mathematical Practice: "[m]ake sense of problems and persevere in solving them"; "[r]eason abstractly and quantitatively"; [m]odel with mathematics; [u]se appropriate tools strategically"; [l]ook for and make use of structure; and [l]ook for and express regularity in repeated reasoning." Common Core State Standards Initiative, *supra* note 67, at 6-8.
[70] *See* Common Core State Standards Initiative, *supra* note 67, at 8.

mathematical subject area.[71] In these Standards for Mathematical Content, proof does not appear until eighth grade. Proof receives the heaviest coverage in geometry,[72] but it also appears in the standards for algebra and functions.[73] Even when the standards do not require proof, however, they emphasize making sure students can understand and explain their reasoning rather than simply solving problems by rote.[74] "The standards intentionally bring the reasoning skills of geometric proofs . . . to all levels of math. This means students start to articulate *why* a given answer must be true — or *how* a logical conclusion can be reached — long before 11th grade, when students were traditionally required to use proofs."[75]

These standards are not just wishful thinking; teachers using the standards are incorporating the ideals of the standards in their classrooms. Under the Common Core mathematics standards, "[m]ore teachers are requiring students to use writing to explain their

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[71] *See id.* ("The Standards for Mathematical Content are a balanced combination of procedure and understanding.").

[72] *Id.* at 74-78.

[73] *Id.* at 64-65, 68, 7071.

[74] *See id.* at 4 ("These Standards define what students should understand and be able to do in their study of mathematics. . . . One hallmark of mathematical understanding is the ability to justify, in a way appropriate to the student's mathematical maturity, why a particular mathematical statement is true or where a mathematical rule comes from.").

[75] Nancy S. Gardner & Nicole Smith, *Math and ELA Meet at the Common Core,* 97 THE PHI DELTA KAPPAN 53, 55 (2016) (emphasis in original). This change has led to much consternation among parents who are surprised to see math homework problems so different from those of their own school days. *See* Motoko Rich, *Math Under Common Core Has Even Parents Stumbling*, N.Y. TIMES (June 29, 2014), https://www.nytimes.com/2014/06/30/us/math-under-common-core-has-even-parents-stumbling.html [https://perma.cc/TGC3-CPEA] ("Across the country, parents who once conceded that their homework expertise petered out by high school trigonometry are now feeling helpless when confronted with first-grade worksheets."). Where a parent might expect to solve a multiplication problem by writing down numbers in a certain way and going through certain steps, the child is learning to instead "solve . . . by drawing a chart, breaking apart numbers, multiplying, adding and maybe more." Lyndsey Layton, *Common Core Math Can be a Mystery, and Parents are Going to School to Understand It*, WASH. POST (Nov. 1, 2014), https://www.washingtonpost.com/local/education/common-core-math-can-be-a-mystery-and-parents-are-going-to-school-to-understand-it/2014/11/01/af57efa0-604f-11e4-9f3a-7e28799e0549_story.html [https://perma.cc/UC5P-HU2P] (describing a parent stumped by her daughter's homework, which consisted of a "seem[ingly] simple" multiplication problem).

thinking."[76] Furthermore, research has shown that the more time teachers spend teaching using the Common Core mathematics standards, the more likely it is that the teachers will require written explanations from their students.[77] This focus on reasoning skills throughout the K-12 mathematics curriculum should mean that incoming law students can transfer their knowledge of mathematics reasoning to the legal reasoning they are called on to do in law school.[78]

To help students transfer their knowledge of Common Core style mathematical reasoning to legal writing, the professor could first show students two basic algebra problems, the second of which requires deeper understanding and more reasoning skills.[79] As with the geometry example above, the law students and professor do not need to attempt to understand or solve the algebra problems, as the point is not about the solution itself but rather about the process. If time permits, however, the legal writing professor could give the students time to work in small groups on the second problem before moving on to a class discussion.

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[76] Jennifer Bay-Williams, Ann Duffett & David Griffith, Common Core Math in the K-8 Classroom: Results from a National Teacher Survey 11 (2016).

[77] *Id.* ("[T]eachers who have been teaching to the [Common Core Mathematics Standards] for longer (four years) are more likely than those who have taught to them for a shorter period (one year) to require that students explain in writing how they got their answers. . . .").

[78] More than forty states had adopted the Common Core standards by 2013, *see supra* note 64 and accompanying text, meaning that many current entering law students learned mathematics under the Common Core for most or all of high school.

[79] In a book designed to help teachers implement the Common Core Mathematics Standards, the National Council of Teachers of Mathematics indicated that a problem like Example 2 in Figure 4 would promote reasoning skills in a way that a problem like Example 1 in Figure 4 would not. NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS, PRINCIPLES TO ACTIONS: ENSURING MATHEMATICAL SUCCESS FOR ALL 4, 17-20 (2014).

Figure 4: Algebra Problems

Example 1:
Solve this system of equations.

$6x + 7y = 51$
$8x - y = 37$

Example 2:
You are deciding between two cellphone plans. The plan from Alpha Mobile costs $20 per month for unlimited talk and text plus $10 for each gigabyte of data used. The plan from Beta Cellular costs $50 per month for unlimited talk and text plus $5 per month for each gigabyte of data used. How much data do you need to use each month to make Beta Cellular the better option? Work in small groups to find a solution and write up an explanation of your answer.

The questions below or questions like them should help elicit a discussion that will help students begin to make the connections to legal writing.

Question: Why would an algebra teacher ask you to do the second type of problem rather than the first?

Discussion: The second problem calls for more reasoning skills than the first one. All the first one requires is that you (remember and) complete a certain procedure.

Question: Why does the second problem ask students to explain their answers?

Discussion: The teacher wants to see the students' reasoning and work to make sure that they understand the problem, that their reasoning was correct as they worked toward the answer, and that they reached the right answer.

After this preliminary discussion, the professor can show the students the connections to legal writing. The professor should note that legal writing is more like the second type of algebra problem than the first. The goal is not, as in the first problem, to work through a pre-set procedure. Rather, the goals are to use solid reasoning and to show that reasoning in order to convince the reader that the answer is correct. This comparison can help reinforce the idea that, in legal analysis, just stating the "answer"—guilty or not guilty, liable or not liable—is often not enough.[80] In most situations, lawyers need to work

[80] As with the geometry example above, it is worthwhile here to note that, while legal analysis and mathematical analysis are similar in many ways, they are not identical. Unlike a straightforward algebra problem such as this one, the answers to legal questions are rarely definitive. *See Termini*, *supra* note 2.

through an analysis carefully in order to be sure the analysis is sound and that it will convince others.

III. Teaching Legal Analysis Like Math: Learning from the Experiences of Mathematics Professors and Teachers

Even without explicitly invoking mathematics in the classroom as suggested in the previous section, legal writing professors can borrow ideas from their colleagues in mathematics, who have experience teaching many of the same skills we address in legal writing classes. This section of the Article identifies two techniques mathematics educators and mathematics education researchers have found to be useful in teaching mathematical analysis and discusses how those techniques could also be useful in the legal writing classroom. First, legal writing professors can add discussions of logic to their courses at times when it is relevant to the other topics they are covering. Second, legal writing professors can provide more opportunities for students to practice their analysis and reasoning skills.

A. The Pedagogical Value of Using Techniques from the Mathematics Classroom in the Law School Classroom

Both mathematics and legal writing professors recognize that "[e]ffective writing and clear thinking are inextricably linked."[81] While that statement is from an article by a professor of mathematics about his method for teaching undergraduate mathematics courses with a

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[81] David W. Cohen, *A Modified Moore Method for Teaching Undergraduate Mathematics*, 89 AM. MATHEMATICAL MONTHLY 473, 474 (1982); *accord* Nathaniel Miller, *Teaching Writing and Proof-Writing Together*, in BEYOND LECTURE: RESOURCES AND PEDAGOGICAL TECHNIQUES TO IMPROVE STUDENT PROOF-WRITING ACROSS THE CURRICULUM 263, 265 (Rachel Schwell, et al., eds., 2016) (describing a writing seminar about mathematics and the professor's conclusion that "the more clearly a student can explain something, the better he or she understands it"); *accord* Mary Beth Beazley, *Better Writing, Better Thinking: Using Legal Writing Pedagogy in the "Casebook" Classroom (Without Grading Papers)*, 10 LEG. WRITING: J. LEG. WRITING INST. 23, 27, 44 (2004) ("Legal Writing faculty have analyzed writing as it relates to the act of thinking itself, and as it relates to how best to teach the process of communicating legal thought to a reader.").

heavy emphasis on proof,[82] similar statements have been made by legal writing professors.[83]

Mathematics educators teach their students how to write effectively and think clearly. Mathematics courses emphasize reasoning skills[84] and, as students advance, proof-writing skills.[85] Further, these courses do seem to succeed in helping students develop those skills; in a study, education professors reporting on students in their classes indicated that "mathematics students were likely to write more concise and organized papers."[86] Students surveyed in the same study "mentioned transferring communication and writing skills [from their mathematics classes] to [their] other classes."[87] The authors of the study reported that their "data and analysis suggested that . . . logical thinking and communication skills . . . are developed through mathematical problem solving, reasoning, and writing proofs."[88]

Since legal writing courses seek to instill effective reasoning and communication skills, the same types of skills that are developed in mathematics classes, legal writing professors can tap into the

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[82] *See* Cohen, *supra* note 81, at 474 (describing three principles of the author's teaching method).

[83] *See, e.g.*, Beazley, *supra* note 81, at 27 ("[T]here is a strong intersection between writing and thinking."); Christine M. Venter, *Analyze This: Using Taxonomies to "Scaffold" Students' Legal Thinking and Writing Skills*, 57 MERCER L. REV. 621, 626 (2006) ("[W]riting and thinking are interrelated.").

[84] *See* Larry Sowder & Guershon Harel, *Toward Comprehensive Perspectives on the Learning and Teaching of Proof, in* SECOND HANDBOOK OF RESEARCH ON MATHEMATICS TEACHING AND LEARNING, 805, 807 (Frank K. Lester, ed. 2007) ("[C]ommon to mathematics curricula in different parts of the world is the goal of training students in the construction and the formation of deductive reasoning, which is defined as a careful sequence of steps with each step following logically from an assumed or previously proved statement and from previous steps.").

[85] *See* Mikio Miyazaki, Taro Fujita & Keith Jones, *Students' Understanding of the Structure of Deductive Proof*, 94 EDUC. STUD. IN MATHEMATICS 223, 237 (2017) ("The teaching and learning of deductive proofs in mathematics is one of the most important goals in mathematics education."); Selden & Selden, *supra* note 54, at 95 ("[S]tudents in courses like abstract algebra, real analysis, and topology normally demonstrate their competence by solving problems and proving theorems. And, if students go beyond a few lower-division courses such as calculus or first differential equations, this usually involves constructing original proofs or proof fragments . . . .").

[86] Curtis D. Bennett & Jacqueline M. Dewar, *The Question of Transfer: Investigating How Mathematics Contributes to a Liberal Education*, in DOING THE SCHOLARSHIP OF TEACHING AND LEARNING IN MATHEMATICS 183, 185 (Jacqueline M. Dewar and Curtis D. Bennett, eds. 2015).

[87] *Id.*

[88] *Id.* at 186.

experiences of mathematics educators. In the legal writing classroom, we can use techniques from the mathematics classroom to help our students pursue the goal of clear thinking and effective writing.

B. Example: Adding Integrated Logic Instruction

Mathematics professors vary in the extent to which they teach logic before teaching proof writing.[89] While all mathematics professors would likely agree about the importance of logic in writing proofs, some believe "that logic is too dry to capture students' interest and that it is more important to engage students right away with interesting mathematical problems."[90] In contrast, other mathematics professors explicitly incorporate logic instruction into their courses.[91]

Researchers have found mixed results when studying the effects of explicit logic instruction on later performance in mathematical reasoning.[92] Some studies have found that the study of logic correlates to higher performance in tasks related to mathematical reasoning, while other studies have found no effect.[93] The differing results may relate to the timing of the logic instruction: teaching logic in a separate unit did not seem to improve students' proofs, but teaching logic did seem to improve students' proofs "if the logic units were interwoven with the geometry and if cues were given to help students realize the relevance of the logic to the specific geometry tasks."[94]

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[89] *See* Susanna S. Epp, *The Role of Logic in Teaching Proof,* 110 AM. MATHEMATICAL MONTHLY 886, 894 (2003) (noting that the author, who teaches "a course with a focus on developing mathematical reasoning," spends time "at the beginning of [that] course discussing basic notions of elementary logic and giving students formal and informal practice in working with the language of the logical connectives and the quantifiers," but that "[s]ome mathematics educators are impatient with this approach"); Annie Selden & John Selden, *The Role of Logic in the Validation of Mathematical Proofs* 1 (1999), available at https://files.eric.ed.gov/fulltext/ED518763.pdf [https://perma.cc/2Y2R-YPHM] ("Mathematics departments rarely require students to study very much logic before working with proofs.").

[90] *See* Epp, *supra* note 89, at 894 (reporting the arguments of "[s]ome mathematics educators").

[91] *See* Reisel, *supra* note 53, at 490-91 (indicating that the author's course in how to construct proofs begins with "a brief explanation of those parts of logic that are needed in proofs").

[92] *See* Epp, *supra* note 89, at 892 (summarizing results of prior studies) (citations omitted).

[93] *See id.*

[94] *Id.* at 893 (citations omitted). This conclusion is perhaps not surprising in light of researchers' conclusions about the importance of "interleaving" and relevance to student learning. *See* Elizabeth Adamo Usman, *Making Legal*

Educators have also realized that, in teaching logic, an important first step is to acknowledge the differences between the language of formal logic and ordinary language.[95] Formal logic makes use of many words that are also commonly used in the English language, such as "if," "then," "and," "or," and "not."[96] These words have precise meanings in logic and those meanings do not always coincide with the everyday meanings of the words.[97]

Based on the empirical research on logic instruction and mathematical reasoning, it seems the best way to incorporate logic instruction into the legal writing classroom is to interweave the two topics of formal logic and legal writing rather than to address logic in a separate unit. While incorporating logic into their courses, legal writing professors should explicitly show students the relevance of the logic concepts to the legal writing students will be doing. Further, legal writing professors should acknowledge the differences between formal logic and ordinary language.

One way in which concepts of logic can arise in the legal writing classroom is when an argument involves negation, taking a given statement and stating the opposite or the contradiction of that statement. In this context, there can be important differences

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Education Stick: Using Cognitive Science to Foster Long-Term Learning in the Legal Writing Classroom, 29 GEO. J. LEG. ETHICS 355, 367 (2016) (noting that interleaving, which is "when various skills or subjects are practiced in a mixed fashion rather than one at a time" aids student learning); Deborah Starkey, *Integration of Medical Images to the Teaching of Systematic Pathology: An Evaluation of Relevance*, 4 J. OF LEARNING DESIGN 63, 64 (2011) (summarizing research concluding that an "academic environment which encourages deep learning includes 'demonstration of the relevance of the course'") (quoting Keith Trigwell & Michael Prosser, *Improving the Quality of Student Learning: The Influence of Learning Context and Student Approaches to Learning on Learning Outcomes*, 22 HIGHER ED. 251, 263 (1991)).

95 *See* Sowder & Harel, *supra* note 84, at 827 ("The disparities between everyday usages and mathematical usages are so marked that explicit instruction in logic as used in mathematics would seem to be necessary, with contrasts to the less precise everyday usages pointed out . . . ."); Ayalon & Even, *supra* note 4, at 237 ("Evolutionary psychology researchers suggest that people do not naturally think in logical terms. On the other hand, people do reason naturally about social situations, using logics that are different from the formal one."); Epp, *supra* note 89, at 895 (noting that "[i]t is also helpful . . . to acknowledge explicitly some of the differences between mathematical logic and the logic used in everyday life").

96 *See* Epp, *supra* note 89, at 888-90 (relating examples of "differences between everyday and mathematical language"); Sowder & Harel, *supra* note 84, at 827 ("An important point is that everyday usage of logical expressions may differ considerably from the precise usage in mathematics.").

97 *See* Epp, *supra* note 89, at 888-90.

between an informal, everyday negation and a precise, formal negation. For example, "when students are asked to write the negation of 'John is tall and John is thin,' a large number respond with 'John is not tall and John is not thin.' "[98] While this may seem intuitively correct to students as a matter of their understanding of the English language, it is not correct under the lens of formal logic. For any statement of the form "A and B," the negation of that statement—"not (A and B)"—is "not A **or** not B" rather than "not A **and** not B."[99] Using the tall and thin example, the negation of "John is tall and John is thin" is "John is not tall or John is not thin." In other words, if John is thin but not tall, the statement "John is tall and John is thin" is not true. Similarly, if John is tall but not thin, the statement "John is tall and John is thin" is not true. For law students and lawyers, this distinction between "not A **or** not B" and "not A **and** not B" is important. If a statute requires three elements for someone to be guilty of a certain crime, to show a person is not guilty requires negating only one of the elements rather than all three elements.

Lawyers and law students also need an understanding of logic to avoid inadvertently misstating legal rules. For example, some statutes take the form "X is not Y unless Z." A legal writer might want to rephrase the rule to eliminate the double negative for clarity.[100] Intuitively, the writer might restate the rule as "X is Y if Z." While that is close in meaning to the original, it is not the same. Instead, the phrase "X is Y only if Z" carries the same meaning as the original. An example of this comes from the revisions to the Federal Rules of Civil Procedure in 2007, which aimed to "redraft[] the civil rules to improve their clarity, consistency, and readability—making substantive changes."[101] Under the previous version of the rules, Rule 55(b)(2) stated, in part, that "no judgment by default shall be entered against an infant or incompetent person unless represented in the action by a general guardian, committee, conservator, or other such representative who has appeared therein."[102] The drafters of the 2007 revisions changed that part of the rule to read, "A default judgment may be entered against a minor or incompetent person only if

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[98] *See id.* at 890.

[99] Symbolically, the statement would be expressed as "$A \land B$," and its negation would be "$\neg (A \land B)$," which is logically equivalent to "$\neg A \lor \neg B$." The symbol "$\land$" means "and," the symbol "$\lor$" means "or," and the symbol "$\neg$" means "not."

[100] *See* Joseph Kimble, *Lessons in Drafting from the New Federal Rules of Civil Procedure*, 12 SCRIBES J. LEGAL WRITING 25, 54 (2009) (noting a preference for avoiding "multiple negatives" and "put[ting] statements in positive form").

[101] *See id.* at 25-26 (summarizing the work done for the 2007 amendments to the rules).

[102] *Id.* at 55 (citing FED. R. CIV. P. 55(b)(2) (pre-2007)).

represented by a general guardian, conservator, or other like fiduciary who has appeared."[103]

While the difference between "if" and "only if" might not matter in everyday language, the distinction is an important one in logic, and often in law. In everyday language, a parent might say to her teenager, "You can't go to the mall unless you clean your room." If the parent wanted to make the same point but with positive framing, she might instead say "You can go to the mall if you clean your room," or "You can go to the mall only if you clean your room." Both parent and teenager would probably understand the "if" statement and the "only if" statement to mean the same thing. In law, however, the use of "if" rather than "only if" can make an important difference. If the revised Rule 55(b)(2) said "if" instead of "only if," the rule would have read, "A default judgment may be entered against a minor or incompetent person if represented by a general guardian, conservator, or other like fiduciary who has appeared." This would have changed the rule's meaning: that "if" version of the rule would have allowed default judgment if the minor or incompetent person was represented as required, but it would not have carried over the original meaning that such representation is the only circumstance allowing entry of a default judgment.

In the law school classroom, professors can interweave logic concepts into their lessons when they are discussing statutes.[104] This would provide a way to introduce basic concepts of logic, to discuss the differences between the language of formal logic and ordinary language, and to connect those discussions to legal analysis and writing.

When preparing to discuss a statute with an "and" requirement, the professor could start with an everyday language example, such as the "tall and thin" example above. The professor could ask the class what the negation of "John is tall and John is thin" is. This could lead to discussion of the different possibilities and which one is correct as a matter of formal logic. The professor could then move the discussion to the statute. For example, in a class covering copyright law, the professor might discuss this statutory provision:

> Recordation of a document in the Copyright Office gives all persons constructive notice of the facts stated in the recorded document, but only if (1) the document, or

[103] *Id.* (citing FED. R. CIV. P. 55(b)(2)).

[104] Professor Barbara A. Kalinowski has suggested other ways in which logic could be incorporated into the law school curriculum. *See* Barbara A. Kalinowski, *Logic Ab Initio: A Functional Approach to Improve Law Students' Critical Thinking Skills*, 22 LEG. WRITING: J. LEG. WRITING INST. 109, 139-49 (2018).

> material attached to it, specifically identifies the work to which it pertains so that, after the document is indexed by the Register of Copyrights, it would be revealed by a reasonable search under the title or registration number of the work; and (2) registration has been made for the work.[105]

Showing this statute to the class, the professor could ask the students what they need to show to prove that there was no constructive notice under this section of the code. Since the students would have the "tall and thin" example fresh in their minds, they should see that they only need to show that one of the two elements is not true. They could either show that the document does not specifically identify the work such that "it would be revealed by a reasonable search" or that the work was not registered. They do not need to show both.[106]

The professor can take a similar approach when discussing a statute with a "not . . . unless" construction. Again, the professor could start with the everyday language example, asking the students to rewrite the parent's requirement that "you can't go to the mall unless you clean your room" to eliminate the "can't . . . unless" double negative. A class discussion of the possibilities could lead to a question of whether there is any difference between the "if" version and the "only if" version. After the class discussion on that point, the professor could note that, while those two statements might have the same meaning in everyday language, the distinction between "if" and "only if" is important in the law. The professor could then introduce the statutory language.

In a class covering copyright law, the professor could discuss the following language: "A transfer of copyright ownership, other than by operation of law, is not valid unless an instrument of conveyance, or a note or memorandum of the transfer, is in writing and signed by the owner of the rights conveyed or such owner's duly authorized agent."[107] The professor could ask students how to rewrite the rule to eliminate the "not . . . unless" double negative. With the room-cleaning example in mind, the students might realize that "only if" is needed. The professor could present both the "if" and "only if" versions to discuss the important differences in meaning. The "only

[105] 17 U.S.C.A. § 205(c) (West 2021).
[106] The professor could note that, as a practical and strategic matter, a lawyer likely would make both arguments if she could reasonably do so. If it were clear, however, that the work was registered, the lawyer still could and should proceed with an argument that there was no constructive notice because the first requirement was not met.
[107] 17 U.S.C.A. § 204(a) (West 2020).

if" version carries the same meaning as the original,[108] while the "if" version does not.[109] The "if" version leaves open the possibility of other valid transfers of copyright ownership, while the "only if" version, like the "not . . . unless" original, indicates that the statutory language provides the only way to validly transfer copyright ownership (aside from the exception provided, in all versions, by the "other than by operation of law" language).[110]

C. Example: Providing More Opportunities to Practice Writing (and Speaking) Arguments

Mathematics professors and mathematics education researchers have insights into what helps students learn to write proofs. First, mathematics professors have noted that students' "acquisition [of proof-writing skills] seems to be considerably aided by practice."[111] While adding more graded assignments is likely not feasible for most legal writing professors, whenever there is class time available for it, professors could incorporate exercises to help their students practice their writing and reasoning skills. These exercises could focus on smaller pieces of the legal analysis, such as writing a synthesized rule statement, describing one precedent case, or analogizing or distinguishing one precedent case.

Second, in addition to showing the importance of practice in general, research from the mathematics classroom shows that students learn proof-writing better when the focus is more on their own construction of proofs and less on the presentation to them of completed proofs.[112] In the legal writing classroom, this suggests that

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[108] "A transfer of copyright ownership, other than by operation of law, is valid only if an instrument of conveyance, or a note or memorandum of the transfer, is in writing and signed by the owner of the rights conveyed or such owner's duly authorized agent."

[109] "A transfer of copyright ownership, other than by operation of law, is valid if an instrument of conveyance, or a note or memorandum of the transfer, is in writing and signed by the owner of the rights conveyed or such owner's duly authorized agent."

[110] Legal writing professors should also acknowledge that not all legal rules are easily translatable to the language of formal logic. For example, a factor test is neither an "and" – not all factors are required – nor an "or" – just one factor is probably not enough. To continue the federal copyright law, the statute provides four factors to be considered "[i]n determining whether the use made of a work in any particular case is a fair use . . . ." 17 U.S.C.A. § 107 (West 2021).

[111] Selden & Selden, *supra* note 54, at 95.

[112] *See* Pedemonte, *supra* note 40, at 25 ("Experimental research shows that proof is more 'accessible' to students if an argumentation activity is developed for the construction of a conjecture. The teaching of proof, which

the students will be better able to produce a strong written analysis if they spend more time on writing their own memos than on studying existing examples. In a typical first-year legal writing class, the professor provides one or more sample memos near the beginning of the first semester as she is teaching the students about the basics of memos and legal analysis. The mathematics education research indicates that providing students with sample memos (or sample briefs or sample contracts) is not as helpful as allowing the students to spend time writing their own "examples." It might be difficult to find the time to do this, but the payoff is worth it. If a legal writing professor uses a flipped classroom approach, students could learn about memo components and legal analysis by watching video lectures before coming to class.[113] The students and professor could then spend class time writing different memo components, working on a problem different from any graded memo assignment the students have. Over the course of the first few weeks of class, the students could write the various components of the memo to create their own "sample." During each class, the professor could circulate while the students are writing to provide feedback and answer questions. At the end of each class, the professor could lead a class discussion of the most effective way to write each component. At the end of this process, the students would have a sample memo that they would understand much more completely than an example provided by the professor or in the book.

Third, research from the mathematics classroom also shows that students' written proofs may not fully capture students' abilities to create valid and convincing proofs. When secondary students were asked to generate and then explain a proof orally, their attempts were

is mainly based on 'reproductive' learning (proofs are merely presented to students, they do not have to construct them) appears to be unsuccessful.") (citations omitted); Selden & Selden, *supra* note 54, at 107 ("[U]niversity teachers should consider including a good deal of student-student and teacher-student interaction regarding students' proof attempts, as opposed to just presenting their own or textbook's."). In fact, some mathematics professors believe students should learn mathematics—not just proof-writing but the substantive topic itself—by constructing their own proofs rather than by watching a professor present a completed proof during a lecture. *See, e.g.*, Cohen, *supra* note 81, at 473 (describing a method where the professor gives no lectures but instead gives students a list of theorems and students then spend the semester working on proofs of those theorems).

[113] *See* Gerald F. Hess, Michael Hunter Schwartz, Nancy Levit, *Fifty Ways to Promote Teaching and Learning*, 67 J. LEGAL EDUC. 696, 724 (2018) (describing a flipped classroom as one where "students read, watch videos, or listen to podcast lectures (or voiceovers with accompanying slides) on basic concepts outside of the classroom and then focus[] on skills development during class time").

more likely to lead to valid proofs than if the students merely wrote the proofs.[114] In a study, after learning "what counts as a proof," students were asked to produce a proof themselves.[115] The students first wrote their proofs and then presented their proofs to the class orally.[116] The students' teacher gave verbal input during only four of the seventeen oral presentations.[117] Of those four, in two of the presentations, the input from the teacher was not "substantial," meaning it "simply reiterated or briefly clarified a point mentioned by the student without an apparent influence on the quality of the presented argument."[118] Thus, in only two of the students' presentations was the verbal input substantial and "potentially influential of the quality of the presented arguments"[119] The researchers classified the arguments in the written proofs and oral presentations, indicating whether the arguments were weak or strong.[120] The researchers found that "all of the orally presented arguments had the same or better quality than their written counterparts."[121] This was true even for those oral presentations – the large majority – where the teacher did not provide substantial verbal input.[122]

This research suggests that, in the legal writing context, professors should continue, and add to, opportunities for students to present their analyses orally. In most legal writing courses, students participate in mock oral arguments, arguing before judges after submitting briefs during the second semester of the first-year legal writing class.[123] In addition, some legal writing courses incorporate additional oral presentation exercises, such as oral reports to a supervisor or oral research reports.[124] While these experiences are

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114 Andreas J. Stylianides, *Secondary Students' Proof Constructions in Mathematics: The Role of Written versus Oral Mode of Argument Representation*, 7 REV. OF ED. 156, 156 (2019) ("[T]he oral mode of representation is more likely than the written mode to be associated with the construction of arguments that meet the standard of proof.").
115 *Id.* at 163-64.
116 *Id.* at 164, 166.
117 *Id.* at 169-71.
118 *Id.* at 168, 170-71.
119 *Id.* at 171.
120 *Id.* at 167.
121 *Id.* at 171.
122 *Id.*
123 Larry Cunningham, *Using Principles from Cognitive Behavioral Therapy to Reduce Nervousness in Oral Argument or Moot Court*, 15 NEV. L.J. 586, 592 (2015) (indicating "most schools have a compulsory oral argument component as part of their legal writing curricula").
124 *See* Katrina June Lee, *Process Over Product: A Pedagogical Focus on Email as a Means of Refining Legal Analysis*, 44 CAP. U. L. REV. 655, 659

valuable, the insights from mathematics indicate that legal writing professors can do more with oral presentations.

Legal writing professors can ask students to present arguments orally as they are first learning to construct a written legal analysis. When first teaching new law students about the IRAC organization paradigm commonly used in legal writing, many professors ask students to write a very basic IRAC analysis. That would be a good moment to insert an oral presentation exercise. Once students have time to write down their analysis, perhaps as homework after class, the professor could then start the next class by asking students to present the analysis orally. Since there is likely not enough class time for each student to present to the whole class, the professor could ask for a few volunteers to present to the whole class and then break the class into small groups and have students present to each other.[125] A similar technique could be used in other first year law classes as well. If the professor asks students to write an answer to a practice exam question, perhaps as part of or in preparation for a midterm, the professor could then ask the students to present their answers orally.

Legal writing professors can add oral presentations that do not focus on questions and answers with a judge or supervisor. While preparing to answer a judge's or supervisor's questions is an important part of preparing for oral argument or an oral report to a supervisor, the mathematics education researchers did not find that students needed input from the teacher to produce better oral proofs. Instead, the students' oral arguments were as strong or stronger than their written arguments even when the teacher did not comment during the oral presentation,[126] suggesting that our legal writing students can benefit from presenting their arguments orally even if that presentation does not involve responding to questions. This means incorporating additional oral presentation opportunities into legal writing does not need to place any additional burden on the students or the professors in terms of preparing for, asking, and responding to questions. Rather, the students can benefit by simply presenting their arguments orally.

(2016) (noting "many legal writing professors assign simulated partner-associate meetings or 'research reports' in the course of a legal writing class").

[125] Alternatively, this could be handled asynchronously as a homework assignment to be submitted outside of class. Students could use their phone or laptop to film themselves presenting the analysis orally, and submit the video through the class page in the school's course management system. Because the mathematics education research indicates the oral presentation process is helpful even without instructor feedback, professors would not need to comment on each presentation.

[126] Stylianides, *supra* note 114, at 171.

Legal writing professors can ask students to present arguments orally without giving any instruction on or weight to formal oral presentation skills. When legal writing professors teach students about oral arguments and oral reports to their supervisors, they often spend time discussing oral presentations skills such as maintaining a professional demeanor, paying attention to pace and volume, and making eye contact.[127] Instruction in these skills does not seem to have formed a part of the mathematics class described above.[128] Further, if students spend time focusing on the softer presentation skills, that may be to the detriment of students' argumentation. Therefore, it seems useful for legal writing classes to include more informal oral argument exercises where students focus solely on the analysis and not on the oral presentation skills.

IV. Conclusion

Helping students develop their reasoning and writing skills is no easy task, whether in the legal writing classroom, the mathematics classroom, or elsewhere. While many lawyers and law students believe they are not good at math, the connections between legal reasoning and mathematical reasoning can provide a basis for new and revised teaching techniques in legal writing classes. This Article has provided a few such techniques, many of which can also be used in other law school classes. In addition, the Article's broader framework suggests avenues for innovations in legal pedagogy and for future scholarship on legal pedagogy. Because transfer is so helpful to the learning process, legal educators should look for connections between law and other fields so that they can help their students transfer existing knowledge to new areas. Further, to avoid reinventing the wheel and to find inspiration for innovations in the law school classroom, legal educators should look to successful pedagogical techniques from other fields.

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[127] *See* Darby A. Dickerson, *Oral Reports to Supervisors*, 12 SECOND DRAFT 13, 13 (1997) (noting that, when teaching students about oral reports to supervisors, the author and her colleagues "spend time talking about professional appearance and demeanor"); James D. Dimitri, *Stepping Up to the Podium with Confidence: A Primer for Law Students on Preparing and Delivering an Appellate Oral Argument*, 38 STETSON L. REV. 75, 104 (2008) (informing students that, in oral argument, their "demeanor should be deferential but firm" and they should "not take a defensive tone with the judges").

[128] Stylianides, *supra* note 114, at 164, 166.