Illuminating Innumeracy

Lisa Milot

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*"I know for me, I'm a lawyer because I was bad at [science and math]. All lawyers in the room, you know it's true. We can't add and subtract, so we argue."**

Contents

Introduction

It is an open secret that lawyers don't like math. Tales of lawyers who chose the profession over business or medicine at least in part because of discomfort with math are legion, as are reports of math avoidance by lawyers once in the profession.[1] Many lawyers treat

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* Michelle Obama, Remarks by the First Lady at the National Science Foundation Family-Friendly Policy Rollout (Sept. 26, 2011).

1. *See* Myrna S. Raeder, *Cost-Benefit Analysis, Unintended Consequences, and Evidentiary Policy: A Critique and a Rethinking of the Application of a Single Set of Evidence Rules to Civil and Criminal Cases*, 19 Cardozo L. Rev. 1585, 1590 (1998) ("Unquestionably, math phobia was the impetus for many of us to attend law school, rather than pursue other professions."); Martha Ann Sisson & Amy Leafe McCormack,

explicitly math-centric fields, such as tax law and bankruptcy, as impenetrable specialties to be avoided at all costs, segregated even on the judicial level with their own dedicated courts. With the exception of empirical articles and those employing an explicitly economic approach, most legal scholars avoid even the whiff of quantitative analysis in their writings, in part to avoid discouraging use of their ideas by lawyers, legislators, and judges uncomfortable with numerical notations and formulas.[2]

To be clear, it is not only lawyers who struggle with numbers and their calculation. A 2003 study found that only 13% of American adults were "proficient" at quantitative tasks and that only 78% could perform even simple, single-step arithmetic.[3] One study, even though it focused on college-educated individuals, found that nearly half of the subjects could not solve basic problems involving probabilities or convert percentages to proportions.[4] Most of us fare little better in the real world; for example, we avoid financial calculations such as the amount needed for retirement, and we fail to assess and rebalance retirement portfolios.[5] Innumeracy is widespread, even among the most educated and successful Americans.

The profession of law, though, has embraced innumeracy in curious and significant ways that other professions have not. The Law School Admissions Test is the only major post-secondary admissions

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Success in 21st Century Private Practice: Retooling for an Enterprise Culture, UVA Law., Fall 2009, at 32, 33 ("Over the years, we have heard many lawyers muse that they would have attended business school if they were not math-phobic."); *see also* Michelle Obama, Remarks by the First Lady at the National Science Foundation Family-Friendly Policy Rollout (Sept. 26, 2011).

2. *See, e.g.*, Thomas D. Lyon & Jonathan J. Koehler, *The Relevance Ratio: Evaluating the Probative Value of Expert Testimony in Child Sexual Abuse Cases*, 82 Cornell L. Rev. 43, 49 (1996) ("We . . . dispense with much of the mathematical notation which has discouraged even quantitatively minded jurists from applying the relevance ratio in a wider range of cases.").

3. Mark Kutner et al., Nat'l Ctr. for Educ. Statistics, A First Look at the Literacy of America's Adults in the 21st Century 3–4 (2005).

4. Isaac M. Lipkus et al., *General Performance on a Numeracy Scale Among Highly Educated Samples*, 21 Med. Decision Making 37, 39 (2001). This study confirmed prior findings in less-educated populations. *See id.* at 38 (summarizing prior research).

5. *See* Omri Ben-Shahar & Carl E. Schneider, *The Failure of Mandated Disclosure*, 159 U. Pa. L. Rev. 647, 728 (2011) ("Rather than choosing investments, employees often leave pension money wherever their employer puts it.").

examination without a math component.[6] Law students are assumed to lack mathematical backgrounds, and it is well accepted that they are not interested in understanding even basic mathematical concepts.[7] Moreover, many law professors share the math aversion of their students so that the numerical aspects of cases are often left unexplored in class or even edited out of casebooks. As a result, little math is found in the typical law school classroom.

Not surprisingly, law students who are uncomfortable with math become lawyers who self-identify as "bad at math." Indeed, innumeracy is at times almost celebrated within the legal profession. Lawyers bond openly over their distaste for math and accept the same in others. Those who are competent at—or even enjoy—math are seen as an oddity. Only occasionally is the profession's math paralysis criticized or even questioned.[8]

That lawyers are bad at math has become a truism, so that whether we are actually bad at math is subsumed by our image of

6. *See* Mary Ann Glendon, A Nation Under Lawyers: How the Crisis in the Legal Profession is Transforming American Society 202–03 (1994) (providing an overview of the types of intelligence for which the Law School Admissions Test evaluates). While the Medical College Admission Test no longer has a separate quantitative analysis section, basic mathematical competence, including arithmetic, calculation of percentages, calculation of proportions, and estimates of square roots, is tested as part of the biological and physical sciences sections of the exam. *Physical and Biological Sciences Cognitive Skills*, Ass'n of Am. Med. Colls. 4 (2012), https://www.aamc.org/students/download/285238/data/phyandbiocogskills.pdf.

7. For a more complete discussion of law students, law school, and math, see *infra* Part III.

8. For example, in noting that the symposium for which his paper was written was held in 1997 and marked the anniversary of legislation signed into law in 1986, Professor David Hyman stated that "Only lawyers, whose inadequacies in mathematics are well-documented, could conclude that the symposium marked [the legislation's] tenth anniversary." David A. Hyman, *Patient Dumping and EMTALA: Past Imperfect/Future Shock*, 8 Health Matrix 29, 29 n.1 (1998). On a more technical level, in analyzing Internal Revenue Code § 673, which provides that a grantor is treated as the owner of a trust in which he has retained a reversion if, at the time the trust is funded, the reversion is greater than 5% of the value of the portion of the trust to which the reversion applies, Lawrence Katzenstein described a statutory exception as being "included for the benefit of lawyers who aren't good at math," since the described scenario could never exceed the 5% threshold. Lawrence P. Katzenstein, *Planning with Grantor Trusts*, *in* Estate Planning in Depth 1053, 1058 (ALI-ABA Course of Study, June 23–28, 2002), WL SG094 ALI-ABA 1053; *cf.* Lyon & Koehler, *supra* note 2, at 49 n.26 (listing Judge Jack Weinstein and Judge Frank Easterbrook as "notable exceptions in an otherwise remarkably math-phobic population" of judges).

ourselves—and others' image of us—as such.[9] Yet lawyers in all types of practices must grapple with mathematical issues.[10] Are we competent to do so?[11] If at least a sizable portion of the bar is innumerate, why is this the case—is it objective math *competence* or subjective math *confidence* that we lack? And, either way, are our mathematical failings corrected by the checks and balances of legal practice and the legal system, or should we, as members of the legal profession, change our approach to math?

Innumeracy is an issue we must confront: numerical information is pervasive and calculations are central to the practice of many areas of law.[12] Yet many math mistakes in the law and legal practice remain unacknowledged and uncorrected because in our discomfort with numbers we assign undue weight to them, lack the language to engage with numerical ideas, and limit our ability to represent our clients with respect to some of the more interesting and novel legal issues arising in our technological world.[13] Ultimately, innumeracy prevents us from thinking critically about the information and assumptions underlying numbers and compromises transparency and comprehensibility in the law, undermining legal authority.

To date, academic attention has focused primarily on the innumeracy of jurors[14] and of the American public generally.[15] But the spotlight

9. An internet search with the terms "lawyer" and "bad at math" returns approximately 883,000 hits. http://www.google.com/ (search "lawyer" "bad at math") (last visited Feb. 13, 2013).

10. *See infra* Part II.

11. Intriguingly, a preliminary empirical study of the numeracy of law students shows that they are both better and worse at math than graduate students in other fields. The study suggests that while many law students have a high degree of numeracy, a troubling number (3%)—more than in other programs—is genuinely innumerate: incapable of correctly answering even a single, simple arithmetic problem. *See* Arden Rowell & Jessica L. Bregant, *Numeracy and Legal Decisionmaking* (Ill. Pub. Law & Legal Theory Research Paper Series No. 13-29, 2012), *available at* http://ssrn.com/abstract_id=2163645.

12. *See infra* Part III.

13. *See infra* Part III.

14. *See, e.g.*, Joseph H. King, Jr., *Pain and Suffering, Noneconomic Damages, and the Goals of Tort Law*, 57 SMU L. Rev. 163 (2004) (discussing jury difficulties calculating awards for pain and suffering); Laurence H. Tribe, *Trial by Mathematics: Precision and Ritual in the Legal Process*, 84 Harv. L. Rev. 1329 (1971) (noting the danger of jury overvaluation of numerical analysis).

15. *See, e.g.*, Ben-Shahar & Schneider, *supra* note 5 (exploring the failure of mandated disclosure laws to protect personal autonomy, in part because of the high rate of consumer innumeracy); Susan Block-Lieb, *Mandatory Protections as Veiled Punishments: Debtor Education in H.R. 975, The Bankruptcy Abuse and Consumer Protection Act of 2003*, 69 Brook. L.

has rarely been focused where it belongs: on practicing lawyers[16] and lawmakers,[17] as well as law students and the law professors who prepare them for their future roles in the legal community. In this Article, I distinguish between three types of mathematical errors commonly made by lawyers: miscalculations, oversimplifications, and misapplications of mathematical principles. I argue that these errors matter because of the centrality of numerical information to the practice of many areas of law. In order to better understand the origins of this innumeracy and begin to move towards a more numerate approach to the law, I distinguish objective innumeracy—a lack of math *competence*—from subjective innumeracy—a lack of math *confidence*. Finally, I conclude by offering practical suggestions for beginning to overcome innumeracy in the legal profession. Dealing head on with these fundamental challenges holds the promise of greatly improving how we think about and practice law.

REV. 425 (2004) (debtor education); Christopher C. Fennell & Lee Anne Fennell, *Fear and Greed in Tax Policy: A Qualitative Research Agenda*, 13 WASH. U. J.L. & POL'Y 75 (2003) (taxpayer filing decisions); David Adam Friedman, *Free Offers: A New Look*, 38 N.M. L. REV. 49 (2008) (debtor disclosures); Bailey Kuklin, *Probability Misestimates in Medical Care*, 59 ARK. L. REV. 527 (2006) (medical risk assessments); Ann Morales Olazábal & Howard Marmorstein, *Structured Products for the Retail Market: The Regulatory Implications of Investor Innumeracy and Consumer Information Processing*, 52 ARIZ. L. REV. 623 (2010) (investor innumeracy).

16. A rare exception is Professor Laurence Tribe's 1971 article critiquing a prosecutor's incorrect use of probabilistic evidence in a criminal trial. *See* Tribe, *supra* note 14, at 1335–38. For further discussion of this case, see *infra* notes 72–78 and accompanying text.

17. In a few instances, commentators have discussed mathematical errors by judges. *See, e.g.*, Paul H. Edelman, *Getting the Math Right: Why California Has Too Many Seats in the House of Representatives*, 59 VAND. L. REV. 297 (2006) (arguing that the Supreme Court made a math error in *United States Department of Commerce v. Montana*, 503 U.S. 442 (1992)); David L. Faigman, *"Normative Constitutional Fact-Finding": Exploring the Empirical Component of Constitutional Interpretation*, 139 U. PA. L. REV. 541 (1991) (reviewing the Supreme Court's use of empirical research in constitutional interpretation); Michael I. Meyerson & William Meyerson, *Significant Statistics: The Unwitting Policy Making of Mathematically Ignorant Judges*, 37 PEPP. L. REV. 771 (2010) (analyzing areas of the law where the "mathematical ignorance" of judges has subverted legal goals); Lars Noah, *An Inventory of Mathematical Blunders in Applying the Loss-of-a-Chance Doctrine*, 24 REV. LITIG. 369 (2005) (cataloguing instances of computational and conceptual errors in the calculation of "loss of a chance" damages in tort law).

I. Enumerating Legal Innumeracy

Lawyers' discomfort with numbers and their calculation can be seen in the ways we approach mathematical issues in the law. As an initial matter, in many instances lawyers simply avoid math.

At times, this avoidance reflects our wariness about the potential for laypersons to assign undue weight to numerical evidence. So, for example, in *People v. Collins*,[18] mathematics professor Daniel Martinez provided expert testimony concerning probability theory in an effort to establish the likelihood that the defendants in question had committed the crime with which they were charged. Upon appeal, the California Supreme Court expressed concern with the power of probabilistic evidence and warned that "[m]athematics, a veritable sorcerer in our computerized society, while assisting the trier of fact in the search for truth, must not cast a spell over him."[19] In particular, the court worried that the jury lacked the competence to properly contextualize the probabilistic evidence with which it had been presented and, as a result, overvalued it in deciding the defendants' guilt.[20]

Professor Laurence Tribe has since expanded on this concern,[21] criticizing the use of "explicitly statistical evidence or overtly probabilistic arguments" at trial.[22] A mathematician himself,[23] Tribe believes that the risk that jurors might overvalue numerical data due to the precision and "overbearing impressiveness of numbers" is too great.[24] Thus, he prefers that jurors be allowed to make inductive inferences rather than be presented with explicitly quantified information.[25] Later commentators have echoed this idea.[26]

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18. People v. Collins, 438 P.2d 33 (Cal. 1968) (en banc).

19. *Id.* at 33. In addition to the concern with overvaluation, the court reviewed the many factual errors made by the prosecution at trial, producing meaningless calculations of probability. *See* George Fisher, Evidence 73 (2d ed. 2008); *see also infra* notes 72–78 and accompanying text.

20. *Collins*, 438 P.2d at 40. The court pointed to flaws in the evidence presented but reserved its harshest criticism for the power of mathematics in the courtroom.

21. Professor Tribe was, in fact, the architect behind the *Collins* opinion. At the time of the decision, he clerked for Justice Tobriner who assisted in drafting the opinion. *See* Fisher, *supra* note 19, at 73 (detailing Tribe's role in assisting Justice Tobriner).

22. Tribe, *supra* note 14, at 1330.

23. Professor Tribe graduated *summa cum laude* in Mathematics from Harvard College prior to his legal career. *Laurence H. Tribe,* Harvard L. Sch., http://www.law.harvard.edu/faculty/directory/index.html?id=74 (last visited Feb. 13, 2013).

24. Tribe, *supra* note 14, at 1361.

25. *Id.* at 1331 & n.2.

At other times, math avoidance may reflect a conscious legal strategy, born of a belief that "[a]necdotal evidence is vivid and reaches us in a way that . . . statistical information cannot."[27] In this view, storytelling is a preferred advocacy tactic, providing context and color, and thus a saliency to the jury, in a way numbers cannot. For example, Michael Saks and Robert Kidd have argued that:

> Research demonstrates . . . that people do not process probabilistic information well, that in the face of particularistic information, they cannot integrate the statistical and anecdotal evidence and consequently tend to ignore the *statistical* information. Intuitive, heuristic, human decision makers must dispense with certain information, and that tends strongly to be the quantitative information. While commentators' arguments have been that the data are inordinately persuasive, the evidence says the reverse is true.[28]

This reasoning resonates with the actual experience of jurors in *Collins*, who later reported that they had disregarded Professor Martinez's testimony in reaching the verdict, focusing instead on the evidence provided by eyewitnesses to the crime.[29]

This research illustrates that math avoidance can be a conscious technique used by lawyers to develop a persuasive narrative that avoids confusion or the misinterpretation of numerical evidence by laypersons charged with legal decision making. But that is just the tip of the iceberg with regard to math avoidance in the law: as other

26. *See, e.g.*, Leonard R. Jaffee, *Prior Probability—A Black Hole in the Mathematician's View of the Sufficiency and Weight of Evidence*, 9 Cardozo L. Rev. 967 (1988) (arguing ardently against the use of probabilistic evidence); Richard O. Lempert, *Modeling Relevance*, 75 Mich. L. Rev. 1021 (1977) (agreeing with Tribe as an initial matter that the costs of using probabilistic evidence in the fact-finding process at trial outweigh the benefits of such use); *see also* David McCord, *A Primer for the Nonmathematically Inclined on Mathematical Evidence in Criminal Cases:* People v. Collins *and Beyond*, 47 Wash. & Lee L. Rev. 741 (1990) (providing an overview of the issues and arguments concerning probabilistic evidence and the associated case law and social science research).

27. Panel on Statistics Assessments as Evidence in the Courts, Nat'l Research Council, The Evolving Role of Statistical Assessments as Evidence in the Courts 154 (Stephen E. Fienberg ed., 1989).

28. Michael J. Saks & Robert F. Kidd, *Human Information Processing and Adjudication: Trial by Heuristics*, 15 Law & Soc'y Rev. 123, 149 (1980–1981).

29. *See* Fisher, *supra* note 19, at 72.

commentators have noted, lawyers often avoid math simply because they are uncomfortable with it.[30]

Avoidance, though, is not the primary problem. Instead, the central issue is that when lawyers do math,[31] they often do it badly. Indeed, the ways innumeracy manifests itself are so varied and overlapping that any taxonomy of the problem is necessarily incomplete. But it is worth parsing the types of numerical errors lawyers most commonly make in order to better understand the reasons for them and identify those that are most in need of systemic correction. Three problems are of particular importance due to their pervasiveness and the ways in which they compromise transparency in the law and, thus, undermine the legitimacy of our legal system: (1) persistent computational errors, (2) the reduction of complex calculations to overly simplistic formulas that obscure their failure to accomplish their intended goals, and (3) the production and use of meaningless data through fundamental misunderstandings of the principles underlying mathematical calculations.

A. Innumeracy Through Miscalculation

Computational errors are the simplest of math mistakes: for example, a figure is calculated incorrectly, numbers are transposed, or addition is performed rather than multiplication. In many instances, such errors are caught quickly, before they become of any significance. However, when errors are not self-evident, a lawyer must be secure enough with numbers to think critically about them so as to ensure that an *apparent* result is in fact the *actual* result.

Sometimes individuals do not have the basic tools to think critically about numbers. In his bestseller about the existence and consequences of innumeracy, mathematics professor John Allen Paulos catalogued Americans' difficulties with identifying internal inconsistencies in calculations because of difficulties with estimation and scale.[32] For example, Paulos analyzes the story of Noah's Ark

30. For example, in an article for young practitioners, Scheherazade Fowler comments on "lawyers who try really hard to not look too closely at numbers, who accept the accountant's numbers blindly, whose eyes glaze over at spreadsheets and balance sheets." Scheherazade Fowler, *Journal of a Young Lawyer*, Law Prac. Today (Mar. 2005), http://apps.americanbar.org/lpm/lpt/articles/mgt03054.html.

31. In fact, in some instances math cannot be avoided as the substance of the controversy is itself mathematical—for example, the calculation of damages or the valuation of a company. Professor Tribe specifically excepts such cases from his criticisms of the use of math at trial. Tribe, *supra* note 14, at 1338.

32. John Allen Paulos, Innumeracy: Mathematical Illiteracy and Its Consequences 7–32 (paperback ed. 2001).

from the Book of Genesis for mathematical possibility.[33] For water deep enough to cover the world's mountains, he calculates that at least half a billion cubic miles of rain would need to fall in the allotted forty-day period.[34] On an hourly basis, this is a rate of rainfall of at least fifteen feet per hour, more than sufficient to sink an aircraft carrier—or a fully-loaded ark.[35] Thus simple mathematical estimations and calculations and a sense of scale—of what fifteen feet of rain an hour looks like—clarifies that the story cannot be literally true.

As a more practical and legal example of this sort of problem, Professor Allan Felsot has critiqued policymakers' "inability to grasp the magnitude of numbers" with respect to the level of contaminants in the environment.[36] As such, lawmakers cannot distinguish between levels that are biologically significant and those that are not, leading them to impose completely impractical requirements for contaminant management.[37] When lawyers fail to understand the context of numbers, they lose the ability to think critically about them, and the results can prove nonsensical.

Absent a sense of how numbers should work and an interest in engaging with them, moreover, errors that should be easily correctable often become legally significant.[38] Take, for example, the calculation of the value of an interest in a family limited partnership (FLP)[39] for gift and estate tax purposes. A common estate-planning tool, an FLP transforms assets that were once wholly owned and freely transferable by a taxpayer into interests in an illiquid company.[40] Since a buyer

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33. *Id.* at 16–17.

34. *Id.*

35. *Id.*

36. Allan S. Felsot, *Numbers, Numbers Everywhere—And Not a Drop of Meaning*, 13 J. Envtl. L. & Litig. 91, 91 (1998).

37. *See id.* at 92 (discussing how "regulatory standards have begun to overreach the true significance of the numbers").

38. In fact, innumeracy of this sort is often behind malpractice actions against attorneys. *See* Julie A. Goren, *Getting the Date Right*, Cal. Law., Dec. 2010, at 39, 39 (reporting that the American Bar Association has identified calendaring and deadline-related errors as a leading cause of attorney malpractice actions including, among others, miscounting the days until a deadline expired).

39. Ostensibly referring only to "limited partnerships," FLPs may in fact be created as limited liability companies, business trusts, or other closely-held business entities. While the details of the entity and capitalization structure differ depending on the type of entity employed, the basic technique and calculation of discounts are the same. As used in this Article, "FLP" is a term of art independent of the entity type.

40. *See* James R. Repetti, *Minority Discounts: The Alchemy in Estate and Gift Taxation*, 50 Tax L. Rev. 415, 452–58 (1995) (containing a critical discussion of the use of FLPs in estate planning).

would pay less for such a restricted interest than for outright ownership of the underlying assets, the successful use of an FLP depresses the taxable value of the asset.[41] Thus, when a taxpayer transfers interests in the FLP to his children or other intended beneficiaries, he pays tax on the lower value of the FLP interest rather than on the value of the assets he transferred to the FLP in the first instance.

To illustrate this technique, consider the valuation of one share of common stock that is traded on the New York Stock Exchange. Because the stock is publicly traded, its tax valuation is straightforward: simply find the mean of its high and low trading values on the day in question.[42] Compare this value to that of an interest in an FLP that holds shares of publicly traded stock. Because the FLP interest is not regularly sold on any established market, there is no high or low value to average. Instead, its value for tax purposes is based on "all relevant factors," including the FLP's net asset value and demonstrated earning capacity, the economic outlook for its particular business, and the value of the securities of comparable companies that are publicly traded.[43]

If we assume the FLP interest being valued represents 10% of the interests in the company, at first blush the value of the interest should be worth 10% of the overall value of the FLP. But finding an unrelated buyer for the interest at this price would most likely be impossible: the buyer would have no guarantee of receiving any return on his investment, could not determine the FLP's investment or dividend policy, and would not even be able to determine who would manage the company's investments. Moreover, finding a subsequent buyer for the interest would prove difficult if the initial buyer decided against holding the investment at some point in the future. As such, a buyer would expect to pay something less than 10% of the FLP's overall value for the interest.

Thus, in most instances the value of an FLP interest must be discounted from a proportionate portion of the FLP's overall value. Where the interest being valued represents less than a controlling interest in the company, its value is often discounted to reflect its

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41. *See* Treas. Reg. §§ 20.2031-2(a), 25.2512-2(a) (as amended in 1992 and 1976, respectively) (establishing that the value of an interest for gift and estate tax purposes is its fair market value on the valuation date).

42. *See* Treas. Reg. §§ 20.2031-2(b)(1), 25.2512-2(b)(1) (as amended in 1992 and 1976, respectively) (establishing that the mean between the highest and lowest selling price on the date of the gift is the fair market value per share).

43. Treas. Reg. §§ 20.2031-3, 25.2512-3(a) (as amended in 1992 and 1960, respectively). *See also* Treas. Reg. §§ 20.2031-2(f), 25.2512-2(f) (as amended in 1992 and 1976, respectively) (listing factors); Rev. Rul. 59-60, 1959-1 C.B. 237 (same).

holder's lack of control.[44] Moreover, where the value of the company was initially determined by comparison to publicly-traded companies in a similar business, a discount accounting for the comparative difficulty in selling the privately-held FLP interest is appropriate.[45] In each case, the appropriate adjustment is generally determined by appraisal.

Taken as a whole, the valuation of an interest in a company that is not publicly traded involves a series of high-stakes judgment calls that can substantially reduce the taxable value of a taxpayer's interest in a company,[46] and thus his tax burden. As a result, estate-planning attorneys are careful in their related documentation and calculations. Yet miscalculations in this realm are legion.

The most common error reflected in the case law involves the application of discounts for lack of control and lack of marketability to the same underlying FLP value. As with any set of discounts, the proper calculation involves a sequential application of the discounts.[47] For illustration, consider a $100 item that was initially marked down by 30%, and then by a further 20%. Its final marked-down price can be found by calculating the initial discount and subtracting this amount from the initial price, then calculating the second discount on this initial marked-down price and subtracting it from this intermediate price.[48] Thus:

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44. This is often termed a "lack of control" or "minority" discount. *See, e.g.*, Estate of Kelley *ex rel.* Louden v. Comm'r, 90 T.C.M. (CCH) 369, 372 (2005) ("A minority discount will therefore apply . . . where a partner lacks control."). Alternatively, where the interest is a controlling one, a "control interest premium" may be appropriate if the initial valuation did not assume control. *See* Treas. Reg. §§ 20.2031-2(e), 25.2512-2(e) (as amended in 1992 and 1976, respectively) ("[I]f the block of stock to be valued represents a controlling interest . . . the price at which other lots change hands may have little relation to its true value.").

45. This is commonly called a "discount for lack of marketability." *See generally* Mukesh Bajaj et al., *Firm Value and Marketability Discounts,* 27 J. CORP. L. 89, 100–03 (2001).

46. *See* Louis A. Mezzullo, *Valuation of Corporate Stock*, 831-3d TAX MGMT. PORTFOLIOS (BNA), at B-101–02 (2010) (showing lack of control discounts up to 35% and lack of marketability discounts of up to 50% in a selection of 77 reported cases).

47. *See* GARY R. TRUGMAN, UNDERSTANDING BUSINESS VALUATION: A PRACTICAL GUIDE TO VALUING SMALL TO MEDIUM-SIZED BUSINESSES 286–87 (1998).

48. Because of the commutative property, the answer is the same regardless of the order in which the discounts are applied. Thus, a $100 item that is first marked down by 20% and then by 30% yields the same final marked-down price as one that is first marked down by 30% and then by 20%.

initial sales price		\$100
less initial discount	(\$100 × 30%)	- \$30
initial marked-down price		\$70
less second discount	(\$70 × 20%)	- \$14
final marked down price		\$56

The resulting total mark-down in percentage terms is 44%.[49]

Similarly, where a block of stock is appropriately subject to a 30% lack of control discount and a 20% discount for lack of marketability, its total applicable discount is the same 44%. Yet lawyers, judges, and law students all frequently incorrectly calculate the overall discount. In some instances, the discounts are added together to produce a total applicable discount of 50%.[50] In others, the final marked-down price and discount are transposed; thus the taxable value is reported as \$44 instead of \$56.[51] In still others, the discounts are combined in a way that defies explanation and thus is only attributable to a miscalculation.[52]

Each of these mistakes is easy to catch and correct for an attorney comfortable with numbers and their calculation. For example, when one recognizes that discounts are multiplicative rather than additive, even a quick review should reveal that discounts of 30% and 20% cannot yield an overall discount of 50%. Yet these sorts of errors may well evade notice by lawyers unaccustomed to

49. This is calculated as: \$100 initial price − \$56 final price = \$44 total discount. The percentage discount is: \$44 total discount = 0.44 = 44%.

50. *See, e.g.*, Estate of Bailey *ex rel.* Foster v. Comm'r, 83 T.C.M. (CCH) 1862 (2002) (claiming incorrectly that discounts of 20% and 40% yielded an overall discount of 60%); Estate of Barudin *ex rel.* Clarke v. Comm'r, 72 T.C.M. (CCH) 488 (1996) (asserting that discounts of 26% and 19% yielded a total discount of 45%); *cf.* Dickerson v. Comm'r, 103 T.C.M. (CCH) 1280 (2012) (erroneously discounting the valuation of the gift of lottery proceeds made by the taxpayer by a total of 67%, based on individual discounts of 65% and 2%).

51. *Cf.* Repetti, *supra* note 40, at 425 ("A few confused courts initially valued the corporation assuming control and then added a control premium to the controlling block, in effect, double counting for the premium." (footnote omitted)).

52. For example, in *Estate of Kelley ex rel. Louden v. Commissioner*, 90 T.C.M. (CCH) 369, 370 (2005), the taxpayers claimed discounts of 38% for lack of marketability and of 25% for lack of control. Without explanation, their counsel repeatedly asserted that these discounts together produced a total discount of 55.15%. *Id.* at 370 n.1. As the court noted, this assertion contradicted the actual total discount—53.5%—correctly applied by the appraiser in calculating the taxable value of the interest. *Id.* Ultimately, the court correctly applied the adjusted discounts it allowed. *Id.* at 373–74.

estimating and thinking critically about numbers, causing serious harm to their clients.[53]

B. Innumeracy Through Oversimplification

Complex numerical ideas frequently defy simplification. This has not, however, prevented lawyers and lawmakers from seeking to express complex mathematical concepts in simple terms, even when the result makes no economic sense.

One example of an oversimplified formula is that for the division of equity in homes that are classified as hybrid property upon a couple's divorce.[54] "Hybrid property" is property owned by a couple that has both separate and marital components,[55] often because of its acquisition with a combination of premarital and postmarriage funds. Homes that are purchased prior to marriage, with later mortgage payments made with income earned during the marriage, epitomize hybrid property.

In determining how much of a hybrid-property home's equity should be allocated to one spouse's separate estate and how much to the marital estate upon divorce, many courts look to the "source of the

53. The result of these mistakes might be the overpayment of tax or the imposition of penalties and interest for an underpayment. In either case, the mistake can trigger an audit—with the associated emotional and legal costs. See *infra* notes 118–21 and accompanying text for further discussion of these issues. Even where caught by an attorney, there can be negative repercussions for clients. *See, e.g.*, DeCurtins v. DeCurtins, Nos. 92 CA 2, 92 CA 44, 1993 WL 211348, at *4 (Ohio Ct. App. June 16, 1993) (correcting defendant's attorney's simple $19,500 miscalculation in a property settlement agreement only after several years of appeals).

54. For further examples of oversimplification in the law in response to mathematical complexity, see F. Russell Denton & Paul J. Heald, *Random Walks, Non-Cooperative Games, and the Complex Mathematics of Patent Pricing*, 55 RUTGERS L. REV. 1175, 1181–93 (2003) (analyzing the prevailing patent-valuation methods and finding them overly simplistic), and *A New Formula for Divorce, with Uneven Results*, WALL ST. J. (Mar. 11, 2012, 10:30 PM), http://live.wsj.com/video/EBE6C620-C3DA-4EFC-AF7C-F6702B34EA6B.html (featuring Judge Sondra Miller (retired) of the Appellate Division of the Supreme Court of New York criticizing the state's statutory formula for setting predivorce alimony and explaining that the formula, through oversimplification, produces perverse and unexpected consequences when applied to certain more affluent couples). *Cf.* Meyerson & Meyerson, *supra* note 17 (critiquing the initial presumption in paternity cases that, prior to testing, the defendant has a 50% chance of being the father; the focus on race in DNA matching, regardless of its relevance to the crime committed; and the reduction of damages to plaintiffs who are women or members of a racial minority group).

55. PRINCIPLES OF THE LAW OF FAMILY DISSOLUTION: ANALYSIS AND RECOMMENDATIONS § 4.03 (2002); 1 BRETT R. TURNER, EQUITABLE DISTRIBUTION OF PROPERTY § 5:28 (3d ed. 2005).

funds" used to acquire equity in the property.[56] They then divide that equity between the estates based on their contributions.[57] The ultimate goal is to return the invested funds to the estate that provided them, along with a return that fairly allocates the appreciation in the home's value during the time it was owned by the couple.[58]

The most often-used formula for this division is expressed algebraically as:

$$nmc/tc \times e = \text{nonmarital property},$$[59]

where *nmc* is the total of the nonmarital (separate) contributions to the home's equity,[60] *tc* is the total amount contributed by both the separate and marital estates, and *e* is the home's net equity at the time the marriage is dissolved.[61] After calculating the separate estate's share of the equity pursuant to this formula, all remaining equity is allocated to the marital estate.

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56. *See* Brett R. Turner, *Virginia's Equitable Distribution Law: Active Appreciation and the Source of Funds Rule*, 47 Wash. & Lee L. Rev. 879, 890 (1990).

57. *See id.* ("[W]hen property is acquired with marital and separate funds, the ratio between the marital and separate interests is the ratio between the marital and separate contributions.").

58. *See, e.g.*, Maddox v. Maddox, 604 S.E.2d 784, 786 (Ga. 2004) (expressing that each estate should receive a fair and proportionate return on its investment in the home); Hall v. Hall, 462 A.2d 1179, 1181 (Me. 1983) (same); Hoffman v. Hoffman, 614 A.2d 988, 993 (Md. Ct. Spec. App. 1992) (same); *In re* Marriage of Herr, 705 S.W.2d 619, 624 (Mo. Ct. App. 1986) (same); Wade v. Wade, 325 S.E.2d 260, 269 (N.C. Ct. App. 1985) (same); Smoot v. Smoot, 4 Va. Cir. 182, 190 (Va. Cir. Ct. 1984) (same).

59. The court in *Brandenburg v. Brandenburg*, 617 S.W.2d 871, 872–74 (Ky. Ct. App. 1981), explicated this formula. Georgia, Missouri, Virginia, and West Virginia have also adopted it. Snowden v. Alexander-Snowden, 587 S.E.2d 54, 55–56 (Ga. 2003); *In re* Herr, 705 S.W.2d at 625; Hart v. Hart, 497 S.E.2d 496, 505 (Va. Ct. App. 1998); Whiting v. Whiting, 396 S.E.2d 413, 422 (W. Va. 1990).

60. Nonmarital contributions are the equity in the home at the time of marriage together with any later payments from separate funds towards the mortgage principal and the value of any improvements made to the home that were paid from separate funds. "Marital contributions" equal amounts paid after marriage to reduce the mortgage principal and the value of any improvements made to the property after marriage, in each case paid for from funds that are not one spouse's separate property. *See Brandenburg*, 617 S.W.2d at 872 (providing definitions for the terms in the formula).

61. Dissolution can either be the time of separation or divorce, depending on state law. If the home is sold prior to that time, *e* equals the net proceeds from the sale. *See id.*

Consider, for example, a $250,000 home purchased by an unmarried individual using conventional financing.[62] At purchase, the downpayment is $50,000 and the mortgage balance is $200,000. Assuming the homeowner pays $5,000 of the principal of the loan prior to marriage two years later[63] and the value of the home stays constant, the homeowner's nonmarital contributions (*nmc*) total $55,000.[64] If the couple makes mortgage principal payments of $20,000 during their six year marriage, as well as an additional lump sum payment of $35,000 near the end of the marriage, the total contributions (*tc*) to the home's equity equals $110,000.[65] If the home appreciates to be worth $500,000 at the time of divorce, its net equity (*e*) at that time is $360,000.[66]

Using the above formula, the value allocated to the separate estate is:

$$(\$55{,}000/\$110{,}000) \times \$360{,}000 = \$180{,}000.$$

The remaining home equity—$180,000[67]—is allocated to the marital estate. This makes intuitive sense, since each estate contributed an equal amount to the home's equity and thus should receive an equal portion of the available equity.

Yet it makes no economic sense. Each estate's interest is misvalued under the formula because it allocates an identical return

62. The conventional financing for a home purchase is provided by a 20% down payment and a 30-year fully amortized mortgage. *See* Matthew Chambers et al., *Accounting for Changes in the Homeownership Rate,* 50 Int'l Econ. Rev. 677, 700–01 (2009).

63. This is the typical total of the principal payments in the first two years of a conventional mortgage with a 6.5% interest rate. *See* Lisa Milot, *Accounting for Time: A Relative-Interest Approach to the Division of Equity in Hybrid-Property Homes Upon Divorce*, 100 Ky. L.J. 585, 607–09 (2011–2012) (providing a more in-depth example and explanation of the components of and variations to the formula).

64. This amount consists of the $50,000 down payment and $5,000 principal payments.

65. $55,000 (*nmc*) + $20,000 (scheduled marital principal payments) + $35,000 (lump-sum marital principal payment) = $110,000.

66. The net equity equals the home's value less the outstanding mortgage. The original $200,000 mortgage has been reduced by the $5,000 principal payment prior to marriage, the $20,000 monthly payments during the marriage, and the $35,000 lump sum payment, so $140,000 is outstanding at the time the marriage dissolves. Thus,

$$\begin{aligned} e &= \$500{,}000 - \$140{,}000 \\ &= \$360{,}000. \end{aligned}$$

67. Net equity (*e*) – nonmarital property = marital property, or

$$\$360{,}000 - \$180{,}000 = \$180{,}000.$$

to each estate even though the separate contributions were made many years before the marital contributions. In effect, the formula simply operates as though each estate held an equal 50% interest in the home from the moment of marriage forward. A truly "proportionate" allocation of the appreciation would have to account for the greater investment timeframe of the separate interest.

The formula also ignores the fact that changes in a home's value are not smooth. While our hypothetical home, for example, doubled in value between its owners' marriage and divorce, this growth did not occur in 72 equal monthly increments. Instead, in some months it was greater and in some months it was less—or may even have been a loss. A "fair" allocation of the appreciation would allocate the periodic gain (or loss) between the estates each time their relative interests in the property changed.

The current formula is straightforward, intuitive, and easy to apply. Because it values the home only at marriage and divorce, it requires little record-keeping and only a few very simple calculations. Yet the cost of this simplicity is a substantial transfer of wealth between the separate and marital estates. This transfer, moreover, is invisible and unacknowledged. While courts and legislatures are free to knowingly choose this outcome, there is no indication they have done so in adopting this formula. From all appearances, courts have simply assumed that the existing formula produces an economically sound allocation of appreciation, and lawyers have uncritically applied it. Put simply, legal innumeracy has produced a formula that sacrifices fairness and accuracy for simplicity. And, notwithstanding the formula's widespread use over more than thirty years, this fact has gone largely unrecognized.[68]

C. Innumeracy Through Misunderstanding

A final form of innumeracy involves a problem at the heart of innumeracy in the law: many lawyers misunderstand fundamental mathematical principles.[69] In other words, mistakes in calculations

68. This oversimplification is the central problem addressed in my most recent article. Milot, *supra* note 63, at 618–23; *cf.* William A. Reppy, Jr., *Apportioning Business Profits Generated by Spousal Labor and Capital Owned Over Time by Shifting Fractional Shares of the Separate and Community/Marital Estates*, 31 Fam. L.Q. 63 (1997) (making an analogous critique of the law concerning hybrid-property businesses).

69. One manifestation of this misunderstanding is the misuse of numerical terms. For example, a recent student note states that the author is "saddled with massive debt," but in the next sentence refers to the author's three-digit net worth, seemingly without awareness that this formulation means that the author has assets with a value even greater than his "massive debt." *See* Joshua Plager, Note, *Trim, Plan, Law School: We Have a Situation (Now Let's Fix It)*, 67 U. Miami L. Rev. (forthcoming 2013).

reflect a deeper lack of comprehension about how numbers work. This problem is well documented in legal writings: both courts[70] and commentators,[71] for example, have often criticized lawyers for misunderstanding statistical evidence.

One troublesome example involves the use of faulty probabilistic evidence to establish a defendant's guilt or innocence in a criminal case. In *Collins*, for example, the court was not only concerned with the power of math to bewitch the jury.[72] It also criticized the prosecutor's misapplication of statistical principles that led to the production of erroneous and ultimately meaningless probabilistic evidence.

At trial, the defendant, Malcolm Collins, had been convicted of second-degree robbery based largely on probabilistic evidence. The prosecutor had proposed probabilities for the occurrence of each of six factors to establish an extremely high likelihood that Mr. Collins had assisted his wife Janet[73] in stealing a purse.[74] Based on these probabilities, the prosecutor argued that there was only 1 chance in 12 million that the defendant could be innocent.

In reviewing Mr. Collins's case on appeal, the California Supreme Court sharply criticized the prosecutor's misuse of statistics. Instead of being based on statistical (or, really, any) research, the probability factor for each of the characteristics was merely a guess.[75] Moreover,

70. *See, e.g.*, Branion v. Gramly, 855 F.2d 1256, 1263–66 (7th Cir. 1988) (claiming that "people must be sure of what they are looking for, and how they can prove it, before they start fooling with algebra" before asserting that the defendant's lawyers failed at the task of analyzing the probabilities and statistics); People v. Collins, 438 P.2d 33, 38–42 (Cal. 1968) (en banc) (finding that the prosecutor's use of probability statistics was improper since the testimony lacked foundation in statistical theory and evidence).

71. *See, e.g.*, Aaron Taggart & Wayne Blackmon, *Statistical Base and Background Rates: The Silent Issue Not Addressed in* Massachusetts v. EPA, 7 Law, Probability & Risk 275, 276 (2008) ("The ability to use statistical base rates is necessary for a competent argument and ruling in a vast number of cases, yet the problem is seemingly addressed without cognizance of the frequency with which the challenge arises."); Tribe, *supra* note 14, at 1334–38 (criticizing the use of statistical evidence in *Collins*).

72. *See supra* notes 19–21 and accompanying text (discussing the court's concern with the effect of statistical evidence on the jury).

73. Mrs. Collins did not appeal her conviction. *Collins*, 438 P.2d at 33. As a result, this analysis focuses only on the use of probabilistic evidence with respect to Mr. Collins.

74. The factors and probabilities asserted were: a partly yellow automobile ($1/10$), a man with a mustache ($1/4$), a girl with a ponytail ($1/10$), a girl with blond hair ($1/3$), an African-American man with a beard ($1/10$), and an interracial couple in a car ($1/1000$). *Id.* at 37 n.10.

75. In fact, the prosecutor even invited the jurors to substitute their own guesses for his. *Id.* at 38.

the prosecutor's treatment of the six factors as mutually independent—and thus properly multiplied together to find their collective probability[76]—was a "glaring defect" since it was clearly untrue. For example, the sets of girls with blond hair and of those with ponytails are obviously partly overlapping, as are the sets of African-American men with a beard and of men with a mustache.[77] To multiply the probabilities, as the prosecution had done, "inevitably yield[s] a wholly erroneous and exaggerated result even if all of the individual components had been determined with precision."[78] The court held that the prosecutor's misapplication of fundamental statistical principles constituted a miscarriage of justice and overturned Mr. Collins's conviction on that ground.

Despite the scathing critiques of the misuse of probabilistic evidence in *Collins*, this form of innumeracy has proven tenacious. Twenty years later, Judge Frank Easterbrook confronted the flipside of the *Collins* issue: whether proffered statistical evidence was sufficient to establish that a defendant's guilt was too *im*probable for conviction as a matter of law.[79] And again, the court held that counsel had misused statistical principles, rendering the resulting probabilistic evidence untrustworthy.

In the case before Judge Easterbrook, *Branion v. Gramly*, Dr. John Branion Jr. was appealing his conviction for the murder of his wife, Donna.[80] He had been convicted based on circumstantial

76. This is the "product rule" or "multiplication rule." *Id.* at 39 (citing Note, *Evidence: Admission of Mathematical Probability Statistics Held Erroneous for Want of Demonstration of Validity*, 1967 Duke L.J. 665, 669 n.25).

77. *Id.*

78. *Id.*

79. Branion v. Gramly, 855 F.2d 1256, 1261–64 (7th Cir. 1988). Similarly, at O.J. Simpson's trial for the murder of his ex-wife, law professor Alan Dershowitz testified that there was only a 0.04% chance that Mr. Simpson had killed his ex-wife. D. Kim Rossmo, *Failures in Criminal Investigations*, Police Chief, Oct. 2009, at 54, 62. But the statistics to which Professor Dershowitz testified were in fact only relevant as to the probability that Nicole Simpson would be killed by her ex-husband based solely on the evidence that he had battered her. *Id.* at 61–62. The more relevant statistic, which was not disclosed at trial, was that the likelihood that a battered woman's abuser was her killer once she was, in fact, killed, was almost 90%. *Id.* at 62. In whole numbers, this represents the difference between a 9-in-22,500 chance and a 9-in-10 chance.

80. *Branion*, 855 F.2d at 1258–59. Mrs. Branion had been strangled and shot at least four times in her apartment. There was no evidence she had been molested, that the apartment had been forcibly entered, or that anything had been stolen. She was found by her husband who, despite being a physician, did not assist her. The murder weapon was a rare type of gun that Dr. Branion, a gun collector, owned. When asked

evidence and appealed to the Seventh Circuit, claiming that it was impossible for him to have killed her because the murder simply took more time than he had available.[81] In support of this position, Dr. Branion's lawyers asserted that the probability that he could have committed the murder was less than 0.0001% based on individual probabilities of less than 0.01% for each of two timing factors: the drive time between the hospital at which Dr. Branion worked that day and the apartment where the murder occurred and the length of time it takes for bruises like those on Mrs. Branion's neck to form.[82]

The court acknowledged the importance of statistical evidence as a general matter, but objected to the specific use by the defendant's lawyers, finding that they had misunderstood how to produce a meaningful calculation of probabilities.[83] Indeed, as in *Collins*, the probabilities asserted by the defendant's lawyers were based on ungrounded or faulty assumptions with no actual data collection.[84] Moreover, the court expressed disbelief that the defendant's lawyers "simply multiplied two small numbers to get a smaller one, without

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to produce it by the police, though, Dr. Branion gave them a different gun; his gun that matched the description of the murder weapon was never produced. Four shell casings matching the type located in the couple's locked gun cabinet were found next to Mrs. Branion's body. Shortly after Mrs. Branion's murder, Dr. Branion married his mistress. In the words of the court, "The evidence was circumstantial, but what circumstances!" *Id.* at 1258. Indeed, the noteworthy circumstances were not limited to the facts of the murder: the judge at Dr. Branion's trial might have tried to solicit bribes in return for overturning the jury's verdict, the prosecutor engaged in ex parte communications with the judge, and, at the end of the trial, Dr. Branion fled to Africa, where he became Idi Amin's personal physician for several years prior to being returned to the United States upon regime change and appealing his conviction. *Id.* at 1258–59.

81. *Id.* at 1261–63.

82. *Id.* at 1263.

83. *Id.* at 1263–65. *Cf.* People v. Collins, 438 P.2d 33, 33 (Cal. 1968) (en banc) ("While we discern no inherent incompatibility between the disciplines of law and mathematics and intend no general disapproval or disparagement of the latter as an auxiliary in the fact-finding processes of the former, we cannot uphold the technique employed in the instant case.").

84. Moreover, the court noted that, even without these misconceptions, the defense attorneys simply miscalculated the probability that the drive time could have been as needed for Dr. Branion to have committed the murder. *Branion*, 855 F.2d at 1265. Instead of being a probability of 0.01% based on the assumption that it was three standard deviations from the mean, the court asserted that the probability was actually 0.1%. *Id.* In fact, a few more than 99.7% of all outcomes will fall within three standard deviations in a normal curve; so the actual probability is just under 0.15%.

describing why these were plausible numbers or why we ought to multiply them."[85] Ultimately the court found the lawyers' arguments unpersuasive because they lacked a sound statistical basis.

At issue in both *Collins* and *Branion* was a fundamental misunderstanding by attorneys about the principles of mathematical probability. Instead of collecting and analyzing data through the use of statistical tools, the lawyers invented data and multiplied the resulting figures to produce probabilities favorable to their legal positions. As a result, the numbers standing in for evidence in each case were unmoored from meaning. For the lawyers, though, the very mystique of the numbers provided sufficient evidence to paint a picture about the defendant's guilt or innocence. But such efforts do not involve a proper use of mathematics. As noted by the *Branion* court, the sound assessment of probabilities "can be a daunting task."[86] When lawyers fail to understand background mathematical principles, the task becomes impossible.

Not all lawyers are bad at math. And not all instances of "bad math" involve innumeracy. Often, however, the difficulty lawyers have with selecting, presenting, calculating, analyzing, and critiquing numbers *is* a product of innumeracy and bears consequences for our ability to fully represent our clients.

II. The Significance of Legal Innumeracy

Despite our often profound discomfort with numbers, for many lawyers numerical analysis is a part of the everyday practice of law. Mathematical data illuminating legal issues are pervasive; in fact, "[m]uch of the evidence we think of as most reliable is just a compendium of statistical inferences."[87] Thus, proof of causation in toxic torts litigation often relies on statistically based epidemiological proof,[88] and statistical evidence showing disparate hiring practices

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85. *Id.*

86. *Id.* at 1264.

87. *Id.*

88. United States v. Shonubi, 895 F. Supp. 460, 517 (E.D.N.Y. 1995) (citing Steve Gold, *Causation in Toxic Torts: Burdens of Proof, Standards of Persuasion, and Statistical Evidence*, 96 Yale L.J. 376, 377 (1986)), *vacated*, 103 F.3d 1085 (2d Cir. 1997); *see also* David L. Faigman et al., Science in the Law: Standards, Statistics and Research Issues § 7-1.1 (2002) (noting the importance of statistical evidence in mass tort litigation). Where such statistical evidence is absent, plaintiffs are often unsuccessful in obtaining relief, particularly in cases that do not involve a signature disease or in which the disease in question does not manifest itself immediately. *Shonubi*, 895 F. Supp. at 517 (citing Joseph Sanders, *From Science to Evidence: The Testimony on Causation in the Bendectin Cases*, 46 Stan. L. Rev. 1, 14–18 (1993)).

based on an applicant's race or sex is often critical to establishing employment discrimination.[89] Antitrust litigation includes evidence based on regression analysis,[90] and trial attorneys use the discounted value of lost future earnings to calculate damages in personal injury lawsuits.[91] Indeed, the formula chosen to calculate individual investors' gains and losses will determine the winners and losers of billions of dollars in cases such as that involving the misdeeds of Bernie Madoff.[92]

In other contexts, mathematical analysis plays a supporting role. Judge Learned Hand famously expressed the standard of care that defines negligence in tort law algebraically,[93] although at trial this analysis is at most a background defense to forestall juries from punishing defendants for the cold quantification of lives and pain the formula embodies.[94] More recently, courts have extended this formula

89. *See, e.g.*, Christine E. Webber, *A Plaintiff's Perspective on Some Evidentiary Issues and Jury Instructions in Employment Discrimination Litigation*, *in* EVIDENCE ISSUES AND JURY INSTRUCTIONS IN EMPLOYMENT CASES 169, 173–74 (ALI-ABA Course of Study 2007) (stating that "[s]tatistical evidence showing a pattern of conduct by an employer is considered evidence of pretext in an individual case," and explaining that "[c]ourts have often held that mere numerical evidence is insufficient to prove a *prima facie* case, and must be subjected to analysis including comparison to the available labor pool to be admitted"); *see also Shonubi*, 895 F. Supp. at 517) (noting the centrality of statistical evidence in employment discrimination cases).

90. *See* Daniel L. Rubinfeld, *Econometrics in the Courtroom*, 85 COLUM. L. REV. 1048, 1048 n.4 (1985) (providing examples of cases that discuss the use of regression analysis and statistical techniques in antitrust litigation).

91. *See* Tribe, *supra* note 14, at 1338 n.29 (listing cases focusing on calculations of the plaintiffs' expected lifetime earnings).

92. *See* Ken Belson & Alison Leigh Cowan, *Mets Owners Hope Courts Will Limit Liability*, N.Y. TIMES, Mar. 1, 2011, at B12 (describing the possible formulas for recovering and allocating invested funds).

93. United States v. Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947) ("Possibly it serves to bring this notion into relief to state it in algebraic terms: if the probability [of injury] be called P; the injury, L; and the burden [of preventing the injury], B; liability depends upon whether B is less than L multiplied by P: i.e., whether $B < PL$.").

94. *See, e.g.*, Raeder, *supra* note 1, at 1590 ("Who among us would not find it a true challenge to defend a corporation, in a case involving serious personal injury or death, by telling the jury that a cost-benefit analysis of the missing safety device demonstrated its economic infeasibility?"); *see also* Stephen G. Gilles, *On Determining Negligence: Hand Formula Balancing, the Reasonable Person Standard, and the Jury*, 54 VAND. L. REV. 813, 839 (2001) (noting that one limitation on the use of the Hand Formula is jurors' "tendencies to be swayed by sympathy for the victim, by hindsight, and by the pull of strict liability intuitions"); Michael D. Green, *Negligence = Economic Efficiency: Doubts >*, 75 TEX. L. REV. 1605, 1640–42 (1997) (discussing the aftermath of

to help decide issues as disparate as whether governmental action was reckless, whether there was probable cause for a warrantless search, and whether there was sufficient evidence to allow a preliminary injunction.[95] Probabilistic proof based on genetic markers is prevalent, but not alone determinative, in paternity litigation and many criminal prosecutions.[96]

Outside of the courtroom, some legal practices are explicitly predicated on numerical analysis. Estate planning attorneys calculate intestate and elective shares.[97] Environmental regulators rely on statistically based risk assessments in defining acceptable levels of pollutants,[98] as do drug regulators evaluating permissible side effects of new medications.[99] Family law attorneys calculate child support and assist in the division of property between divorcing spouses,[100] always with an eye to statutory formulas and the tax consequences of the arrangements they negotiate. Transactional attorneys draft

Grimshaw v. Ford Motor Co., 174 Cal. Rptr. 348 (Ct. App. 1981), in which Ford was publicly castigated for a report, unused at trial, that showed that the cost of design changes to prevent 180 burn deaths was not economically sensible, and stating that because of such sensibilities, trial lawyers cannot practically, and do not, defend negligence suits by pointing to the economic rationality of not preventing the harm in question).

95. Barbara Ann White, *Risk-Utility Analysis and the Learned Hand Formula: A Hand that Helps or a Hand that Hides?*, 32 Ariz. L. Rev. 77, 79 (1990). *But see* Richard W. Wright, *Hand, Posner, and the Myth of the "Hand Formula"*, 4 Theoretical Inquiries L. 1, 4 (2003) (stating that the Hand formula is "infrequently mentioned by the courts, almost never included in jury instructions, rarely actually employed in judicial opinions, and almost never explains the actual results reached by the courts").

96. *See, e.g.*, Branion v. Gramly, 855 F.2d 1256, 1263–66 (7th Cir. 1988) (critiquing the use of probabilistic evidence in a criminal trial); William C. Thompson & Rachel Dioso-Villa, *Turning a Blind Eye to Misleading Scientific Testimony: Failure of Procedural Safeguards in a Capital Case*, 18 Alb. L.J. Sci. & Tech. 151, 155–69 (2008) (same).

97. *See supra* notes 39–49 and accompanying text (discussing the calculation of the value of an interest in an FLP for estate planning purposes).

98. *See* Faigman, *supra* note 88, § 8-1.1 (discussing the use of hazard identification, dose-response estimation, exposure assessment, and risk characterization for environmental hazards).

99. *See id.* ("Toxicological evidence plays a central role in the regulation of drugs . . . .").

100. *See, e.g.*, Wall St. J., *supra* note 54 (discussing New York's formula for temporary spousal support); *supra* notes 54–68 and accompanying text (analyzing the dominant formula for dividing the equity in hybrid-property homes on divorce).

antidilution formulas and calculate stock exchange ratios.[101] The valuation of intellectual property is one of the higher-stakes and ofttimes more contentious issues in many mergers and acquisitions.[102] And the list could go on.[103]

Moreover, the importance of numerical understanding in the law is growing. Oliver Wendell Holmes declared more than 100 years ago that "[f]or the rational study of law the black-letter man may be the man of the present, but the man of the future is the man of statistics and the master of economics."[104] Time has proven Justice Holmes prescient. In the 1960s there were fewer than 600 federal district court opinions that included the terms "statistic," "statistics," or "statistical."[105] In striking contrast, by the 1990s there were nearly ten times as many such opinions,[106] and this count more than tripled again in the last ten years,

101. *See* Michael A. Woronoff, *Teaching Numeracy*, 12 TRANSACTIONS: TENN. J. BUS. L. (SPECIAL REPORT) 243, 253 (2011) (including a nonexhaustive list of fourteen tasks commonly performed by transactional lawyers that require numeracy).

102. *See* Ted Hagelin, *Valuation of Intellectual Property Assets: An Overview*, 52 SYRACUSE L. REV. 1133, 1133–40 (2002) (reviewing the three basic valuation methods, discussing the valuation methods developed for intellectual property, and presenting a new valuation method); *see also* Charles R. McManis, *Intellectual Property and International Mergers and Acquisitions*, 66 U. CIN. L. REV. 1283, 1309–14 (1998) (explaining the net present value approach to intellectual property valuation).

103. And it does. For additional examples, see FAIGMAN, *supra* note 88, §§ 5-1.1 to -1.3 (describing the use of statistical assessments in antitrust, voting rights, employment discrimination, psychological tests, and DNA fingerprinting); Meyerson & Meyerson, *supra* note 17, at 772 ("Statistics are regularly used to prove or disprove issues as diverse as causation of injuries in toxic torts cases, breach of contracts, discrimination in employment and voting, DNA identification in criminal and family law, trademark and patent violations, environmental harm, securities fraud, and loss of future earnings."); Tribe, *supra* note 14, at 1338 (noting that use of mathematical techniques at trial is required where "the governing substantive law makes a controversy turn on such questions as percentage of market control, expected lifetime earnings, likelihood of widespread public confusion, or the randomness of a jury selection process" (footnotes omitted)).

104. O.W. Holmes, *The Path of the Law*, 10 HARV. L. REV. 457, 469 (1897).

105. A Westlaw search shows 596 federal district court cases mentioning at least one of these terms from January 1, 1960 through December 31, 1969.

106. A similar search returns 5,937 hits for January 1, 1990 through December 31, 1999. This approach was suggested by the court in *United States v. Shonubi*, 895 F. Supp. 460, 514 (E.D.N.Y. 1995), which found around half as many cases using a LEXIS search through July 31, 1995. *Cf.* Rubinfeld, *supra* note 90, at 1048 (discussing the increasing importance of econometrics in litigation).

with almost 19,000 such opinions issued.[107] While these numbers offer only a crude measure of the increasing importance of numerical analysis in litigation, they point to the significance to the legal profession of understanding and appropriately referencing numerical concepts, at least in federal cases. Indeed, the even more recent explosion of technological innovations, such as smart phones, tablet computers, and cloud computing further increases the significance of numerical confidence and competence in the law. Locating, understanding, and analyzing the associated metadata produced in electronic discovery requires experts—legal and otherwise—who are comfortable with information technology and statistical calculations to make sense of the resulting deluge of data.

While the extent to which numerical understanding is important in the practice of law has increased in recent years, innumeracy in the law is not itself a new problem. Self-deprecating references and jokes about lawyers' incompetence with math have been around for generations, as have well-documented manifestations of innumeracy: *Collins* was decided in 1968;[108] Professor Tribe critiqued the use of probabilistic proof in criminal cases in 1971;[109] *Brandenburg* was decided in 1981;[110] and *Branion* is from almost a quarter century ago.[111] Despite its acknowledged difficulties with numbers, the legal profession has flourished. Ultimately, does it matter if lawyers are bad at math?

Many mathematical errors that lawyers make are corrected before they do harm. In *Estate of Kelley*, the court noted that the taxpayer's counsel incorrectly discounted the value of the FLP's assets in determining the tax due on the transfer of its interests but the court correctly combined the discounts it determined in its own calculations.[112] The California Supreme Court reversed Mr. Collins's

107. A search of the period January 1, 2002 through December 31, 2011 returns 18,988 cases.

108. People v. Collins, 438 P.2d 33 (Cal. 1968) (en banc) (overturning the defendant's conviction because of the misuse of probabilistic evidence); *see also supra* notes 18–20, 72–78 and accompanying text (discussing *Collins*).

109. *See* Tribe, *supra* note 14, at 1358–77 (detailing the costs of using probabilistic proof in the fact-finding process of a legal trial).

110. Brandenburg v. Brandenburg, 617 S.W.2d 871, 872 (Ky. Ct. App. 1981) (setting forth the current formula for the division of equity in hybrid-property homes); *see also supra* notes 54–68 and accompanying text (discussing *Brandenburg*).

111. Branion v. Gramly, 855 F.2d 1256, 1263–66 (7th Cir. 1988) (rejecting the defendant's appeal that relied on faulty probabilistic evidence); *see also supra* notes 79–87 and accompanying text (discussing *Branion*).

112. Estate of Kelley *ex rel.* Louden v. Comm'r, 90 T.C.M. (CCH) 369 (2005); *see supra* note 52 (explaining the error in *Kelley*).

conviction despite his own counsel's inability to show why the probabilistic evidence offered at trial was problematic.[113] The Seventh Circuit deftly waded through the probabilistic evidence with which Dr. Branion's counsel presented it, rejecting the argument that statistics compelled the jury to acquit.[114] In each case, the mathematical errors of attorneys were discovered and corrected by more numerate courts.

In other instances, the cost of the error is so low that innumeracy may prove to be an efficient outcome. For example, while the dominant formula for dividing the equity in hybrid-property homes upon divorce produces an invisible and systemic transfer of wealth between the separate and marital estates, in any given divorce the total sum in question may be relatively low—thousands of dollars, at most—and there are costs to a more accurate division: time invested, information required, and expert assistance procured.[115] The total cost of preventing the errors by addressing the innumeracy of lawyers may be higher than the total cost of allowing them.

Even so, efficiency concerns clearly do not explain or justify many instances of innumeracy in the law. A less numerate court than the Seventh Circuit might well have accepted Dr. Branion's probabilistic proof and released him despite the jury verdict of guilty. Malcolm Collins's conviction was overturned but that of his wife was not,[116] even though both convictions were based on the same probabilistic evidence.

Mathematical errors, moreover, can prove extremely costly. Many FLPs have net asset values in the tens—or even hundreds—of millions of dollars.[117] Miscalculating the value of an interest by even a few percentage points can change a taxpayer's liability by millions of dollars.[118] While these sorts of errors would generally be resolved on audit if caught by the Internal Revenue Service, in cases where it

113. *Collins*, 438 P.2d at 41–42; *see supra* notes 72–86 and accompanying text.

114. *Branion*, 855 F.2d at 1263–66; *see supra* notes 79–86 and accompanying text.

115. *See supra* notes 55–66 and accompanying text.

116. *Collins*, 438 P.2d at 33.

117. *See, e.g.*, Estate of Schutt *ex rel.* Schutt v. Comm'r, 89 T.C.M. (CCH) 1353, 1362 (2005) (valuing the FLPs in question at a combined total of \$93,778,121); Estate of Bongard *ex rel.* Bernards v. Comm'r, 124 T.C. 95, 132 (2005) (underlying value of FLP assets was \$158,259,261); Estate of Strangi *ex rel.* Gulig v. Comm'r, 85 T.C.M. (CCH) 1331, 1335 (2003) ("The total value of the property held by [the FLP] as of the date of death was \$11,100,922 . . . .").

118. As of 2013, the maximum gift and estate tax rate is 40% and applies to assets over \$5,250,000 that a taxpayer gratuitously transfers in a taxable transaction. American Taxpayer Relief Act of 2012, Pub. L. No. 112-240, § 101, 126 Stat. 2313 (2013).

results in the overvaluation of a taxpayer's interest in an FLP—and thus an *over*payment of transfer tax—that is unlikely to occur.[119] In addition, audit itself bears financial (and often psychological) costs for clients. Even when the ultimate tax burden is reduced, in some instances the client's overall bill is increased due to additional accounting and attorneys' fees, and for many clients the stress of an audit itself is a cost not to be assumed lightly.[120] Finally, in many instances the transfer of FLP interests is designed to exactly equal the amount a taxpayer may transfer each year without being subject to gift tax.[121] Where the value of an FLP interest that is the subject of such a gift is initially understated, the later correction on audit may cause the value of the gift to exceed this annual limit. Thus, the excess value is subject to gift tax despite the taxpayer's effort to limit the size of the gift to one without tax consequence.

There is a broader point, too. Innumeracy in the law matters even when specific miscalculations, oversimplifications, and misunderstandings are later corrected. Too often our discomfort with numbers means that we fail to challenge, or even recognize, the subjective assessments made in the compilation and presentation of numerical information. Additionally, numeracy involves more than the ability to perform mechanical calculations: it is a way of thinking with a distinct language. As a result, innumeracy limits more than just our ability to work with numbers; it limits our ability to think about legal issues involving numbers. Even where we do have doubts about the accuracy or objectiveness of numerical information, lawyers often lack the ability to effectively think through or express these doubts because of a discomfort and unfamiliarity with the language of numbers. Thus, we are less likely to self-correct our errors or identify underlying inconsistencies than if we had a greater degree of facility with numbers. Finally, and most intangibly, it may be that, especially in a world so focused on science and technology, innumeracy simply matters by concealing the inner workings of the law in a troubling way,

119. In addition, it places the burden on the government to monitor and catch math errors by attorneys. At a time when funding for the IRS is subject to repeated cuts, limiting its ability to conduct audits, such miscalculations contribute to the difference between what taxpayers owe in taxes and what they pay each year. *See The Tax Gap*, Internal Revenue Serv. (Jan. 7, 2013), http://www.irs.gov/uac/The-Tax-Gap (explaining "tax gap" calculations).

120. Similarly, even Mr. Collins's acquittal was far from costless to both him and the state, as it consumed substantial amounts of time, money, and emotional energy.

121. Known as the "annual exclusion amount," it is currently equal to $14,000. *See* I.R.C. § 2503(b) (2006); Rev. Proc. 2012-41, 2012-45 I.R.B. 539, 541 (setting forth the inflation adjustment for 2013). For a discussion of annual gifting techniques for FLP interests, see generally Repetti, *supra* note 40.

undermining the legitimacy of the resulting legal rules and outcomes. Below, I examine each of these ways that innumeracy limits our understanding of legal issues.

A. Overvaluing Numerical Information

Lawyers who are not comfortable working with numbers oftentimes overvalue them. Instead of thinking critically about numbers, we mistake their preciseness and concreteness for accuracy and objectivity,[122] and we leave unquestioned the underlying assumptions on which data collection is based and calculations are made. By overvaluing numerical information, lawyers treat calculations as a black box—to be accepted and looked at from the outside, but not opened for the inner workings to be understood and appropriately challenged. The result is that innumeracy separates numbers from their underlying meanings.

A further aspect of *Collins* provides a classic example of this sort of overvaluation. While not the focus of its opinion, as a tertiary issue the court worried that Mr. Collins's defense counsel was unable to effectively defend his client from the prosecutor's "engaging but logically irrelevant expert demonstration" because of his lack of statistical training.[123] Not only did mathematics bewitch the *jury*, but it also enchanted the *lawyers*.[124] Without the skills needed to look behind the probabilities and statistical analysis put forward by the prosecutor, Mr. Collins's lawyer was unable even to begin to rebut the prosecution's case. As a result, Mr. Collins was convicted despite the lack of any data or statistical analysis underlying the probabilistic evidence presented.

One consequence of this overvaluation is that lawyers fail to question or even recognize the existence of the subjective judgments that underlie numerical information. Michael Meyerson and William Meyerson have focused attention on the problem with respect to judges:

> Too many judges . . . fail to see that the meaning to be given to mathematical results is frequently not a matter of scientific necessity, but a reflection of specific value judgments. By ignoring those judgments that are inherent in the mathematical

122. Historian Patricia Cline Cohen noted a similar concern outside the legal arena: "Well into the nineteenth century, the novelty of numbers, and especially their concreteness, conferred such reality on quantitative data that few people were moved to examine the process by which they had been generated. The specificity of numbers was mistaken for accuracy and exactitude." Patricia Cline Cohen, A Calculating People: The Spread of Numeracy in Early America 211 (1982).

123. People v. Collins, 438 P.2d 33, 38 (Cal. 1968) (en banc).

124. Presumably, even the prosecutor did not understand the failings of the probabilistic evidence he proffered or he would not have introduced it into evidence.

> choices, judges have acquiesced to values that are at odds with our system of justice.[125]

For the Meyersons, this blind acquiescence results in mathematical rather than judicial policy making[126]: he who controls the numbers, controls the policies. In similar fashion, when lawyers overvalue math, they fail to see the subjective perspectives informing the compilation, calculation, and presentation of numerical information. Instead, they rely on opposing counsel or experts to explain reality through a lens of their own self-interested making.

The phenomenon of overvaluation may help explain the wide acceptance of the now-dominant formula for valuing the respective interests in a hybrid-property home on divorce.[127] On its face, the formula seems to make sense: simply compute the dollar value of the respective contributions to the home's value and divide any appreciation based on the resulting ratio. Yet on closer analysis it is clear that it in fact does not make economic sense. It may be that the very mathematical formulation of the approach—$nmc/tc \times e =$ nonmarital property[128]—has created a visceral impression of its sophistication (and thus its correctness) and dissuaded serious analysis.

Numbers and statistics do not speak for themselves; they require interpretation to have meaning.[129] When lawyers are taken in by a facade of objectivity, they overvalue the numerical interpretations of others. We need mathematical competence and confidence to understand the difference between math that *looks* good and math that *is* good to effectively represent our clients.

B. *Failing to Speak the Language of Numbers*

Numeracy also matters to our ability to even think about numerical information. Because mathematics has its own language and is a distinct system of thought,[130] lawyers must be comfortable with its vocabulary and syntax in order to be able to formulate and express criticisms of numerical data. Numerical fluency allows for argument and analysis rather than rhetoric and suppositions.[131]

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125. Meyerson & Meyerson, *supra* note 17, at 776; *see also supra* note 54 (listing the Meyersons' areas of research).

126. *See* Meyerson & Meyerson, *supra* note 17, at 845.

127. *See supra* notes 55–66 and accompanying text.

128. *See supra* notes 55–66 and accompanying text (explaining the formula).

129. Paulos, *supra* note 32, at xiv.

130. *Cf. id.* at xiii ("[M]athematics [is] a way of thinking and a set of intricately connected higher-level skills . . . .").

131. In reference to the current debates over Medicare, Professor David Hyman has stated only somewhat facetiously that "our efforts at

Without understanding the language of math, lawyers will find themselves confused and ineffective in the face of numerical data. For example, while Mr. Collins's defense counsel objected to the probabilistic evidence the prosecution presented,[132] he lacked the ability to articulate *why* the testimony was problematic. As a result, his objections were overruled and Mr. Collins was convicted based on faulty inferences posing as numerical facts.

Even with time for reflection, Mr. Collins's counsel did little better on appeal.[133] Although he rightly pointed to the high likelihood of interdependence among the factors provided by the prosecutor,[134] his "speculation about the nature of that interdependence was too goofy" to include in the court's opinion[135]: while he attempted to peer into the shadows to see what stood behind the government's numbers, he was unable to do so without the language of math.[136] Instead, the court provided its own articulation of the prosecution's failings in the absence of coherent guidance from the defense in overturning the conviction.[137] The point is that a key limitation imposed by innumeracy is a linguistic one: without a solid grounding in mathematics, lawyers are unable to articulate criticisms of numerical information, even when they perceive that it has weaknesses.

C. Legitimacy, Meaning, and the Practice of Law

Both the overvaluation of numerical information and the failure to speak the language of numbers hamper the efforts of lawyers to represent their clients well. While some errors based in innumeracy

destroying public education in the United States . . . ha[ve] rendered a large chunk of the population functionally innumerate. The impassioned defenses of Medicare offered by most health policy analysts will accordingly be resolved at the level of rhetoric, instead of through simple addition and subtraction." David A. Hyman, *Medicare Meets Mephistopheles*, 60 Wash. & Lee L. Rev. 1165, 1200 (2003) (footnotes omitted).

132. *See supra* notes 83–85 and accompanying text.

133. Mr. Collins had different counsel on appeal than at trial. Fisher, *supra* note 19, at 72–73. Neither lawyer, though, was able to effectively identify and explain the mathematical shortfalls in the prosecution's case. *Id.*

134. *See supra* text accompanying note 78.

135. Fisher, *supra* note 19, at 73.

136. Similarly, commentators have asserted that the inconsistent language concerning statistical concepts such as background rates and confounding variables used by courts in deciding environmental disputes has contributed to a lack of unity in the law. Taggart & Blackmon, *supra* note 71, at 299.

137. *See* Fisher, *supra* note 19, at 72–73 (noting that the court relied heavily on the work of a law clerk with a mathematics background).

are corrected, are efficient, or prove of little significance, others pose grave threats to a client's economic well-being, freedom, or life. And numeracy matters for other, less-tangible reasons as well.

The practice of law—from e-mail communication to word processing to e-discovery—rests on a base of numbers, math, and science. Many practice areas, such as those that involve patent prosecution, drafting licensing agreements, performing due diligence for high-tech start-up companies, and litigating temporary restraining orders against competitors infringing on intellectual property rights, are rooted in technology. That innumeracy is accepted, and even celebrated, in the legal profession means that many lawyers cannot contribute their voices and critical thinking abilities to some of the many interesting and novel legal questions their clients routinely face. As a result, the practice of law is less client-oriented, and less vibrant, than it could be.

In addition, progress in some fields is hampered as lawyers and lawmakers repeatedly engage in low-level thinking, never getting to higher levels of analysis when decisive questions are numerically based. Wayne Blackmon and Aaron Taggart argue that the law's discomfort with mathematical terms means that the evidentiary wheel is repeatedly reinvented with respect to statistical base rates in environmental policy disputes, with each case being decided on its own facts.[138] Disappointed in the lack of coherence in the case law, they opine that "[m]any great legal questions involving math and science get superficial or inappropriate treatment" because of lawyers' lack of mathematical confidence.[139]

Ultimately, to the extent innumeracy prevails in the law, legal decisions are less than fully comprehensible and transparent. Even laypersons who are not highly numerate may feel put off when legal formulas and results are not numerically sound. Like commentators troubled by the *Brandenburg* formula or Mr. Collins's counsel recognizing that the probabilities entered into evidence were flawed but in each case being unable to articulate *why*, some individuals intuitively recognize the existence of numerical sleights of hand with the result that innumeracy undermines the legitimacy of our legal system.

Without an understanding of what numbers do and do not mean, numerical information is at best meaningless, and at worst harmful: tax liabilities are miscalculated,[140] wealth is shifted unintentionally and invisibly between parties,[141] costly disputes are prolonged,[142] and

138. Taggart & Blackmon, *supra* note 71, at 276.

139. *Id.* at 275.

140. *See supra* notes 39–53 and accompanying text.

141. *See supra* notes 54–68 and accompanying text.

142. *See supra* note 138.

defendants are erroneously convicted,[143] all with the result that the legitimacy of our legal system is lessened. As one court has noted, "people must be sure of what they are looking for, and how they can prove it, before they start fooling with algebra."[144] Even when done well, the selection, presentation, and calculation of numbers conveys and obscures meanings and values.[145] Lawyers must have the numerical competence and confidence to understand and challenge the assumptions and perspectives hiding in the shadows behind such mathematical data.

III. Defining the Problem: Competence or Confidence?

Given the pervasiveness and significance of numbers to the practice of law, why are so many lawyers innumerate? Is it a lack of competence, produced either by cognitive disability or by a persistent failure to engage with numbers and calculations so that they never learn the skills necessary for numeracy? Or is it, instead, a lack of confidence—a reflection of the fact that many lawyers excelled at reading and writing, and so, by comparison, grew to believe they were bad at math? While the fact of innumeracy in lawyers is well accepted, the reasons remain unexplored. Understanding the basis of innumeracy is the first step to overcoming it.

A. Objective Innumeracy

Objective innumeracy is characterized by a lack of numerical competence.[146] It may be evidence of an underlying cognitive disability or the result of a lack of numeric education. Regardless of which of these shortcomings causes the issue, an individual who is objectively innumerate does not possess the tools necessary for thinking about and calculating numbers.

1. Deficits in Cognitive Functioning

One biological cause of objective innumeracy is developmental dyscalculia.[147] The mathematical equivalent of dyslexia,

143. *See supra* notes 72–86 and accompanying text.

144. Branion v. Gramly, 855 F.2d 1256, 1264 (7th Cir. 1988).

145. *Cf.* Meyerson & Meyerson, *supra* note 17 (criticizing the racism and sexism embodied in statistical tables and commonly reflected in damages awards).

146. *See* Wendy Nelson et al., *Clinical Implications of Numeracy: Theory and Practice*, 35 Annals Behav. Med. 261, 264 (2008) (distinguishing between objective and subjective innumeracy).

147. Dyscalculia can also be caused by traumatic brain injury, but that form is not the focus of this discussion. *See* David C. Geary, *Mathematical Disabilities: Cognitive, Neuropsychological, and Genetic Components*, 114 Psychol. Bull. 345, 345 (1993) (distinguishing

developmental dyscalculia is marked by structural abnormalities in the part of the brain that performs mathematical calculations and is thought to be heritable.[148] It exists in 5–7% of the population and is, at times, paired with other developmental disorders such as dyslexia and attention-deficit hyperactivity disorder.[149] It is not, though, associated with low intelligence or low academic achievement generally.[150]

For individuals with dyscalculia, numbers lack meaning. The size and relative value of numbers are not readily apparent, making it difficult for a dyscalculic individual to manipulate numbers or think about the relationship between them.[151] Common indicators of dyscalculia include the need to count (sometimes on fingers) to compare or add numbers, as well as difficulty in making numerical estimates.[152] For example, a dyscalculic individual might estimate the height of a normal room as two hundred feet, or, to determine which of two playing cards is greater, he might count all of the symbols on each card.[153]

Relatively little research has been done on the causes and consequences of developmental dyscalculia,[154] an omission that is par-

acquired and developmental dyscalculia). Other biological bases for objective innumeracy may be attention-deficit disorders and anxiety disorders. In either case, it is not clear whether the often-associated difficulties with math are a product of the disorder or a second cognitive deficit. *See* Anna J. Wilson, *Dyscalculia Primer and Resource Guide*, Org. for Econ. Co-operation & Dev., http://www.oecd.org/edu/ceri/dyscalculiaprimerandresourceguide.htm (last visited Feb. 13, 2013).

148. *See generally* Brian Butterworth et al., *Dyscalculia: From Brain to Education*, 332 Science 1049 (2011) (describing the neurology and effects of dyscalculia and proposing research into interventions for it).

149. *Id.* at 1049. *But see* Wilson, *supra* note 147 (citing research showing a prevalence of 3–6%).

150. *See* Butterworth et al., *supra* note 148, at 1049 ("The disability can be highly selective, affecting learners with normal intelligence and normal working memory . . . ."); *see also* Nelson et al., *supra* note 146, at 261 ("Low numeracy cannot be reliably inferred on the basis of patients' education, intelligence, or other observable characteristics."); Wilson, *supra* note 147 (noting that all definitions of dyscalculia recognize some degree of specificity to the disability rather than being associated with universal academic difficulties).

151. Butterworth et al., *supra* note 148, at 1050.

152. *Id.* at 1049.

153. *Id.*

154. *See id.* (observing that between 2000 and 2011 the National Institutes of Health spent $107.2 million on dyslexia research and only $2.3 million on dyscalculia research); Geary, *supra* note 147, at 358 (noting that "relatively little is known about mathematical learning disorders");

ticularly striking in light of the attention that scientists, educators, and policy makers have given to dyslexia and other reading disabilities. Moreover, due to this lack of research, little is known about the populations in which it is most prevalent.[155] One important area for future research is the prevalence of developmental dyscalculia among lawyers.

Because of the widespread perception that lawyers are not—and need not be—good at math, it seems likely that dyscalculic individuals are overrepresented in the law when compared to professionals in fields explicitly requiring numerical analysis, like medicine, business, accounting, science, engineering, and graduate-level social sciences. High-achieving dyscalculic individuals, especially those for whom the disability is not paired with dyslexia or another reading disability, might seek out legal careers to capitalize on their strengths in the belief that their lack of numeracy will not impair them professionally. If in fact dyscalculic individuals are overrepresented, or even just normally represented, among lawyers, specific interventions, such as identifying legal fields in which numerical competence is of reduced importance and consciously pairing highly numerate and dyscalculic individuals on law school assignments and in practice, might well be implemented.

2. Deficits in Mathematics Education

Not all cases of innumeracy reflect a cognitive disability. Instead, some individuals simply do not have the education needed for mathematical competence. It is not that they cannot do math, but rather that they have not learned to do it. Underlying this form of innumeracy may be deficient math instruction[156] or a simple lack of personal motivation with respect to learning the subject.[157]

Most law students do not come to law school with strong math backgrounds. In fact, fewer than 10% of law school students have more than an insignificant amount of undergraduate training in math, science, or engineering.[158] Prior training in statistics is also unusual.[159]

Wilson, *supra* note 147 (describing dyscalculia research as "just in its infancy").

155. *See* Butterworth et al., *supra* note 148, at 1053 (noting that dyscalculia is not widely recognized by educators and that recognition is vital for subsequent improvement).

156. Researchers have suggested that one issue may be the emphasis on the mechanics of math in school without a corresponding emphasis on understanding how to apply those mechanics. *See* Stanislas Dehaene, The Number Sense: How the Mind Creates Mathematics 141 (1997).

157. *Cf.* Lauren E. Willis, *Against Financial-Literacy Education*, 94 Iowa L. Rev. 197, 202 (2008) ("People are financially illiterate not because they are stupid, but because they have better things to do with their time.").

158. *See* Mark Graham & Bryan Adamson, *Law Students' Undergraduate Major: Implications for Law School Academic Support Programs*

In writing about the relationship between science and legal decision making, David Faigman noted that "law students, as a group, seem particularly averse to math and science. . . . Students who display a talent in math and science typically pursue careers in medicine, engineering, biology, chemistry, computer science, and similar subjects. Students with less inclination toward quantitative analysis very often go to law school."[160] In short, many law students lack a solid math background.

Once in law school, this deficit is not corrected. Most law schools include few, if any, explicitly numerically focused classes in their curricula.[161] When offered, these classes are often considered necessary only for the practice of corporate law or tax law; few students not already planning to enter one of these fields opt into these courses.[162] This is a unique feature of legal education. Unlike other graduate-level programs such as those in the natural and social sciences, successful completion of law school generally does not require even a basic level of competence in statistics, quantitative methods, or mathematics.[163] By contrast, medical school students are expected to learn the basics

(ASPs), 69 UMKC L. REV. 533, 549 (2001) (finding that only 9 out of 102 law students had this background); Peter Lee, *Patent Law and the Two Cultures*, 120 YALE L.J. 2 (2010) (less than 10% of law students have degrees in these areas); *see also* Daniel Keating, *Ten Myths About Law School Grading*, 76 WASH. U. L.Q. 171, 171 (1998) (postulating that law students' misunderstanding of law school grading is based in part on the fact that "most law students had non-mathematical majors in college"); Woronoff, *supra* note 101, at 252 ("Often [law students] majored in undergraduate subjects in which they never had to use sophisticated mathematical concepts.").

159. *See* Steven B. Dow, *There's Madness in the Method: A Commentary on Law, Statistics, and the Nature of Legal Education*, 57 OKLA. L. REV. 579, 595 (2004) (noting that an earlier prediction that lawyers would become skilled in statistics was "largely wrong").

160. FAIGMAN, *supra* note 88, at v.

161. For example, of 24 law schools surveyed, almost half offered no numerically focused classes and one-third offered only one such class. Of course, a law student may be permitted to take classes in other departments, and classes not obviously numerically focused may include significant numerical analysis or calculation (and even those seemingly more mathematical might avoid calculations), but the point is that most law schools prioritize neither math teaching nor numerical analysis in their curricula. *See infra* Appendix (listing the schools surveyed and the numerically focused classes offered).

162. *See, e.g.*, Woronoff, *supra* note 101, at 252 ("[M]any people who go to law school do not want to learn material that requires understanding complex mathematical concepts. I'm not saying everyone, but I do think a large portion of law students have no desire to take courses that require proficiency with numerical ideas." (footnote omitted)).

163. Dow, *supra* note 159, at 579.

of statistics, read research articles replete with statistical analysis, and relate that research to medical problems they encounter.[164] One study that examined the effect of graduate training on students' reasoning ability found that, while medical and psychology programs improved students' statistical-methodological reasoning abilities to a significant degree, law programs failed to do so.[165]

Law professors often share the numerical discomfort of their students.[166] Even when numbers and calculations are not edited out of the cases in casebooks, in many instances law professors gloss over them, instead giving preference to discussions of theories, arguments, holdings, and procedure. The implicit message to students is that math has little, if any, bearing on the practice of law. The content and context of legal education are such that any numerical skills that students may possess upon entering law school may well be dulled through three years of disuse.

While tests for cognitive disabilities that result in innumeracy exist,[167] this subject remains relatively unexplored as a general matter. And, as for lawyers, the problem of objective innumeracy is completely unexamined. Whether a product of an underlying biological condition like dyscalculia or a lack of mathematics education, objective innumeracy limits a lawyer's effectiveness in representing clients. At the least, it requires some lawyers to rely entirely on more numerate individuals whose interests may not be aligned with a client's interests for the calculations and assessments needed for the practice of law.

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164. *See* Darrin R. Lehman et al., *The Effects of Graduate Training on Reasoning: Formal Discipline and Thinking About Everyday-Life Events*, 43 Am. Psychologist 431, 440 (1988) (examining the medical curriculum at the University of Michigan). Even here, though, some commentators have criticized doctors' ability to understand and communicate medical risk based on probabilistic data. *See, e.g.*, Kuklin, *supra* note 15, at 527.

165. Lehman et al., *supra* note 164, at 440. Statistical reasoning is the ability to reason using statistical ideas, often involving ideas about data, chance, and risk, while methodological reasoning involves understanding causal relationships and the role of confounding variables in the scientific process. *Id.* at 434. Law programs are not alone in this shortcoming, though. Graduate chemistry students similarly showed no improvement in these types of reasoning. *Id.*

166. *See, e.g.*, Keating, *supra* note 158, at 171 (opining that law professors lack both math skills and an interest in math); Meyerson & Meyerson, *supra* note 17, at 772 (same).

167. *See generally* Lipkus et al., *supra* note 4 (developing a test to assess basic arithmetic and statistical skills); Lisa M. Schwartz et al., *The Role of Numeracy in Understanding the Benefit of Screening Mammography*, 127 Annals Internal Med. 966 (1997) (setting forth a simple three-question test of objective numeracy).

B. Subjective Innumeracy

As with objective innumeracy, subjective innumeracy—that is, a lack of confidence in working with numbers—is not limited to individuals with low intelligence. Instead, it occurs with equal frequency across the intelligence spectrum and is present even among highly educated individuals.[168] This lack of confidence may have an underlying biological cause such as math anxiety, which causes an objectively numerate individual to experience tension or fear when faced with mathematical tasks.[169] In other individuals, subjective innumeracy may result from feelings of inadequacy with respect to math in relation to other cognitive tasks. In other words, an individual with a high degree of competence in reading and writing might simply feel inadequate in his mathematical ability by comparison, even though in an objective sense the person possesses good math skills. The important point is that each cause of subjective innumeracy in lawyers—whether math anxiety or relative incompetence—requires much closer attention than it has received in the past. In the remainder of this Part III, I offer some preliminary thoughts on these long-overlooked difficulties that many lawyers face.

1. Math Anxiety

Math anxiety is a biological condition in which feelings of discomfort, nervousness, or fear interfere with an individual's ability to perform tasks requiring mathematical ability.[170] Someone with math anxiety may avoid learning or practicing numerical analyses in order to avoid the associated feelings of panic, leading to objective innumeracy.[171] Alternatively, math anxiety may cause otherwise math-competent individuals to lose confidence in their math ability, associating the biological markers of anxiety with a lack of actual ability when confronted with problems as basic as $46 + 18 = ?$ and $34 - 19 = ?$.[172] Not surprisingly, mental arithmetic causes substantially more anxiety than that done on paper.[173] Working with mixed-fraction

168. Lipkus et al., *supra* note 4, at 37.

169. *See* Wilson, *supra* note 147 ("'Math anxiety' is the name given to the feeling of tension and fear that some children and adults experience, and which is often specifically associated with mathematical activity." (citation omitted)).

170. Mark H. Ashcraft, *Math Anxiety: Personal, Educational, and Cognitive Consequences*, 11 Current Directions Psychol. Sci. 181, 181 (2002).

171. *See id.* (summarizing research showing that highly math anxious individuals "take fewer elective math courses, both in high school and in college, than people with low math anxiety").

172. *Id.*

173. *Id.* at 182.

problems,[174] percentages, basic algebra, and factoring, as compared with doing arithmetic involving whole numbers, also heightens unease.[175] Of particular concern to lawyers, individuals with a high degree of math anxiety often speed through the most difficult tasks in order to minimize the time they spend on anxiety-provoking work, with a correspondingly high increase in errors.[176]

Achievement tests bear out the fact that math anxiety can exist alongside math competence.[177] One study involved participants identified as having math anxiety who were tested for math competence before and after receiving treatment for the condition.[178] Even though they were not taught any additional math skills and did not practice math as part of the treatment, after treatment they showed significant improvement in math achievement scores.[179] This improvement suggests that the scores achieved prior to treatment reflected a lower level of competence than the participants actually had.[180] In the real world, math-anxious individuals begin to develop negative perceptions of their mathematical ability.[181] Over time, a self-perpetuating cycle takes hold as students who believe they are bad at math avoid taking math classes to avoid the associated anxiety.[182]

Math anxiety is correlated with high anxiety generally, although math anxiety is believed to be a form of anxiety that is distinct from general anxiety or test anxiety.[183] Moreover, women self-report math anxiety at a higher rate than do men.[184] Certain teaching methods are

174. For example, $10\ \frac{1}{4} - 7\ \frac{2}{3} = ?$. *Id.* at 182.

175. *Id.*

176. *Id.* at 183.

177. *See id.* at 181 (noting that timed, online tests revealed math anxiety effects, while achievement tests revealed no competence differences).

178. *Id.* at 182–83 (citing Ray Hembree, *The Nature, Effects, and Relief of Mathematics Anxiety*, 21 J. for Res. Mathematics Educ. 33 (1990)).

179. *Id.* at 183.

180. *Id.*

181. *Id.* at 181–82.

182. *Id.* at 182.

183. *Id.* (noting that those with high math anxiety also have high anxiety in other areas, but that math anxiety is nonetheless a “separate phenomenon”).

184. *See id.* (hypothesizing that this might reflect a greater willingness by women to admit to such anxiety instead of an actual greater occurrence).

correlated with math anxiety in students.[185] For example, students with teachers who demand correctness without providing corresponding support may develop math anxiety based on feelings of vulnerability.[186]

As with students with dyscalculia, students with math anxiety may well choose law disproportionately over other professions because of the perception that math ability is not important to the practice of law. For these students, law school becomes a sophisticated math-avoidance mechanism that deflects attention from an underlying—and professionally significant—personal and practical problem. This danger merits attention, in part because math anxiety in the law student population responds well to treatment and relief alone can improve a student's math performance. In addition, it is an area in which there is strong evidence that approaches to teaching can exacerbate or relieve underlying anxiety.

To minimize math anxiety, professors including math in their courses should ensure that students know from the outset that they will be expected to discuss numerical information in class[187] so that they can prepare appropriately ahead of time.[188] Class discussions of numerical aspects of cases should be situated to help all students, including efforts to prevent the more anxious students from minimizing the time they spend on math[189] or focusing on their anxiety rather than on what they can do.[190] At the least, law professors should be cognizant of the forms

185. *Id.* at 184 (citing Julianne C. Turner et al., *The Classroom Environment and Students' Reports of Avoidance Strategies in Mathematics: A Multimethod Study*, 94 J. Educ. Psychol. 88 (2002)).

186. *Id.* (citing Turner, *supra* note 185, at 101).

187. Professor Woronoff reports that the course description for his Venture Capital class explicitly states: "Math competence through algebra is assumed and important." Woronoff, *supra* note 101, at 253. Similarly, on the syllabus for my Trusts & Estates class, I recommend that the students bring a calculator to the final, alerting them to the fact that math is a component of the course from the start.

188. *See* Ashcraft, *supra* note 170, at 182 (identifying time-pressured mental math as more anxiety provoking than when math is performed in writing).

189. *See supra* text accompanying note 176, discussing this issue.

190. *See* Ashcraft, *supra* note 170, at 183–84 (discussing the tendency of individuals with high math anxiety to focus on disrupting thoughts such as "one's dislike or fear of math, one's low self-confidence, and the like" rather than the task presented, so that "paying attention to these intrusive thoughts acts like a secondary task, distracting attention from the math task").

of teaching that may lead to math anxiety in order to avoid needlessly increasing anxiety in law students.[191]

2. Relative Competence

Subjective innumeracy often surfaces even in the absence of biological factors such as anxiety. One explanation for this type of innumeracy may be a lack of *relative* competence. The problem arises because individuals who do less well in math than in other academic areas learn to self-identify as bad at math relative to their other strengths. In other words, students who perform at a high level on tasks requiring reading and writing, but only moderately well on quantitative tasks, may undervalue their math competence and thus develop a self-perception of innumeracy that does not correlate with objective reality.

Tests of subjective numeracy with respect to statistics illustrate the important difference between objective and subjective innumeracy.[192] In particular, the STAT-Confidence Scale tests subjects' confidence in their ability to understand medical statistics by asking individuals to self-assess their competence.[193] Actual results on this test only weakly correlate with objective measures of math skills, thus showing a high degree of independence of objective and subjective innumeracy.[194] Put simply, the test shows that an individual who has the objective capacity to work competently with numbers may lack confidence in his ability to do so—and act accordingly.

Professor David Hyman has suggested that one explanation for lawyers' inability to do basic arithmetic is that they had higher scores on the verbal part of the Scholastic Aptitude Test than on the math part.[195] To the extent this is true, this greater facility with verbal and

191. For example, researchers have identified professors who demand correctness without providing explanations for mistakes and misunderstandings as one cause of math avoidance in students. *Id.* at 184 (citing Turner, *supra* note 185, at 101).

192. *But see* Nelson, *supra* note 146, at 265 (summarizing research that tests subjective innumeracy using questions that measure participants' perception of their numerical ability and preferences for whether information should be presented using numbers or verbal descriptions, and finding a significant correlation between subjective and objective numeracy (citing Angela Fagerlin et al., *Measuring Numeracy Without a Math Test: Development of the Subjective Numeracy Scale*, 27 MED. DECISION MAKING 672, 672–80 (2007))).

193. *Id.* (citing Steven Woloshin et al., *Patients and Medical Statistics: Interest, Confidence, and Ability*, 20 J. GEN. INTERNAL MED. 996 (2005)).

194. *Id.* at 266 (explaining that "the STAT-Confidence scale showed only a weak correlation ($r = 0.15$; $p = 0.04$) with an objective measure of numeracy, the Medical Data Interpretation Test").

195. Hyman, *supra* note 131, at 1168 n.12.

written tasks may very well contribute to subjective innumeracy among lawyers. Lawyers, after all, are accustomed to overachieving on verbal tasks throughout their lives. Thus, they may have developed early self-identities as being bad at math in comparison to their verbal achievements. This self-identification then becomes a self-fulfilling prophecy, as they seek out tasks that reinforce their (verbal) strengths and avoid those that play to their (numerical) weaknesses.

To the extent a crisis of confidence underlies law students' innumeracy, law schools cannot rely on students to choose the classes they most need. Instead, professors interested in improving their students' numeracy should include confidence-building math exercises—for example, simply working through the calculation of damages in a case and the allocation of the proceeds—in classroom discussions. Numerical information should be presented in multiple ways to reach as many students as possible and to help them become competent with thinking about numbers from multiple perspectives.[196] Numerical tasks that build progressively[197] and appropriately on each other over the course of the semester may assist students in developing numerical competence through familiarity, repetition, and the application of quantitative reasoning skills to actual legal situations. We should expect and reward tenacity in identifying and solving mathematical problems to encourage students to persevere in understanding numerical information.

Innumeracy is a real, although not insurmountable, problem for many lawyers. It is also largely unexamined in the legal and scientific literature. Whether the product of objective or subjective factors, innumeracy contributes to a perception that lawyers in general are bad at math. Because of the importance of sound math skills to the practice of law, empirical research into innumeracy is needed.[198] This research should consider whether, and the extent to which, each form of innumeracy is present in law students and lawyers, with a goal of providing useful guidance to law professors in helping students overcome the problem before beginning to practice law.

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196. *Cf.* Lipkus et al., *supra* note 4, at 42 (stating that "verbal translations that accompany numeric risks may help people better comprehend risk messages," and suggesting that visual displays may assist in the effective communication of numerical data).

197. To this end, Professor Michael Woronoff asserts that he teaches fundamental venture capital mathematical concepts incrementally by starting with very simple examples, then building in complexity by adding elements to the analysis throughout the course of the semester. Woronoff, *supra* note 101, at 253.

198. Arden Rowell, of the University of Illinois College of Law, has recently begun such research. *See* Rowell & Bregant, *supra* note 11.

Conclusion: Moving Past Innumeracy

Innumeracy matters. Just as reading, writing, and forming coherent legal arguments are skills we expect all lawyers to have, numeracy is critical to the practice of law. We must make a conscious effort to identify what underlies innumeracy in the law—an objective lack of mathematical ability or a subjective lack of confidence, or both—so that we can better understand its prevalence, causes, and solutions.

On a systemic level, law schools need to provide the necessary resources to transmit numerical skills to their students. Medical schools could serve as a model for this, with their focus on teaching and applying basic mathematical analysis to medical problems. To the extent empirical studies show that dyscalculia is a particular disability of law students, moreover, law schools should design appropriate accommodations for coursework, testing, and career counseling.

In the classroom, professors interested in enhancing the numeracy of their students should focus attention on the numerical components of cases no less than they do those cases' nonnumerical aspects. At least some professors should integrate readings or numerical analysis into casebooks, or supplement existing casebooks with case excerpts including numerical information.

Law students, too, have a role to play in improving their own numeracy. They should take responsibility for ensuring they have the skills they need before they leave law school. To the extent this is an area of concern for students, they should make it clear to administrators that courses improving quantitative reasoning skills are important and hold their professors accountable for working through the numerical aspects of cases. They should struggle to understand what a calculation means, what assumptions are behind a statistic, and how a formula acts across the range of applicable scenarios. Most of all, they should ask for clarification without apology: ultimately each law student is responsible for ensuring he receives the numerical training and exposure he needs for the successful practice of law.

With this background, lawyers will enter the field with the skills they need to understand and soundly use numerical information. Once in practice, lawyers should utilize experts to ensure that legal outcomes reflect good math.[199] Moreover, they should take care to understand numerical evidence just as they work to understand all other types of evidence presented and be cautious of introducing statistical evidence they do not fully understand.

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199. Similarly, Professor Daniel Rubinfeld has suggested that courts appoint neutral experts as needed to advise on technical and statistical matters based on an arbitration model. *See* Rubinfeld, *supra* note 90, at 1095; *see also* Meyerson & Meyerson, *supra* note 17, at 775 ("On more subtle points of mathematics or science, it would be appropriate for judges to turn to experts to help identify whether proposed evidence is 'good science.'").

It is time that we stop pretending that numbers and math are not important in the practice of law. As lawyers, lawmakers, law professors, and law students, we need to take responsibility for illuminating the meanings hiding in the shadows of numerical information.

Appendix

Survey of Numerically Focused Law Classes[a]

Law School	Numerically Focused Classes Offered
Appalachian School of Law[b]	*None*
Ave Maria School of Law[c]	*None*
Baylor Law School[d]	Basic Tax & Accounting for Lawyers
Benjamin N. Cardozo School of Law[e]	*None*
California Western School of Law[f]	Accounting for Lawyers
Campbell Law School[g]	*None*
Columbia Law School[h]	Financial Statement Analysis & Interpretation Statistics for Lawyers
Drake University Law School[i]	*None*
Dwayne O. Andreas School of Law[j] (Barry University)	*None*
Florida State University College of Law[k]	*None*
Harvard Law School[l]	Analytical Methods for Lawyers Applied Quantitative Analysis Financial Statement Analysis Fundamentals of Statistical Analysis Introduction to Accounting & Corporate Financial Reports
John Marshall Law School[m] (Atlanta, GA)	Accounting for Lawyers
Loyola Marymount University[n] (Los Angeles, CA)	Accounting for Income Taxes Accounting for Lawyers
New York University School of Law[o]	Accounting for Lawyers Accounting for Tax Consequences Quantitative Methods in Law I Quantitative Methods in Law II
Pacific McGeorge School of Law[p]	Accounting for Lawyers
Saint Louis University School of Law[q]	*None*
SMU Dedman School of Law[r]	Tax Accounting
Stanford Law School[s]	Accounting Research Design for Empirical Legal Studies
Texas Tech University School of Law[t]	Accounting for Lawyers
Tulane University Law School[u]	*None*
University of Chicago Law School[v]	Advanced Law & Economics Financial Accounting for Lawyers Fundamentals of Accounting for Attorneys
Villanova Law School[w]	Accounting for Lawyers
West Virginia University College of Law[x]	*None*
Yale Law School[y]	Legal Accounting

a. The table includes classes offered at schools ranked 1–6, 51–56, and 101–106 in U.S. News & World Reports' 2012 law school rankings and the first six schools alphabetically of those that are unranked. *See Best Law Schools*, U.S. NEWS & WORLD REP., http://grad-schools.usnews.rankingsandreviews.com/best-graduate-schools/top-law-schools/law-rankings (last visited Jan. 13, 2013). Classes emphasizing the development of numerical analysis or mathematical skills are included; those only incidentally employing math are not. In a few cases, two sections of the same class were offered during the surveyed period; in each case, such duplicative offerings were counted only once. All web addresses listed in this Appendix were last visited February 13, 2013.

b. *2011–2012 Catalog*, APPALACHIAN SCH. LAW, http://www.asl.edu/Documents/Student%20Services/Admissions/2011-2012%20ASL%20Catalog.pdf.

c. *Course Descriptions,* AVE MARIA SCH. LAW, http://legacy.avemarialaw.edu/index.cfm?event=academics.coursedescriptions.

d. *Curriculum Information*, BAYLOR L. SCH., http://www.baylor.edu/law/ps/index.php?id=75581; *Schedule of Classes*, BAYLOR L. SCH., https://www1.baylor.edu/scheduleofclasses/Results.aspx?TermCC=20&Term=121&College=LW&Prefix=LAW&StartCN=&EndCN=&Status=&Days=&Instructor=&IsMini=false.

e. *Upper-Level Courses — Fall 2011*, CARDOZO SCH. LAW, http://www.cardozo.yu.edu/uploadedFiles/Cardozo/Info_For/Current_Students/Fall-2011-Upper-Level-Class-Schedule.pdf; *Upper-Level Courses — Spring 2012*, CARDOZO SCH. LAW, http://www.cardozo.yu.edu/uploadedFiles/Cardozo/Profiles/registrar-124/UL%20Block%20Jan%2011%202012.pdf.

f. *Fall 2012 Course Schedule by Requirement*, CAL. W. SCH. LAW, http://www.cwsl.edu/content/registrar/20123_sched_require.pdf; *Spring 2013 Course Schedule by Requirement*, CAL. W. SCH. LAW, http://www.cwsl.edu/content/registrar/20131_sched_require.pdf.

g. *Course Catalog*, CAMPBELL U., http://www.law.campbell.edu/page.cfm?id=391&n=course-catalog. Class schedules by year are not available online.

h. *Courses*, COLUMBIA L. SCH., http://www.law.columbia.edu/courses (click on "advanced search" and search for 2011–12 Fall and Spring Term courses).

i. *2011 Fall Class Offerings*, DRAKE U.L. SCH., http://www.law.drake.edu/academics/docs/archivedSchedules-fall2011Schedule.pdf; *2012 Spring Class Offerings*, DRAKE U.L. SCH., http://www.law.drake.edu/academics/docs/archivedSchedules-spring2012Schedule.pdf; *2012 Summer Course Offerings*, DRAKE U.L. SCH., http://www.law.drake.edu/academics/docs/schedules-summer2012.pdf.

j. *Recent Course Offerings*, BARRY U., http://www.barry.edu/includes/docs/law/current-course-listing.pdf.

k. *Schedule of Classes*, FLA. ST. U. COL. LAW, http://www.law.fsu.edu/academic_programs/curriculum/schedule_of_classes.html.

l. *Course Catalog*, HARVARD L. SCH., http://www.law.harvard.edu/academics/curriculum/catalog/index.html.

m. *Course List — Master*, ATLANTA'S JOHN MARSHALL L. SCH., http://www.johnmarshall.edu/wp-content/uploads/2012/02/Course-Descriptions-AJMLS1.pdf; *Course Schedule: Spring Semester 2013*, ATLANTA'S JOHN MARSHALL L. SCH., http://www.johnmarshall.edu/wp-content/uploads/2012/12/2013-Spring-Semester-Schedule-Revised-1-11-132.pdf.

n. *Course Offerings — Fall 2011*, LOYOLA L. SCH. L.A., https://technology.lls.edu/courses/crs-table.php?yt=2011%20FA&sf=c; *Course Offerings — Spring 2012*, LOYOLA L. SCH. L.A., https://technology.lls.edu/courses/crs-table.php?yt=2012+SP; *Course Offerings—Summer 2012*, LOYOLA L. SCH. L.A., https://technology.lls.edu/courses/crs-table.php?yt=2012+SU.

o. *Fall 2011 Schedule of New York Classes*, NYU L., https://its.law.nyu.edu/cms/public/schedules/index.cfm?fuseaction=Public.AreasOfStudyCategories&Semester=Fall&TermYear=2011&GeoLocID=nyc; *Spring 2012 Schedule of New York Classes*, NYU L., https://its.law.nyu.edu/cms/public/schedules/index.cfm?fuseaction=Public.AreasOfStudyCategories&Semester=Spring&TermYear=2012&GeoLocID=nyc; *Summer 2012 Schedule of New York Classes*, NYU L., https://its.law.nyu.edu/cms/public/schedules/index.cfm?fuseaction=Public.AreasOfStudyCategories&Semester=Summer&TermYear=2012&GeoLocID=nyc.

p. *Fall Semester 2012 Academic Schedule*, MCGEORGE L. SCH., http://www.mcgeorge.edu/Documents/Academics/2012FallAcademicSchedule.pdf; *Spring Semester 2013 Academic Schedule*, MCGEORGE L. SCH., http://www.mcgeorge.edu/Documents/Academics/2013SpringAcademicSchedule.pdf; *Pacific McGeorge Summer Sessions 2013*, MCGEORGE L. SCH., http://www.mcgeorge.edu/Documents/Academics/2013SummerAcademicSchedule.pdf.

q. *Recent Offerings*, ST. LOUIS U. SCH. LAW, http://www.slu.edu/school-of-law-home/academics/academic-curriculum/recent-offerings.

r. *Upper Class Courses: Fall 2011*, SMU DEADMAN SCH. LAW, http://www.law.smu.edu/Registrar/App/Upper-Class-Courses.aspx?Term=Fall-2011&Year=2; *Upper Class Courses: Spring 2012*, SMU DEADMAN SCH. LAW, http://www.law.smu.edu/Registrar/App/Upper-Class-Courses.aspx?Term=Spring-2012&Year=2; *Upper Class Courses: Summer 2012*, SMU DEADMAN SCH. LAW, http://www.law.smu.edu/Registrar/App/Upper-Class-Courses.aspx?Term=Summer-2012&Year=2.

s. *Autumn 2012 Course Overview,* STANFORD L. SCH., http://lawreg.stanford.edu/stanford/prereg/course_overview.asp?Term=Fall; *Winter 2013 Course Overview*, STANFORD L. SCH., http://lawreg.stanford.edu/stanford/prereg/course_overview.asp?Term=Winter; *Spring 2013 Course Overview*, STANFORD L. SCH., http://lawreg.stanford.edu/stanford/prereg/course_overview.asp?Term=Spring.

t. *2011–2012 Catalog*, TEXAS TECH U. SCH. LAW, http://www.depts.ttu.edu/officialpublications/LawSchool/index.html.

u. *Course Descriptions*, TULANE U. L. SCH., http://www.law.tulane.edu/tlsAcademicPrograms/courseDetail.aspx?id=1936&ekmensel=c580fa7b_76_92_1936_1.

v. *The Law School Announcements 2011-2012*, U. CHICAGO, 227, http://catalogs.uchicago.edu/law-folder/law1112.pdf.

w. *Search for Courses*, VILLANOVA U., https://novasis.villanova.edu/pls/bannerprd/bvckctlg.p_disp_dyn_ctlg (search by term "Fall 2011" then select all subjects; search by term "Spring 2012" then select all subjects).

x. *Upper Level Courses: 2011–12 (and beyond)*, W. VA. U. COL. LAW, http://law.wvu.edu/r/download/90456.

y. *Fall 2012 Course Overview*, YALE L. SCH., http://ylsinfo.law.yale.edu/wsw/prereg/course_overview.asp?Term=Fall; *Spring 2013 Course Overview*, YALE L. SCH., http://ylsinfo.law.yale.edu/wsw/prereg/course_overview.asp?Term=Spring.

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