

**PROOF AND PROVING IN SCHOOL AND UNIVERSITY MATHEMATICS  
EDUCATION RESEARCH: A SYSTEMATIC REVIEW**

Gabriel J. Stylianides<sup>1</sup>

University of Oxford, Department of Education, UK, <https://orcid.org/0000-0003-1770-8753>

Andreas J. Stylianides

University of Cambridge, Faculty of Education, UK, <https://orcid.org/0000-0002-3526-0342>

Andreas Moutsios-Rentzos

National and Kapodistrian University of Athens, Department of Pedagogy and Primary  
Education, Greece, <https://orcid.org/0000-0002-9614-2825>

**All Papers Included in the Review**

- Aaron, W. R., & Herbst, P. G. (2019). The teacher's perspective on the separation between conjecturing and proving in high school geometry classrooms. *Journal of Mathematics Teacher Education*, 22(3), 231-256.
- Aberdein, A. (2019). Evidence, proofs, and derivations. *ZDM*, 51(5), 825-834.
- Ahmadpour, F., Reid, D., & Reza Fadaee, M. (2019). Students' ways of understanding a proof. *Mathematical Thinking and Learning*, 21(2), 85-104.
- Andrews-Larson, C., McCrackin, S., & Kasper, V. (2019). The next time around: Scaffolding and shifts in argumentation in initial and subsequent implementations of inquiry-oriented instructional materials. *Journal of Mathematical Behavior*, 56, 100719.
- Antonini, S. (2019). Intuitive acceptance of proof by contradiction. *ZDM*, 51(5), 793-806.
- Aricha-Metzer, I., & Zaslavsky, O. (2019). The nature of students' productive and non-productive example-use for proving. *Journal of Mathematical Behavior*, 53, 304-322.
- Ayalon, M., & Hershkowitz, R. (2018). Mathematics teachers' attention to potential classroom situations of argumentation. *Journal of Mathematical Behavior*, 49, 163-173.

---

<sup>1</sup> Corresponding author. Email address: [gabriel.stylianides@education.ox.ac.uk](mailto:gabriel.stylianides@education.ox.ac.uk).

- Ayalon, M., Wilkie, K. J., & Eid, K. H. (2022). Relating students' emotions during argumentative discourse to their learning of real-life functional situations. *Educational Studies in Mathematics*, *110*(1), 23-48.
- Azrou, N., & Khelladi, A. (2019). Why do students write poor proof texts? A case study on undergraduates' proof writing. *Educational Studies in Mathematics*, *102*(2), 257-274.
- Baldinger, E. E., & Lai, Y. (2019). Pedagogical context and proof validation: The role of positioning as a teacher or student. *Journal of Mathematical Behavior*, *55*, 100698.
- Belin, M., & Akar, G. K. (2020). The effect of quantitative reasoning on prospective mathematics teachers' proof comprehension: The case of real numbers. *Journal of Mathematical Behavior*, *57*, 100757.
- Bergwall, A. (2021). Proof-related reasoning in upper secondary school: characteristics of Swedish and Finnish textbooks. *International Journal of Mathematical Education in Science and Technology*, *52*(5), 731-751.
- Bissell, J. J. (2021). An elementary proof by contradiction of the exactness condition for first-order ordinary differential equations. *International Journal of Mathematical Education in Science and Technology*, *52*(6), 965-971.
- Blanton, M., Gardiner, A. M., Ristroph, I., Stephens, A., Knuth, E., & Stroud, R. (2022). Progressions in young learners' understandings of parity arguments. *Mathematical Thinking and Learning*, 1-32. <https://doi.org/10.1080/10986065.2022.2053775>
- Brown, S. (2018). Difficult dialogs about degenerate cases: A proof script study. *Journal of Mathematical Behavior*, *52*, 61-76.
- Brown, S. (2019). Leveraging the perceptual ambiguity of proof scripts to witness students' identities. *For the Learning of Mathematics*, *39*(1), 7-12.
- Brown, S. A. (2018). Are indirect proofs less convincing? A study of students' comparative assessments. *Journal of Mathematical Behavior*, *49*, 1-23.

- Brunner, E., & Reusser, K. (2019). Type of mathematical proof: personal preference or adaptive teaching behavior? *ZDM*, *51*(5), 747-758.
- Buchbinder, O. (2018). Guided discovery of the nine-point circle theorem and its proof. *International Journal of Mathematical Education in Science and Technology*, *49*(1), 138-153.
- Buchbinder, O., & McCrone, S. (2020). Preservice teachers learning to teach proof through classroom implementation: Successes and challenges. *Journal of Mathematical Behavior*, *58*, 100779.
- Buchbinder, O., & Zaslavsky, O. (2019). Strengths and inconsistencies in students' understanding of the roles of examples in proving. *Journal of Mathematical Behavior*, *53*, 129-147.
- Campbell, T. G., Boyle, J. D., & King, S. (2020). Proof and argumentation in K-12 mathematics: A review of conceptions, content, and support. *International Journal of Mathematical Education in Science and Technology*, *51*(5), 754-774.
- Campbell, T. G., King, S., & Zelkowski, J. (2021). Comparing middle grade students' oral and written arguments. *Research in Mathematics Education*, *23*(1), 21-38.
- Chamberlain Jr, D., & Vidakovic, D. (2021). Cognitive trajectory of proof by contradiction for transition-to-proof students. *Journal of Mathematical Behavior*, *62*, 100849.
- Cirillo, M., & Hummer, J. (2021). Competencies and behaviors observed when students solve geometry proof problems: an interview study with smartpen technology. *ZDM*, *53*(4), 861-875.
- Conner, A. (2022). Adaptive instruction that supports collective argumentation. *Journal of Mathematical Behavior*, *66*, 100969.

- Conner, A., & Singletary, L. M. (2021). Teacher support for argumentation: An examination of beliefs and practice. *Journal for Research in Mathematics Education*, 52(2), 213-247.
- Czocher, J. A., & Weber, K. (2020). Proof as a cluster category. *Journal for Research in Mathematics Education*, 51(1), 50-74.
- David, E. J., & Zazkis, D. (2020). Characterizing introduction to proof courses: A survey of US R1 and R2 course syllabi. *International Journal of Mathematical Education in Science and Technology*, 51(3), 388-404.
- Davies, B., Alcock, L., & Jones, I. (2020). Comparative judgement, proof summaries and proof comprehension. *Educational Studies in Mathematics*, 105(2), 181-197.
- Davies, B., Alcock, L., & Jones, I. (2021). What do mathematicians mean by proof? A comparative-judgement study of students' and mathematicians' views. *Journal of Mathematical Behavior*, 61, 100824.
- Dawkins, P. C., & Zazkis, D. (2021). Using moment-by-moment reading protocols to understand students' processes of reading mathematical proof. *Journal for Research in Mathematics Education*, 52(5), 510-538.
- Demiray, E., Işiksal-Bostan, M., & Saygi, E. (2022). Types of global argumentation structures in conjecture-generation activities regarding geometry. *International Journal of Science and Mathematics Education*, 20(4), 839-860.
- Dimmel, J. K., & Herbst, P. G. (2018). What details do teachers expect from student proofs? A study of proof checking in geometry. *Journal for Research in Mathematics Education*, 49(3), 261-291.
- Dimmel, J. K., & Herbst, P. G. (2020). Proof transcription in high school geometry: A study of what teachers recognize as normative when students present proofs at the board. *Educational Studies in Mathematics*, 105(1), 71-89.

- Dogan, M. F., & Williams-Pierce, C. (2021). The role of generic examples in teachers' proving activities. *Educational Studies in Mathematics*, *106*(1), 133-150.
- Dogruer, S. S., & Akyuz, D. (2020). Mathematical practices of eighth graders about 3D shapes in an argumentation, technology, and design-based classroom environment. *International Journal of Science and Mathematics Education*, *18*(8), 1485-1505.
- Erickson, A., & Herbst, P. (2018). Will teachers create opportunities for discussion when teaching proof in a geometry classroom? *International Journal of Science and Mathematics Education*, *16*(1), 167-181.
- Erickson, S. A., & Lockwood, E. (2021). Investigating undergraduate students' proof schemes and perspectives about combinatorial proof. *Journal of Mathematical Behavior*, *62*, 100868.
- Erkek, Ö., & Işıksal Bostan, M. (2019). Prospective middle school mathematics teachers' global argumentation structures. *International Journal of Science and Mathematics Education*, *17*(3), 613-633.
- Fernández-León, A., Gavilán-Izquierdo, J. M., & Toscano, R. (2021). A case study of the practices of conjecturing and proving of research mathematicians. *International Journal of Mathematical Education in Science and Technology*, *52*(5), 767-781.
- Fujita, T., Jones, K., & Miyazaki, M. (2018). Learners' use of domain-specific computer-based feedback to overcome logical circularity in deductive proving in geometry. *ZDM*, *50*(4), 699-713.
- Gabel, M., & Dreyfus, T. (2020). Analyzing proof teaching at the tertiary level using Perelman's new rhetoric. *For the Learning of Mathematics*, *40*(2), 15-19.
- Gabel, M., & Dreyfus, T. (2022). Rhetorical aspects of the flow of a proof—A shared basis of agreement between lecturer and students. *Journal of Mathematical Behavior*, *66*, 100971.

- Gomez Marchant, C. N., Park, H., Zhuang, Y., Foster, J. K., & Conner, A. (2021). Theory to practice: Prospective mathematics teachers' recontextualizing discourses surrounding collective argumentation. *Journal of Mathematics Teacher Education*, 24(6), 671-699.
- Haj-Yahya, A. (2020). Do prototypical constructions and self-attributes of presented drawings affect the construction and validation of proofs? *Mathematics Education Research Journal*, 32(4), 685-718.
- Hanna, G., & Yan, X. (2021). Opening a discussion on teaching proof with automated theorem provers. *For the Learning of Mathematics*, 41(3), 42-46.
- Hegg, M., Papadopoulos, D., Katz, B., & Fukawa-Connelly, T. (2018). Preservice teacher proficiency with transformations-based congruence proofs after a college proof-based geometry class. *Journal of Mathematical Behavior*, 51, 56-70.
- Kanellos, I., Nardi, E., & Biza, I. (2018). Proof schemes combined: Mapping secondary students' multi-faceted and evolving first encounters with mathematical proof. *Mathematical Thinking and Learning*, 20(4), 277-294.
- Karpuz, Y., & Atasoy, E. (2020). High school mathematics teachers' content knowledge of the logical structure of proof deriving from figural-concept interaction in geometry. *International Journal of Mathematical Education in Science and Technology*, 51(4), 585-603.
- Kazemi, E., Ghouseini, H., Cordero-Siy, E., Prough, S., McVicar, E., & Resnick, A. F. (2021). Supporting teacher learning about argumentation through adaptive, school-based professional development. *ZDM*, 53(2), 435-448.
- Kempen, L., & Biehler, R. (2019). Fostering first-year pre-service teachers' proof competencies. *ZDM*, 51(5), 731-746.
- Knuth, E., Zaslavsky, O., & Ellis, A. (2019). The role and use of examples in learning to prove. *Journal of Mathematical Behavior*, 53, 256-262.

- Ko, Y. Y., & Rose, M. K. (2021). Are self-constructed and student-generated arguments acceptable proofs? Pre-service secondary mathematics teachers' evaluations. *Journal of Mathematical Behavior*, *64*, 100912.
- Komatsu, K., & Jones, K. (2022). Generating mathematical knowledge in the classroom through proof, refutation, and abductive reasoning. *Educational Studies in Mathematics*, *109*(3), 567-591.
- Komatsu, K., Fujita, T., Jones, K., & Sue, N. (2018). Explanatory unification by proofs in school mathematics. *For the Learning of Mathematics*, *38*(1), 31-37.
- Kontorovich, I. (2021). Minding mathematicians' discourses in investigations of their feedback on students' proofs: A case study. *Educational Studies in Mathematics*, *107*(2), 213-234.
- Lesseig, K., Hine, G., Na, G. S., & Boardman, K. (2019). Perceptions on proof and the teaching of proof: a comparison across preservice secondary teachers in Australia, USA and Korea. *Mathematics Education Research Journal*, *31*(4), 393-418.
- Lew, K., & Mejía Ramos, J. P. (2020). Linguistic conventions of mathematical proof writing across pedagogical contexts. *Educational Studies in Mathematics*, *103*(1), 43-62.
- Lew, K., & Mejía-Ramos, J. P. (2019). Linguistic conventions of mathematical proof writing at the undergraduate level: Mathematicians' and students' perspectives. *Journal for Research in Mathematics Education*, *50*(2), 121-155.
- Lew, K., & Zazkis, D. (2019). Undergraduate mathematics students' at-home exploration of a prove-or-disprove task. *Journal of Mathematical Behavior*, *54*, 100674.
- Lockwood, E., Caughman, J. S., & Weber, K. (2020). An essay on proof, conviction, and explanation: Multiple representation systems in combinatorics. *Educational Studies in Mathematics*, *103*(2), 173-189.

- Lockwood, E., Reed, Z., & Erickson, S. (2021). Undergraduate students' combinatorial proof of binomial identities. *Journal for Research in Mathematics Education*, 52(5), 539-580.
- Lynch, A. G., & Lockwood, E. (2019). A comparison between mathematicians' and students' use of examples for conjecturing and proving. *Journal of Mathematical Behavior*, 53, 323-338.
- Marco, N., Palatnik, A., & Schwarz, B. B. (2021). Mind the gaps: Gap-filling in proving activities. *For the Learning of Mathematics*, 41(2), 21-25.
- Mariotti, M. A., & Pedemonte, B. (2019). Intuition and proof in the solution of conjecturing problems'. *ZDM*, 51(5), 759-777.
- Mejía-Ramos, J. P., & Weber, K. (2020). Using task-based interviews to generate hypotheses about mathematical practice: Mathematics education research on mathematicians' use of examples in proof-related activities. *ZDM*, 52(6), 1099-1112.
- Mejía-Ramos, J. P., & Weber, K. (2019). Mathematics majors' diagram usage when writing proofs in calculus. *Journal for Research in Mathematics Education*, 50(5), 478-488.
- Meyer, M., & Schnell, S. (2020). What counts as a "good" argument in school?—How teachers grade students' mathematical arguments. *Educational Studies in Mathematics*, 105(1), 35-51.
- Miller, D., & CadwalladerOlsker, T. (2020). Investigating undergraduate students' view of and consistency in choosing empirical and deductive arguments. *Research in Mathematics Education*, 22(3), 249-264.
- Miller, D., Infante, N., & Weber, K. (2018). How mathematicians assign points to student proofs. *Journal of Mathematical Behavior*, 49, 24-34.
- Nickel, G. (2019). Aspects of freedom in mathematical proof. *ZDM*, 51(5), 845-856.

- Nordin, A. K., & Boistrup, L. B. (2018). A framework for identifying mathematical arguments as supported claims created in day-to-day classroom interactions. *Journal of Mathematical Behavior*, 51, 15-27.
- Ozgur, Z., Ellis, A. B., Vinsonhaler, R., Dogan, M. F., & Knuth, E. (2019). From examples to proof: Purposes, strategies, and affordances of example use. *Journal of Mathematical Behavior*, 53, 284-303.
- Pinto, A., & Karsenty, R. (2018). From course design to presentations of proofs: How mathematics professors attend to student independent proof reading. *Journal of Mathematical Behavior*, 49, 129-144.
- Pinto, A., & Karsenty, R. (2020). Norms of proof in different pedagogical contexts. *For the Learning of Mathematics*, 40(1), 22-27.
- Regier, P., & Savic, M. (2020). How teaching to foster mathematical creativity may impact student self-efficacy for proving. *Journal of Mathematical Behavior*, 57, 100720.
- Reid, D. A., & Vallejo Vargas, E. A. (2019). Evidence and argument in a proof based teaching theory. *ZDM*, 51(5), 807-823.
- Reinholz, D. L., & Pilgrim, M. E. (2021). Student sensemaking of proofs at various distances: The role of epistemic, rhetorical, and ontological distance in the peer review process. *Educational Studies in Mathematics*, 106(2), 211-229.
- Rø, K., & Arnesen, K. K. (2020). The opaque nature of generic examples: The structure of student teachers' arguments in multiplicative reasoning. *Journal of Mathematical Behavior*, 58, 100755.
- Rogers, K. C., & Kosko, K. W. (2019). How elementary and collegiate instructors envision tasks as supportive of mathematical argumentation: A comparison of instructors' task constructions. *Journal of Mathematical Behavior*, 53, 228-241.

- Satyam, V. R. (2020). Satisfying moments during the transition-to-proof: Characteristics of moments of significant positive emotion. *Journal of Mathematical Behavior*, 59, 100784.
- Sevgi, S., & Orman, F. (2022). Eighth grade students' views about giving proof and their proof abilities in the geometry and measurement. *International Journal of Mathematical Education in Science and Technology*, 53(2), 467-490.
- Sevimli, E. (2018). Undergraduates' propositional knowledge and proof schemes regarding differentiability and integrability concepts. *International Journal of Mathematical Education in Science and Technology*, 49(7), 1052-1068.
- Shinno, Y., Miyakawa, T., Iwasaki, H., Kunimune, S., Mizoguchi, T., Ishii, T., & Abe, Y. (2018). Challenges in curriculum development for mathematical proof in secondary school: Cultural dimensions to be considered. *For the learning of mathematics*, 38(1), 26-30.
- Shongwe, B. (2021). Learners' beliefs about the functions of proof: Building an argument for validity. *Educational Studies in Mathematics*, 107(3), 503-523.
- Solar, H., Ortiz, A., Deulofeu, J., & Ulloa, R. (2021). Teacher support for argumentation and the incorporation of contingencies in mathematics classrooms. *International Journal of Mathematical Education in Science and Technology*, 52(7), 977-1005.
- Sommerhoff, D., & Ufer, S. (2019). Acceptance criteria for validating mathematical proofs used by school students, university students, and mathematicians in the context of teaching. *ZDM*, 51(5), 717-730.
- Sørensen, H. K., Danielsen, K., & Andersen, L. E. (2019). Teaching reader engagement as an aspect of proof. *ZDM*, 51(5), 835-844.
- Stewart, S., & Thomas, M. O. (2019). Student perspectives on proof in linear algebra. *ZDM*, 51(7), 1069-1082.

- Stuhlmann, A. S. (2019). Mathematics students talking past each other: Emergence of ambiguities in linear algebra proof constructions involving the uniqueness quantification. *ZDM*, *51*(7), 1083-1095.
- Stylianides, A. J., & Stylianides, G. J. (2022). Introducing students and prospective teachers to the notion of proof in mathematics. *Journal of Mathematical Behavior*, *66*, 100957.
- Tabach, M., Rasmussen, C., Dreyfus, T., & Apkarian, N. (2020). Towards an argumentative grammar for networking: A case of coordinating two approaches. *Educational Studies in Mathematics*, *103*(2), 139-155.
- Van Ness, C. K., & Maher, C. A. (2019). Analysis of the argumentation of nine-year-olds engaged in discourse about comparing fraction models. *Journal of Mathematical Behavior*, *53*, 13-41.
- Verzosa, D. M. B., De Las Peñas, M. L. A. N., Aberin, M. A. Q., & Garces, L. P. D. M. (2019). App-based scaffolds for writing two-column proofs. *International Journal of Mathematical Education in Science and Technology*, *50*(5), 766-778.
- Weber, K., & Czocher, J. (2019). On mathematicians' disagreements on what constitutes a proof. *Research in Mathematics Education*, *21*(3), 251-270.
- Weber, K., Mejía-Ramos, J. P., & Volpe, T. (2022). The relationship between proof and certainty in mathematical practice. *Journal for Research in Mathematics Education*, *53*(1), 65-84.
- Yan, X. (2019). Key ideas in a proof: The case of the irrationality of  $\sqrt{2}$ . *Journal of Mathematical Behavior*, *55*, 100702.
- Yee, S. P., Boyle, J. D., Ko, Y. Y. W., & Bleiler-Baxter, S. K. (2018). Effects of constructing, critiquing, and revising arguments within university classrooms. *Journal of Mathematical Behavior*, *49*, 145-162.

- Yopp, D. A. (2018). When an argument is the content: Rational number comprehension through conversions across registers. *Journal of Mathematical Behavior*, 50, 42-56.
- Yopp, D. A., Ely, R., Adams, A. E., Nielsen, A. W., & Corwine, E. C. (2020). Eliminating counterexamples: A case study intervention for improving adolescents' ability to critique direct arguments. *Journal of Mathematical Behavior*, 57, 100751.
- Zambak, V. S., & Magiera, M. T. (2020). Supporting grades 1–8 pre-service teachers' argumentation skills: constructing mathematical arguments in situations that facilitate analyzing cases. *International Journal of Mathematical Education in Science and Technology*, 51(8), 1196-1223.
- Zhuang, Y., & Conner, A. (2022). Secondary mathematics teachers' use of students' incorrect answers in supporting collective argumentation. *Mathematical Thinking and Learning*, 1-24. <https://doi.org/10.1080/10986065.2022.2067932>