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Thought Experiments

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Introduction

Thought experiments are performed in the imagination. We set up some situation, we observe what happens, then we try to draw appropriate conclusions. In this way, thought experiments resemble real experiments, except that they are experiments in the mind. The terms “thought experiment,” “imaginary experiment,” and “Gedankenexperiment” are used interchangeably. There is no consensus on a definition, but there is widespread agreement on which are standard examples. It is also widely agreed that they play a central role in a number of fields, especially physics and philosophy. There are several important questions about thought experiments that naturally arise, including what kinds of thought experiments there are, what roles they play, and how, if at all, they work. This last question has been the focus of much of the literature: How can we learn something new about the world just by thinking? Answers range from “We don’t really learn anything new” to “We have some sort of a priori insight into how nature works.” In between there are a great variety of rival alternative accounts. There is still no consensus; debate is wide open on almost every question pertaining to thought experiments.

General Overviews

There has always been some interest in the nature of thought experiments, but it is only in recent years that it has become a popular topic of philosophical interest. Arcangeli 2017 and Stuart, et al. 2018 provide recent overviews of the issues. Brown and Fehige 2019 offers a periodically updated survey of thought experiments and the literature on it. Otherwise, the early works from the current period may be the best place to start, since they provide lots of examples and have tended to set the agenda for subsequent discussion. Horowitz and Massey 1991 is one of the first works stimulating the current interest in thought experiments. Brown 2011 (originally published in 1991) is an early work with many examples. For German readers, Cohnitz 2006 and Kühne 2005 both offer extensive coverage of many topics. Häggqvist 1996 is a critical survey, with an emphasis on modal considerations. Rescher 2005 and Sorensen 1992 both cover a variety of issues and provide many examples.

Arcangeli, Margherita. “Thought Experiments in Model-Based Reasoning.” In *Springer Handbook of Model-Based Science*. Edited by Lorenzo Magnani and Tommaso Bertolotti, 463–495. Dordrecht, The Netherlands: Springer, 2017.

An overview of the recent literature on thought experiments, with a focus on model-based reasoning.

Brown, James Robert. *Laboratory of the Mind: Thought Experiments in the Natural Sciences*. 2d ed. New York: Routledge, 2011.

An early work with several standard examples and a taxonomy classifying the different forms that thought experiments take. The author argues for a rationalistic, or Platonistic account of thought experiments, claiming that in some (but not all) we gain a priori access to the abstract realm of laws of nature. Originally published in 1991.

Brown, James Robert, and Yiftach Fehige. “Thought Experiments.” In *The Stanford Encyclopedia of Philosophy*. Edited by Edward N. Zalta. Stanford, CA: Stanford University, 2019.

A survey of the major issues with a comprehensive bibliography, periodically updated.

Cohnitz, Daniel. *Gendankenexperimente in der Philosophie*. Paderborn, Germany: Mentis, 2006.

Presents an argument for the usefulness of thought experiments in philosophy. Extensive discussion of different theories of modality to defend thought experiments in philosophy for different purposes, much like conceptual analysis.

Gendler, Tamar S. *Thought Experiment: On the Powers and Limits of Imaginary Cases*. Abingdon, UK, and New York: Routledge, 2000.

A revised version of Gendler's PhD thesis, which discusses the role of imagination in thought experiments that use "exceptional cases" to generate new knowledge. Focuses on three case studies: Galileo's falling bodies, Theseus's Ship, and Parfit's fission thought experiment concerning personal identity. Provides four separate and useful bibliographies.

Häggqvist, Sören. *Thought Experiments in Philosophy*. Stockholm: Almqvist & Wiksell, 1996.

A critical discussion of the early rival accounts of thought experiments. Especially concerned with the relation between thought experiments and modal notions (necessity and possibility).

Horowitz, T., and G. Massey, eds. *Thought Experiments in Science and Philosophy*. Proceedings of a conference held at the Center for Philosophy at the University of Pittsburgh, 18–20 April 1986. Savage, MD: Rowman & Littlefield, 1991.

Stems from a conference at the University of Pittsburgh in 1986 and contains several excellent and influential articles on a wide range of topics. It is currently out of print, but fortunately, a PDF of the whole book is available online.

Kühne, Ulrich. *Die Methode des Gedankenexperiments*. Frankfurt: Suhrkamp, 2005.

Comprehensive study of the history of inquiry into thought experiments from Kant to the Brown-Norton debate. Noteworthy are the chapters on Ørsted and Einstein. Argues that Ørsted's notion of thought experiment is hopelessly confusing and that Einstein, contrary to widespread belief, did not approve of the method of thought experiments.

Rescher, Nicholas. *What If? Thought Experimentation in Philosophy*. New Brunswick, NJ: Transaction, 2005.

A general and less specialized discussion of thought experiments, includes several historically famous examples. Explores the distinctions between thought experiments and real experiments.

Sorensen, Roy. *Thought Experiments*. Oxford: Oxford University Press, 1992.

Very wide-ranging. Covers a great many topics in both philosophy and the sciences, and provides a great many examples and deep insights on many issues. One of the author's central claims is that thought experiments are experiments that merely have not been performed. Develops a theory of the epistemic power of thought experiments in terms of Darwinian evolution.

Stuart, Michael T., Yiftach Fehige, and James R. Brown. "Thought Experiments: State of the Art." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James R. Brown, 1–28. Abingdon, UK, and New York: Routledge, 2018.

Provides an overview of the literature with examples, and a brief history of the philosophy of thought experiments.

Textbooks and Popular Works

There are no textbooks on thought experiments, but Schick and Vaughn 2010 is a philosophy textbook that makes extensive use of thought experiments. Baggini 2010, Cohen 2005, de Cruz 2018, Falk 2017, Knobe 2011, and Tittle 2005 provide standard examples in an accessible form, aimed at a general audience. The French science magazine *Sciences et Avenir* devoted a whole issue to thought experiments.

Baggini, Julian. *The Pig That Wanted to Be Eaten and 99 Other Thought Experiments*. London: Granata, 2010.

Short presentations of one hundred thought experiments, mainly from philosophy.

Cohen, Martin. *Wittgenstein's Beetle and Other Classical Thought Experiments*. Oxford: Wiley-Blackwell, 2005.

Presents twenty-six thought experiments from both science and philosophy.

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de Cruz, Helen. "8 Philosophical Thought Experiments That I Illustrated to Broaden Your Mind." 2018.

Eight thought experiments, beautifully illustrated and explained by philosopher Helen de Cruz.

Falk, Dan. "Armchair Science." 2017.

A popular piece on the epistemology of scientific thought experiments.

Knobe, Joshua. "Thought Experiments." *Scientific American* 305.5 (November 2011): 56–59.

Introduces "experimental philosophy": the attempt brings experimental methods to bear on philosophical issues, typically by testing people's intuitions about thought experiments.

Schick, Theodore, and Lewis Vaughn, eds. *Doing Philosophy: An Introduction through Thought Experiments*. 4th ed. New York: McGraw-Hill, 2010.

Standard topics in philosophy (ethical issues, time travel, existence of god, and so on) covered by classic articles and commentaries and illustrated by thought experiments, often in the form of a short story.

***Sciences et Avenir*. 1947–.**

This popular French magazine (similar to *Scientific American*) devoted an entire issue (January–February 2008) to thought experiments. Many classic examples are presented with beautiful graphics and accessible discussions of them (in French).

Tittle, Peg. *What If . . . : Collected Thought Experiments in Philosophy*. New York: Pearson-Longman, 2005.

About a hundred thought experiments briefly described and discussed.

Anthologies

As interest in thought experiments grows, the number of articles, conferences, and anthologies can be expected to grow as well. Horowitz and Massey 1991 has been very influential in shaping the field. DePaul and Ramsey 2002 and Gendler and Hawthorne 2002 are important contributions to the issues of intuition and the relation between conceivability and possibility. Frappier, et al. 2013 and Ierodiakonou and Roux 2011 both deal with a range of issues and often engage in debate with earlier authors on thought experiments. Stuart, et al. 2018 contains thirty-one chapters on various topics, and Borstner and Gartner 2017 focuses on the important work of Nenad Miščević. PhilPapers: Thought Experiments is also an excellent, exhaustive resource.

Borstner, Bojan and Gartner, Smiljana (eds). *Thought Experiments between Nature and Society: A Festschrift for Nenad Miščević*. Newcastle upon Tyne: Cambridge Scholars Publishing, 2017.

A collection celebrating the important work of Nenad Miščević on thought experiments. Contains three sections: Thought Experiments – General, Thought Experiments and Nature, and Thought Experiments and Society. Besides an introduction and autobiographical philosophical reflection by Miščević, the volume contains 22 chapters, each with replies from Miščević.

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dePaul, Michael, and William Ramsey, eds. *Rethinking Intuition: The Psychology of Intuition & Its Role in Philosophical Inquiry*. Lanham, MD: Rowman & Littlefield, 2002.

Contains much material that is closely associated with and relevant to thought experiments, especially on the topic of intuition.

Frappier, Mélanie, Letitia Meynell, and James Robert Brown, eds. *Thought Experiments in Philosophy, Science, and the Arts*. New York and Abingdon, UK: Routledge, 2013.

A diverse collection of recent work on thought experiments.

Gendler, Tamar, and John Hawthorne, eds. *Conceivability and Possibility*. New York and Oxford: Clarendon Press, 2002.

Contains much material closely associated with and relevant to thought experiments, especially on what sense, if any, possibility is implied by conceivability.

Horowitz, T., and G. Massey, eds. *Thought Experiments in Science and Philosophy*. Lanham, MD: Rowman & Littlefield, 1991.

Contains several excellent and influential articles on a wide range of topics. It is currently out of print, but a PDF of the entire book is available online.

Ierodiakonou, Katerina, and Sophie Roux, ed. *Thought Experiments in Methodological and Historical Contexts*. Leiden and Boston: E. J. Brill, 2011.

A collection of essays on a variety of topics, many of them historical, others engaging in 21st-century debates.

Jackson, Magdalena Balcerak, ed. PhilPapers: Thought Experiments.

A repository of philosophical papers on thought experiments maintained by Magdalena Balcerak Jackson, with over four hundred entries.

Stuart, Michael T., Yiftach Fehige, and James Robert Brown. *The Routledge Companion to Thought Experiments*. Abingdon, UK, and New York: Routledge, 2018.

The book is split into four sections: historical analysis (seven chapters), domain specific analysis (seven chapters), contemporary philosophical approaches (five chapters), and outstanding issues or challenges (eleven chapters). Also contains an index of thought experiments by field, organized roughly chronologically.

Special Journal Issues

There have been a number of special issues of journals dedicated to the topic of thought experiments, including Miščević 2007a, Miščević 2007b, Miščević 2018, Fehige and Stuart 2014, Stuart and Fehige 2020, de Mey 2003, and Angelucci and Arcangeli 2019.

Angelucci, Adriano, and Margherita Arcangeli, eds. *Special Issue: New Perspectives on Philosophical Thought Experiments*. *Topoi* 38.4 (2019).

A special issue containing papers by, among others, Marco Buzzoni, Julia Langkau, Roy Sorensen, and Sören Häggqvist.

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de Mey, Tim, ed. *Special Issue: Thought Experiments*. *Philosophica* 72 (2003).

An important early special issue, including papers on thought experiments in mathematics, social studies of science, cosmogonies, and personal identity. Also includes Tim de Mey's influential paper "The Dual Nature of Thought Experiments" (pp. 61–78).

Fehige, Yiftach, and Michael T. Stuart, eds. *Special Issue: Thought Experiments*. *Perspectives on Science* 22.2 (2014).

Presents a collection of papers on thought experiments and (1) history of philosophy, (2) phenomenology, (3) fiction, and (4) cognitive science.

Miščević, Nenad, ed. *Special Issue: James Robert Brown; Thought Experiments and Platonism, Part One*. *Croatian Journal of Philosophy* 7.1 (2007a).

Part 1 of a two-issue collection of papers dedicated to the thought of James R. Brown, introduced by Nenad Miščević. The issue contains eleven papers that attack, defend, or question Brown's account of thought experiments.

Miščević, Nenad, ed. *Special Issue: James Robert Brown; Thought Experiments and Platonism, Part Two*. *Croatian Journal of Philosophy* 7.2 (2007b).

The second installment of the two-issue collection of papers dedicated to the thought of James R. Brown, containing a reply by Brown.

Miščević, Nenad, ed. *Special Issue: On Thought Experiments*. *Croatian Journal of Philosophy* 18.1 (2018).

Brings together entries on thought experiments in ethics, mathematics, and law, as well as some historical papers, and others on the relation between thought experiments, computer simulations, and laboratory experiments.

Stuart, Michael T., and Yiftach Fehige, eds. *Special Issue: Thought Experiments in the History of Philosophy of Science*. *HOPOS: The Journal of the International Society for the History of Philosophy of Science* 10 (2020).

Gathers together new work on the history of the philosophy of thought experiments.

Historical Analyses

Most writings on thought experiments are concerned with how they work in general, and provide a range of examples in arguing the case. However, many important articles focus on thought experiments from a particular period, finding features that deserve historical or philosophical attention. Becker 2018, Corcilius 2018, Ierodiakonou 2005, Ierodiakonou 2018, and Rescher 1991 address thought experiments in Antiquity, while King 1991 and McGinnis 2018 survey their use in the Middle Ages. Kühne 2005 covers much of the history of thought experiments. Arthur 2018, El Skaf 2018, Gendler 1998, and Palmerino 2018 focus on mechanics during the scientific revolution.

Arthur, Richard T. W. "Thought Experiments in Newton and Leibniz." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 111–127. Abingdon, UK, and New York: Routledge, 2018.

Identifies an important common feature of Newton and Leibniz's thought experiments, and considers them in the context of Descartes, Hobbes, and Locke.

Becker, Alexander. "Thought Experiments in Plato." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 44–56. Abingdon, UK, and New York: Routledge, 2018.

Discusses several of Plato's thought experiments with a special focus on the Republic. Discusses Plato's uses of myth, simile, and dialogue and his account of how we learn from fiction.

Corcilius, Klaus. "Aristotle and Thought Experiments." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 57–76. Abingdon, UK, and New York: Routledge, 2018.

Examines a number of Aristotle's thought experiments, which Aristotle uses to compensate for lack of data.

El Skaf, Rawad. "The Function and Limit of Galileo's Falling Bodies Thought Experiment." In *Special Issue: On Thought Experiments*. Edited by Nenad Miščević. *Croatian Journal of Philosophy* 18.1 (2018): 37–58.

Argues that philosophers writing on Galileo's falling bodies thought experiment have missed crucial historical details.

Gendler, Tamar. "Galileo and the Indispensability of Scientific Thought Experiment." *British Journal for the Philosophy of Science* 49 (1998): 397–424.

A close textual analysis of the aim and epistemic output of Galileo's falling bodies thought experiment.

Ierodiakonou, Katerina. "Ancient Thought Experiments: A First Approach." *Ancient Philosophy* 25 (2005): 125–140.

Raises interesting questions concerning the nature of Greek and medieval thought experiments.

Ierodiakonou, Katerina. "The Triple Life of Ancient Thought Experiments." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 31–43. Abingdon, UK, and New York: Routledge, 2018.

Argues that thought experiments were used by the pre-Socratics for three main purposes: to support, to attack, and to induce suspension of judgement on philosophical claims.

King, Peter. "Mediaeval Thought-Experiments: The Metamethodology of Mediaeval Science." In *Thought Experiments in Science and Philosophy*. Edited by Tamara Horowitz and Gerald Massey, 43–64. Savage, MD: Rowman & Littlefield, 1991.

Describes the subtle techniques used by medieval philosophers who argued by means of thought experiments.

Kühne, Ulrich. *Die Methode des Gedankenexperiments*. Frankfurt: Suhrkamp, 2005.

Extensive historical account of thought experiments, rich in detail (in German).

Kukkonen, Taneli. "Ibn Sīnā and the Early History of Thought Experiments." *Journal of the History of Philosophy* 52 (2014): 433–459.

Argues that Ibn Sīnā was an important precursor of later philosophers to write about thought experiments, as he was the first Aristotelian philosopher to attempt to identify the processes involved in positing hypothetical scenarios.

McGinnis, Jon. "Experimental Thoughts on Thought Experiments in Medieval Islam." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 77–91. Abingdon, UK, and New York: Routledge, 2018.

Careful consideration of the use of thought experiments in medieval Islam, especially those of Ibn Sīnā, Ibn al-Haytham, and al-Ghazālī.

Palmerino, Carla Rita. "Discussing What Would Happen: The Role of Thought Experiments in Galileo's Dialogues." *Philosophy of Science* 85 (2018): 906–918.

Considers the dialectical context of Galileo's thought experiments, showing that the interlocutors in Galileo's dialogues often disagree about the conclusions of the thought experiments, and even dismiss each other's thought experiments as misleading.

Rescher, Nicholas. "Thought Experiments in Presocratic Philosophy." In *Thought Experiments in Science and Philosophy*. Edited by Tamara Horowitz and Gerald Massey, 31–42. Savage, MD: Rowman & Littlefield, 1991.

An account of thought experiments by pre-Socratic philosophers.

Discipline-Based Analyses

Rather than focusing on historical periods or actors, some philosophers and historians focus instead on entire disciplines. This allows them to draw connections and comparisons between disciplines, and track the changing uses of thought experiments in a single discipline, over time.

Mathematics

The standard view in mathematics is that only proofs can provide evidence of theorems. Nevertheless, pictures, diagrams, and visual reasoning that are similar to thought experiments often play a role. The nature and legitimacy of this role is debated. Brown 2008 argues for the legitimacy of picture proofs, while Giaquinto 2007 is skeptical, though the author considers diagrams to be of great value. Buzzoni 2011 considers differences among kinds of mathematical thought experiments. Lakatos 1976 is a famous work on forms of reasoning in mathematics. Mancosu, et al. 2005 is an important collection of papers on visual reasoning in mathematics, while Shin 2009 explores the rules of diagrammatic reasoning. Starikova and Giaquinto 2018 pursues the visual and experimental nature of mathematical thought experiments.

Brown, James Robert. *Philosophy of Mathematics: A Contemporary Introduction to the World of Proofs and Pictures*. London and New York: Routledge, 2008.

Argues for Platonism in general and for the positive role of pictures as proofs in mathematics. In particular, provides pictorial examples and claims that they are genuine rigorous proofs. Originally published in 1999.

Buzzoni, Marco. "On Mathematical Thought Experiments." *Epistemologia* 34 (2011): 61–88.

Argues that the distinction between empirical and thought experiments holds for applied mathematics, but it does not for pure mathematics.

Giaquinto, Marcus. *Visual Thinking in Mathematics: An Epistemological Study*. Oxford: Clarendon Press, 2007.

Argues that visualization can play an important role in mathematical discovery, but resists going so far as to claim visualization can also provide justification.

Lakatos, Imre. *Proofs and Refutations*. Cambridge, UK: Cambridge University Press, 1976.

A study of the development of geometrical polyhedra via thought experiments.

Mancosu, Paolo, Klaus Frovin Jørgensen, and Stig Andur Pedersen, eds. *Visualization, Explanation, and Reasoning Styles in Mathematics*. Dordrecht, The Netherlands: Springer, 2005.

The first part contains a number of papers exploring the role of visualization in mathematics.

Shin, Sun-Joo. *The Logical Status of Diagrams*. Cambridge, UK: Cambridge University Press, 2009.

An interesting study of diagrams and diagrammatic reasoning, which provides rules and justifications for their use.

Starikova, Irina, and Marcus Giaquinto. "Thought Experiments in Mathematics." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 257–278. Abingdon, UK, and New York: Routledge, 2018.

Introduces and discusses several kinds of mathematical thought experiments, drawing on graph theory, knot theory, and geometric group theory. Interestingly, they argue that such thought experiments can provide *empirical* evidence for mathematical claims.

Physics

Thought experiments have always played a large role in physics. Some of the first things that were identified as thought experiments (by Ørsted) concerned what we would (now) call physical systems. Early views on thought experiments in physics come from Mach (see Thought Experiments as Experiments), Popper 1959, and Yourgrau 1967, and they became a central focus in the debates beginning in the 1980s. A good overview can be found in Peacock 2018.

Peacock, Kent A. "Happiest Thoughts: Great Thought Experiments of Modern Physics." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 211–242. Abingdon, UK, and New York: Routledge, 2018.

Provides a general overview of thought experiments in physics, and considers how the role of thought experiments has changed as the subjects and tools of physics have changed.

Popper, Karl. "On the Use and Misuse of Imaginary Experiments, Especially in Quantum Theory." In *The Logic of Scientific Discovery*. By Karl Popper, 442–456. London: Hutchinson, 1959.

Presents an early taxonomy of thought-experimental aims.

Yourgrau, Wolfgang. "On Models and Thought Experiments in Quantum Theory." *Monatsberichte der Deutschen Akademie der Wissenschaften zu Berlin* 9 (1967): 874–886.

Reviews many thought experiments in physics, as well as views that physicists and philosophers have had about them. Conjectures that thought experiments are "bold inferences" about theoretical consequences, which were needed to test the "shock-resistance" of quantum mechanics.

(Meta)Philosophy

Philosophy appears to be just as indebted to thought experiments as physics and mathematics are. The role played by thought experiments, however, is just as often lamented as lauded. Sören Häggqvist has been discussing the epistemological status of thought

experiments in metaphilosophy since Häggqvist 1996. He provides a good overview of developments in Häggqvist 2019 (see also Cohnitz and Häggqvist 2018). Häggqvist (along with Timothy Williamson in Williamson 2007) sees an important role for thought experiments as validating premises in modal arguments. Ichikawa and Jarvis 2009 and Malmgren 2011 criticize Williamson's proposal. Brown 2011 questions the assumption that thought experiments confirm premises in the way Williamson thinks. Machery 2011 considers thought experiments in philosophy more generally, and argues that many of them fail to provide any evidence. See also Experimental Philosophy, which describes a new subfield of philosophy that has (among other things) called the evidential use of philosophical thought experiments into question.

Brown, Jessica. "Thought Experiments, Intuitions and Philosophical Evidence." *Dialectica* 65 (2011): 493–516.

Distinguishes between different kinds of premises that thought experiments can support. (E.g., does the Gettier thought experiment support the premise that a given subject has a justified true belief without knowledge, or only that a given subject seems to be in such a state?)

Cohnitz, Daniel, and Sören Häggqvist. "Thought Experiments in Current Metaphilosophical Debates." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 406–424. Abingdon, UK, and New York: Routledge, 2018.

Summarizes more than a decade of metaphilosophical debate, and discusses developments on several related issues like conceivability, modal intuition, and experimental philosophy.

Häggqvist, Sören. *Thought Experiments in Philosophy*. Stockholm: Almqvist & Wiksell, 1996.

Argues that philosophical thought experiments provide premises for modal arguments. Presents a formalization schema for such modal arguments, and considers five philosophical thought experiments as case studies.

Häggqvist, Sören. "Thought Experiments, Formalization, and Disagreement." *Topoi* 38 (2019): 801–810.

Reviews the recent literature on formalizing thought experiments, and advocates for a new proposal. Also argues against "Gettier myopia": the sole focus on Gettier cases in formalizations of philosophical thought experiments.

Ichikawa, Jonathan, and Benjamin Jarvis. "Thought-Experiment Intuitions and Truth in Fiction." *Philosophical Studies* 142 (2009): 221–246.

Argues against Williamson's view and for an account that appeals to truth in fiction.

Machery, Edouard. "Thought Experiments and Philosophical Knowledge." *Metaphilosophy* 42 (2011): 191–214.

Uses results in psychology and experimental philosophy to argue against evidential uses of thought experiments in philosophy. Williamson is the prime target.

Malmgren, Anna-Sara. "Rationalism and the Content of Intuitive Judgements." *Mind* 120 (2011): 263–327.

Argues against Williamson that intuitive judgements in thought experiments are not judgements of counterfactuals, but rather a kind of metaphysical possibility judgement. This is used to support a kind of rationalism.

Williamson, Timothy. *The Philosophy of Philosophy*. Malden, MA, and Oxford: Blackwell, 2007.

Thought experiments are considered as parts of counterfactual reasoning. Thought experiments are epistemologically justified insofar as use ordinary cognitive mechanisms, which are themselves justified.

Theology

The distinction between theology and philosophy isn't easy to draw, and so perhaps we should expect to find thought experiments in theology. Indeed, Fehige 2009, Fehige 2014, and Fehige 2018 argue that there are many thought experiments in theology, and consider ways these might work.

Fehige, Yiftach. "Thought Experimenting with God: Revisiting the Ontological Argument." *Neue Zeitschrift für Systematische Theologie und Religionsphilosophie* 51 (2009): 249–267.

Explores theological arguments through the lens of thought experiments.

Fehige, Yiftach. "Intellectual Tennis without a Net? Thought Experiments and Theology." *Theology and Science* 12 (2014): 378–395.

Discusses theological thought experiments and some theological assumptions important for "non-theological" thought experiments, like Newton's bucket.

Fehige, Yiftach. "Theology and Thought Experiments." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 183–194. Abingdon, UK, and New York: Routledge, 2018.

Considers six ways that the literature on thought experiments might intersect with theology, for example, theologians might dismiss the use of thought experiments, and the use of thought experiments in theology and science might be used to defend the methodological rationality of theology.

Biology

Biological thought experiments were not the focus of much attention until recently. Schlaepfer and Weber 2018 considers why this might be. Lennox 1991 argues that Darwin used thought experiments effectively to provide "how-possible explanations," and Buzzoni 2015 argues that there is something that makes biological thought experiments special: their focus on teleology.

Buzzoni, Marco. "Causality, Teleology, and Thought Experiments in Biology." *Journal for General Philosophy of Science* 46 (2015): 279–299.

Argues that thought experiments in biology include teleology, not as an ontological assumption, but as a methodological one. This makes them different from thought experiments in other domains of science.

Lennox, James G. "Darwinian Thought Experiments: A Function for Just-So Stories." In *Thought Experiments in Science and Philosophy*. Edited by Tamara Horowitz and Gerald Massey, 223–245. Savage, MD: Rowman & Littlefield, 1991.

"Just so stories" need not be true, but they can nevertheless shed light on something by showing how that something might be possible. Lennox claims this is important for Darwin.

Schlaepfer, Guillaume, and Marcel Weber. "Thought Experiments in Biology." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 243–256. Abingdon, UK, and New York: Routledge, 2018.

Discusses several roles for thought experiments in biology, and the role empirical evidence should play in them.

Economics

One might think that economics makes heavy use of thought experiments, for example, economists consider what would happen to the economy if war broke out, or if taxes were lowered, etc. Thoma 2016 argues that this is indeed the case. Schabas 2008 provides a classic example from Hume, and Herfeld 2019 discusses another from Ragnar Frisch. Schabas 2018, however, argues that in fact, there aren't that many thought experiments in economics.

Herfeld, Catherine. "Imagination Rather than Observation in Econometrics: Ragnar Frisch's Hypothetical Experiments as Thought Experiments." ***HOPOS: The Journal of the International Society for the History of Philosophy of Science*** **9 (2019): 35–74.**

Identifies several roles for thought experiments in economics, focusing on one in particular: facilitating the definition and measurement of a theoretical concept, which served to bridge theory and data.

Schabas, Margaret. "Hume's Monetary Thought Experiments." ***Studies in History and Philosophy of Science, Part A*** **39.2 (2008): 161–169.**

Demonstrates that David Hume used thought experiments to make some remarkable breakthroughs in monetary economics. In the actual world, money is never neutral for Hume; only in thought experiments does a sudden growth in the money stock result in an identical and hence neutral increase in the price level.

Schabas, Margaret. "Thought Experiments in Economics." In ***The Routledge Companion to Thought Experiments*****. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 171–182. Abingdon, UK, and New York: Routledge, 2018.**

Denies that several alleged thought experiments in economics are genuine thought experiments.

Thoma, Johanna. "On the Hidden Thought Experiments of Economic Theory." ***Philosophy of the Social Sciences*** **46 (2016): 129–146.**

Argues that thought experiments are prevalent in economics, and discusses their relation to economic models.

Politics

Political philosophy from Plato to Hobbes to Rawls appears to be full of thought experiments; see Miščević 2012 and Miščević 2013.

Miščević, Nenad. "Plato's ***Republic*** **as a Political Thought Experiment."** ***Croatian Journal of Philosophy*** **12 (2012): 153–165.**

Characterizes and analyzes Plato's *Republic* as a thought experiment.

Miščević, Nenad. "Political Thought Experiments from Plato to Rawls." In ***Thought Experiments in Science, Philosophy, and the Arts*****. Edited by Mélanie Frappier, Letitia Meynell, and James Robert Brown, 191–206. New York: Routledge, 2013.**

Proposes a general structure for political thought experiments.

Chemistry

Chemistry appears to differ from other domains of science, according to Snooks 2006, at least insofar as it does not employ thought experiments. Why might this be? This is an open question.

Snooks, Rodney J. "Another Scientific Practice Separating Chemistry from Physics." *Foundations of Chemistry* 8 (2006): 255–270.

Points out that chemistry has no thought experiments and draws the anti-reductionist conclusion that chemistry is not reducible to physics.

History

What would have happened if Germany had won World War II? "Counterfactual history" asks questions like this, as a way of establishing causal connections or illuminating the relative contingency of certain actual or possible events. Green 2020, Reiss 2009, and Weber and de Mey 2003 discuss the epistemological reasons for and against the use of this method in history.

Green, Catherine. "Historical Counterfactuals, Transition Periods, and the Constraints on Imagination." *HOPOS: The Journal of the International Society for the History of Philosophy of Science* 10 (2020).

Compares several positions on the use of thought experiments in history, and argues that they are justified when they are used to show the contingency of historical events.

Reiss, Julian. "Counterfactuals, Thought Experiments and Singular Causal Inference in History." *Philosophy of Science* 76 (2009): 712–723.

Argues that thought experiments are used in history to identify difference makers, which are not to be identified as causes.

Weber, Erik, and Tim de Mey. "Explanation and Thought Experiments in History." *History and Theory* 42 (2003): 28–38.

Explores the nature and legitimacy of counterfactual history.

Epistemological Accounts of Thought Experiments

The main epistemological problem concerning thought experiments is simply this: How is it possible to learn something new about the world just by thinking? If our knowledge is based solely on empirical experience, then this is indeed a big problem. Of course, one possible answer is that we in fact do not acquire any knowledge in this way and that thought experiments are dangerous illusions. (See Skepticism about the Epistemological Efficacy of Thought Experiments.) Most philosophers, however, acknowledge that thought experiments are highly useful tools and try to give accounts where we do acquire knowledge—but in a way that is compatible with empiricism. Some, however, go so far as to deny empiricism and embrace a priori intuition as the best way to make sense of thought experiments. There is a range of rival views, but there is no consensus at all on which is the most promising. Some of these consider thought experiments to be arguments, explorations of conceptual frameworks, manipulations of mental models, preconditions for the possibility of real experiments, fictions, genuine experiments, or means of gaining a priori knowledge about the laws of nature. These will be covered in this section. A few that are not so easily classified are included as *additional alternative* views. This is far from exhausting the accounts of thought experiments that have been or could be articulated.

Thought Experiments as Arguments

The *argument* view holds that a thought experiment is really a (possibly disguised) argument and should be evaluated as such after it has been reconstructed: Are the premises empirically plausible? Does the conclusion follow (deductively or inductively) from those premises? Norton 1991 is the original source of this view, while Norton 1996 and Norton 2004 present later refinements and developments. There are several critics of this view, as presented in Bishop 1999, Brendel 2018, and Stuart 2016.

Bishop, Michael. "Why Thought Experiments Are Not Arguments." *Philosophy of Science* 66 (1999): 534–541.

Bishop claims that thought experiments cannot be identified with arguments, since the same thought experiment (Einstein's clock in the box) is best reconstructed as two different arguments.

Brendel, Elke. "The Argument View: Are Thought Experiments Mere Picturesque Arguments?" In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 281–292. Abingdon, UK, and New York: Routledge, 2018.

A very careful breakdown of Norton's views on thought experiments.

Norton, John D. "Thought Experiments in Einstein's Work." In *Thought Experiments in Science and Philosophy*. Edited by Tamara Horowitz and Gerald Massey, 129–148. Savage, MD: Rowman & Littlefield, 1991.

Reconstructs many of Einstein's thought experiments as arguments.

Norton, John D. "Are Thought Experiments Just What You Thought?" *Canadian Journal of Philosophy* 26 (1996): 333–366.

Claims that a thought experiment is really a disguised argument, either deductive or inductive. To be a good thought experiment, the premises should be well supported (typically, this means empirically supported), and the argument should be deductively valid or inductively cogent.

Norton, John D. "Why Thought Experiments Do Not Transcend Empiricism." In *Contemporary Debates in Philosophy of Science*. Edited by Christopher Hitchcock, 44–66. Malden, MA, and Oxford: Blackwell, 2004.

This may be the most thorough presentation of Norton's view. It contains criticisms of several rival accounts, as well.

Stuart, Michael T. "Norton and the Logic of Thought Experiments" *Axiomathes* 26 (2016): 451–466.

Argues that Norton's view is in tension with Norton's own work on induction, and suggests an empiricist-friendly way out.

Thought Experiments as Explorations of Conceptual Frameworks

Kuhn 1977 proposes an account of thought experiments that focuses on their role in establishing or undermining conceptual frameworks (paradigms). A good thought experiment can bring out a tension in a framework that would not otherwise be apparent. Among late-20th- and early-21st-century studies, Gendler 1998 comes close to the views in Kuhn 1977 but also goes well beyond in a number of respects. Gendler 2007 examines the important notion of intuition, and van Dyck 2003 applies a Kuhnian framework to explore Heisenberg's microscope thought experiment.

Gendler, Tamar Szabó. "Galileo and the Indispensability of Scientific Thought Experiment." *British Journal for the Philosophy of Science* 49 (1998): 397–424.

Criticizes Norton's argument view and Brown's Platonism, and argues in favor of a view that emphasizes conceptual framework features.

Gendler, Tamar Szabó. "Philosophical Thought Experiments, Intuitions, and Cognitive Equilibrium." In *Philosophy and the Empirical*. Edited by Peter A. French and Howard K. Wettstein, 68–89. Boston and Oxford: Blackwell, 2007.

A thorough articulation of the author's view on thought experiments with special emphasis on the notion of intuition.

Kuhn, Thomas S. "A Function for Thought Experiments." In *The Essential Tension: Selected Studies in Scientific Tradition and Change*. Edited by Thomas S. Kuhn, 240–265. Chicago: University of Chicago Press, 1977.

A classic article written before *The Structure of Scientific Revolutions* but containing similar concepts, for example, paradigm, anomaly. The main thesis is that thought experiments can bring out conceptual problems that are not explicit in a paradigm, which can in turn lead to a new framework. A good thought experiment teaches us about our framework and the world simultaneously.

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van Dyck, Maarten. "The Roles of One Thought Experiment in Interpreting Quantum Mechanics: Werner Heisenberg Meets Thomas Kuhn." *Philosophica* 72 (2003): 79–103.

A Kuhnian account of Heisenberg's microscope thought experiment.

Thought Experiments as Mental Models

The "mental models" view, proposed independently in Miščević 1992, Nersessian 1992, Nersessian 1993, and Nersessian 2018, holds that we make models of reality in our minds. Once this is done, it is easy to "see" what we have created and quickly to read off properties of the model. We construct a mental model as we hear or read a narrative, and we observe the conclusions from examining the model: this explains, among other things, why our inferences are often so quick. In terms of number of authors, this is probably the most popular view of thought experiments, though Brown, Häggqvist, and Norton have criticized it as being "merely" descriptive and thus epistemologically irrelevant.

Miščević, Nenad. "Mental Models and Thought Experiments." *International Studies in the Philosophy of Science* 6 (1992): 215–226.

This paper, like Nersessian 1992, is a classic presentation of the idea of mental models and how they are employed in the case of thought experiments.

Nersessian, Nancy. "How Do Scientists Think? Capturing the Dynamics of Conceptual Change in Science." In *Cognitive Models of Science*. Edited by Ronald Giere, 3–44. Minneapolis: University of Minnesota Press, 1992.

Like Miščević 1992, this is a standard presentation of the idea of mental models and how they are employed in thought experiments.

Nersessian, Nancy. "In the Theoretician's Laboratory: Thought Experimenting as Mental Modeling." *Proceedings of the Philosophy of Science Association* 2 (1993): 291–301.

A further articulation and defense of the mental models account of thought experiments.

Nersessian, Nancy. "Cognitive Science, Mental Modeling, and Thought Experiments." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 309–326. Abingdon, UK, and New York: Routledge, 2018.

A recent update of the mental models view of thought experiments.

Thought Experiments as Experiments

Ernst Mach inspired many to take the "experiment" in "thought experiment" seriously. For Mach, thought experiments proceed by a variation of variables, but instead of varying a physical quantity, we vary "imagined conditions." We perform "deliberate" manipulations and "observe" the changes that result (Mach 1976, p. 145). Mach 1988 discusses many individual thought experiments, while Mach 1976 presents a more general philosophical analysis. Sorensen 1992 follows Mach in a sense, arguing that thought experiments are real experiments, whose outcomes are justified by the fact that our cognitive capacities were fine-tuned by evolution. Gooding 1992

discusses thought experiments as experiments, emphasizing their embodied nature, and Kujundzic 1998 supports the idea that thought experiments do function by mental variation of some kind. Stuart 2016 argues that the epistemology of laboratory experiments can fruitfully be applied to thought experiments.

Gooding, David C. "What Is Experimental about Thought Experiments?" ***PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association*** **(1992): 280–290.**

Thought experiments require visualization and manipulation, which require physical embodiment. It is this embodiment that makes thought experiments experiments and not arguments.

Kujundzic, Nebojsa. "The Role of Variation in Thought Experiments." ***International Studies in the Philosophy of Science*** **12 (1998): 239–243.**

Discusses the role of mental variation in thought experiments.

Mach, Ernst. ***Knowledge and Error*****. Translated by Thomas J. McCormack, 134–147. Dordrecht, The Netherlands: Reidel, 1976.**

Outlines a number of uses for thought experiments, and develops the view according to which thought experiments are really experiments. Originally published as "Über Gedankenexperimente," in *Erkenntnis und Irrtum* (Leipzig: Verlag von Johann Ambrosius Barth, 1905), 181–197.

Mach, Ernst. ***Die Mechanik in ihrer Entwicklung: Historisch-Kritisch Dargestellt*****. 7th ed. Berlin: Akademie Verlag, 1988.**

A classic in the history and philosophy of science. Thought experiments are discussed throughout. The famous thought experiments of Steven and Newton are discussed at length. Originally published 1897.

Sorensen, Roy. ***Thought Experiments*****. Oxford: Oxford University Press, 1992.**

Provides a naturalistic account of thought experiments as experiments, which are experiments that purport to achieve their aims "without the benefit of execution" (p. 186).

Stuart, Michael T. "Norton and the Logic of Thought Experiments." ***Axiomathes*** **26 (2016): 451–466.**

Takes five criteria for a good laboratory experiment (from Allan Franklin's 1986 classic, *The Neglect of Experiment* [Cambridge, UK: Cambridge University Press]), and applies them to thought experiments.

Kantian Accounts

Kant famously claimed that our minds contribute to our knowledge of the world. Space, time, and causation, for instance, are not part of the noumenal world (which is unknowable), but are our own contributions to experience. Buzzoni 2008, Buzzoni 2011, and Buzzoni 2018 are written by one of the very few philosophers to provide a Kantian account of thought experiments. For Buzzoni, real experiments without thought experiments are blind, and thought experiments without real experiments are empty.

Buzzoni, Marco. ***Thought Experiment in the Natural Sciences*****. Wurzburg, Germany: Königshausen & Neumann, 2008.**

An extensive attempt to understand thought experiments in terms of Kant's philosophical outlook. Translated from the Italian.

Buzzoni, Marco. "Kant und das Gedankenexperimentieren." ***Deutsche Zeitschrift für Philosophie*** **59 (2011): 93–107.**

A further development of a Kantian approach to thought experiments.

Buzzoni, Marco. "Kantian Accounts of Thought Experiments." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 327–341. Abingdon, UK, and New York: Routledge, 2018.

Provides an overview of different possible Kantian accounts of thought experiments and updates Buzzoni's view.

Phenomenological Accounts

Phenomenologists take our first-person experience as the object and starting point of philosophical investigation. Phenomenological accounts of thought experiments therefore ask about the structure of the experience of performing a thought experiment, the objects of imagination, and the role of the body in thought experimental cognition. Hopp 2014 defends a phenomenological account of thought experiments that is compatible with Brown's rationalism, while Wiltsche 2018 develops his own Husserl-inspired view.

Hopp, Walter. "Experiments in Thought." *Perspectives on Science* 22 (2014): 242–263.

Discusses the objects of thought experiments, which are argued to be uninstantiated universals and the relations between them.

Wiltsche, Harald A. "Phenomenology and Thought Experiments: Thought Experiments as Anticipation Pumps." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 342–365. Abingdon, UK, and New York: Routledge, 2018.

Considers how the action of performing a thought experiment can shed light on the different ways that objects and events appear in the imagination, how our background knowledge figures into the action of thought experimentation, and how we can learn from the process.

Rationalist Accounts

The Platonic view holds that some thought experiments can provide a priori knowledge of nature. It is generally thought to be implausible but serves a useful role as a foil for the articulation of other accounts that take some form of empiricism for granted. Brown 2010 and Koyré 1968 are defenders of the view, while Arthur 1999, Grundmann 2018, Häggqvist 2007, and Norton 2004 are highly critical.

Arthur, Richard. "On Thought Experiments as A Priori Science." *International Studies in the Philosophy of Science* 13 (1999): 215–229.

Agrees that thought experiments are a priori but denies any sort of Platonism.

Brown, James Robert. *Laboratory of the Mind: Thought Experiments in the Natural Sciences*. 2d ed. London: Routledge, 2010.

An early work with several standard examples and a taxonomy; argues for a rationalistic, or Platonistic account of thought experiments. Originally published in 1991.

Grundmann, Thomas. "Platonism and the A Priori in Thought Experiments." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 293–308. Abingdon, UK, and New York: Routledge, 2018.

Identifies and criticizes the main arguments for Platonism about thought experiments.

Häggqvist, Sören. "The A Priori Thesis: A Critical Assessment." *Croatian Journal of Philosophy* 19 (2007): 47–61.

Raises a number of objections to Brown's view concerning its explanatory scope and power.

Koyré, Alexandre. *Metaphysics and Measurement*. London: Chapman and Hall, 1968.

A classic work by a great historian of science who praised Galileo for doing physics a priori.

Norton, John D. "Why Thought Experiments Do Not Transcend Empiricism." In *Contemporary Debates in Philosophy of Science*. Edited by Christopher Hitchcock, 44–66. Malden, MA, and Oxford: Blackwell, 2004.

Contains criticisms of several rival accounts, including Brown's Platonism.

Fictionalist Accounts

If Nersessian is right that thought experiments have a narrative character, perhaps we can use resources from the epistemology of fiction to understand how thought experiments enable us to learn about reality. Meynell 2014, Meynell 2018, and Salis and Frigg 2019 use the work of Kendall Walton in aesthetics to characterize the role of imagination in thought experiments. Roughly, we "make-believe" that something is true, and reason accordingly, given certain socially enforced constraints.

Meynell, Letitia. "Imagination and Insight: A New Account of the Content of Thought Experiments." *Synthese* 191 (2014): 4149–4168.

Applies a Waltonian conception of imagination to questions about thought experiments.

Meynell, Letitia. "Images and Imagination in Thought Experiments." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 498–511. Abingdon, UK, and New York: Routledge, 2018.

Extends the Waltonian account, focusing on the role of images as "props" for the imagination.

Salis, Fiora, and Roman Frigg. "Capturing the Scientific Imagination." In *The Scientific Imagination*. Edited by Peter Godfrey-Smith and Arnon Levy, 17–50. New York: Oxford University Press, 2019.

Adopts Walton's account, and argues that the kind of imagination that is epistemologically relevant for thought experiments is "propositional imagination."

Additional Alternatives and Special Points of View

There are important works that do not fit into any of the categories mentioned elsewhere. McAllister 1996 and McAllister 2004 stress the need for a somewhat abstract "phenomena" in order for thought experiments to work. Stuart 2020 argues that Feyerabend also had a unique position on thought experiments.

McAllister, James. "The Evidential Significance of Thought Experiments in Science." *Studies in History and Philosophy of Science* 27 (1996): 233–250.

Argues that phenomena, a particular conceptualization of observation, plays a crucial role in the development of thought experiments.

McAllister, James. "Thought Experiments and the Belief in Phenomena." ***Proceedings of the 2002 Biennial Meeting of the Philosophy of Science Association. Philosophy of Science*** **71 (2004): 1164–1175.**

A development of the preceding article, claiming that phenomena play a crucial role in the development of thought experiments.

Stuart, Michael T. "Telling Stories in Science: Feyerabend and Thought Experiments." ***HOPOS: The Journal of the International Society for the History of Philosophy of Science*** **10 (2020).**

Argues that for Feyerabend, thought experiments are a special kind of story, whose importance for science is both epistemological and ethical.

Interactions with Related Issues and Other Philosophical Concerns

Since thought experiments are ubiquitous but difficult to define, it is worthwhile approaching their study from many different angles. This section points out some of these, including how thought experiments produce understanding (rather than knowledge) and play a role in education, how they relate to other representational tools like computer simulations and literary fictions, and what role intuition plays in thought experiments. This section also introduces the many skeptics about the epistemological efficacy of thought experiments, and some replies to them.

Other Epistemological Aims: Understanding and Pedagogy

The most controversial claim in the literature about thought experiments has been that thought experiments provide genuinely new knowledge. But knowledge is not the only, or perhaps even the most interesting, epistemological desiderata. Plausibly, thought experiments also produce understanding, illumination, and skill. This makes them important for science education and communication, and it explains the large literature that analyzes the use of thought experiments in educational contexts. Dennett 1995 claims that thought experiments are best conceived of as having a pedagogical purpose. In philosophy of science, Stuart 2016 argues that many of the most famous scientific thought experiments in fact had understanding as their aim. Stuart 2018 builds on this by distinguishing between three kinds of understanding, and explaining how thought experiments provide each. In science education studies, Hadzigeorgiou 2016 provides a good overview of the work done on thought experiments.

Dennett, Daniel. "Intuition Pumps." In ***The Third Culture*****. Edited by John Brockman, 181–197. New York: Simon & Schuster, 1995.**

Argues that thought experiments are "intuition pumps" that get conversations started, and are not meant to provide evidence.

Gilbert, John, and Miriam Reiner. "The Symbiotic Roles of Empirical Experimentation and Thought Experimentation in the Learning of Physics." ***International Journal of Science Education*** **26 (2004): 1819–1834.**

Shows that students as young as twelve are competent thought experimenters.

Hadzigeorgiou, Yannis. ***Imaginative Science Education: The Central Role of Imagination in Science Education*****. Cham, Switzerland: Springer, 2016.**

Summarizes the general pedagogical benefits of thought experiments as helping students in developing a creative imagination, developing logical arguments and creative thinking, developing problem-solving skills, learning how to effectively modify laboratory experiments, clarifying concepts, and changing concepts.

Klassen, Stephen. "The Science Thought Experiment: How Might It Be Used Profitably in the Classroom?" ***Interchange*** **37 (2006): 77–96.**

Claims that thought experiments can be used very effectively as teaching devices.

Kösem, Şule Dönertaş, and Ömer Faruk Özdemir. "The Nature and Role of Thought Experiments in Solving Conceptual Physics Problems." *Science & Education* 23 (2014): 865–895.

Shows that students resort to thought experiments on their own when solving difficult conceptual problems.

Reiner, Miriam, and Lior Burko. "On the Limitations of Thought Experiments in Physics and the Consequences for Physics Education." *Science & Education* 12 (2003): 365–385.

Shows that thought experiments can be used effectively to elicit students' tacit beliefs.

Reiner, Miriam, and John Gilbert. "Epistemological Resources for Thought Experimentation in Science Learning." *International Journal of Science Education* 22 (2000): 489–506.

Classifies and evaluates the use of thought experiments in science textbooks.

Stuart, Michael T. "Taming Theory with Thought Experiments: Understanding and Scientific Progress." *Studies in the History and Philosophy of Science Part A* 58 (2016): 24–33.

Provides an operationalization of understanding, and discusses several famous examples of thought experiments that either pass or fail in generating understanding.

Stuart, Michael T. "How Thought Experiments Increase Understanding." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 526–544. Abingdon, UK, and New York: Routledge, 2018.

Distinguishes explanatory, pragmatic, and semantic objectual understanding, and discusses different ways that thought experiments can provide each of these.

Computer Simulations

Increasingly, computer simulations are used to test theories and make predictions. To what extent are they like thought experiments? Recently this has become a topic of considerable interest. Some philosophers claim that computer simulations *are* experiments and that they provide genuine data. If this is right and if computer simulations are indeed a form of thought experiment, then the importance of thought experiments to the evaluation of scientific theories is further strengthened. Arcangeli 2018 argues that we cannot reduce thought, real or computer, experiments to one another. Behmel 2001 and di Paolo, et al. 2000 both deny that simulations and thought experiments are similar, while Lenhard 2011, Lenhard 2018, and Buzzoni 2016 find both similarities and differences. In line with Norton's view, described in Thought Experiments as Arguments, Beisbart and Norton 2012 argues that computer simulations are just arguments. Chandrasekharan, et al. 2013 argues that in some domains of science and for some purposes, computer simulations will replace thought experiments.

Arcangeli, Margherita. "The Hidden Links between Real, Thought and Numerical Experiments." In *Special Issue: On Thought Experiments*. Edited by Nenad Miščević. *Croatian Journal of Philosophy* 18.1 (2018): 3–22.

Argues against reductionist tendencies, and urges for closer attention to be paid to the *processes* of thought, real and numerical experiments, rather than comparing their outputs.

Behmel, Albrecht. *Was sind Gedankenexperimente? Kontrafaktische Annahmen in der Philosophie des Geistes—der Turingtest und das chinesische Zimmer*. Stuttgart: Ibidem, 2001.

A critical discussion of two thought experiments. Takes a skeptical attitude toward thought experiments.

Beisbart, Claus, and John D. Norton. "Why Monte Carlo Simulations Are Inferences and Not Experiments." ***International Studies in the Philosophy of Science*** **26 (2012): 403–422.**

Argues that a specific kind of computer simulation (Monte Carlo simulations) is best understood as an inference, not an experiment.

Buzzoni, Marco. "Thought Experiments and Computer Simulations." In ***Model-Based Reasoning in Science and Technology: Logical, Epistemological, and Cognitive Issues*****. Edited by Lorenzo Magnani and Claudia Casadio, 57–68. Heidelberg, Germany: Springer, 2016.**

Criticizes existing views on the relations between real and thought experiments and computer simulations. Points out structural similarities between the three, and focuses on differences of complexity.

Chandrasekharan, Sanjay, Nancy J. Nersessian, and Vrishali Subramanian. "Computational Modeling: Is This the End of Thought Experiments in Science?" In ***Thought Experiments in Philosophy, Science, and the Arts*****. Edited by Mélanie Frappier, Letitia Meynell, and James Robert Brown, 239–260. New York and Abingdon, UK: Routledge, 2013.**

While thought experiments usually focus on a single imagined scenario, simulations use variables, allowing them to explore entire possibility spaces. Thought experiments idealize and abstract, while simulations can keep or even increase the complexity of a target system. Given the nature of modern science, it is argued that for some domains and purposes, simulations will replace thought experiments.

di Paolo, Ezequiel A., Jason Noble, and Seth Bullock. "Simulation Models as Opaque Thought Experiments." Paper presented at a conference held at Reed College in Portland, OR, 1–6 August 2000. In ***Proceedings of the Seventh International Conference on Artificial Life*****. Edited by Mark A. Bedau, John S. McCaskill, Norman Packard, and Steen Rasmussen, 497–506. Cambridge, MA: Massachusetts Institute of Technology Press, 2000.**

Rejects computer simulation, and thus thought experiments, as a useful method in science.

Lenhard, Johannes. "Epistemologie der Iteration: Gedankenexperimente und Simulationsexperimente." ***Deutsche Zeitschrift für Philosophie*** **59.1 (2011): 131–145.**

Defends computer simulations and thought experiments as a scientific method.

Lenhard, Johannes. "Thought Experiments and Simulation Experiments: Exploring Hypothetical Worlds." In ***The Routledge Companion to Thought Experiments*****. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 484–497. Abingdon, UK, and New York: Routledge, 2018.**

Begins with a useful overview of the literature on the topic, including the similarities between the functions of thought experiments and computer simulations. Focuses on the different levels of cognitive opacity as an important epistemological difference.

Intuition

There is an innocent sense of "intuition" that suggests something like common sense, as in: "My intuitions were rattled when I saw that skinny kid eat sixty-three hotdogs in ten minutes." At the other end of the spectrum is the controversial claim that there are intuitions in the sense of, say, Gödel, who claimed he could perceive or intuit the abstract objects of mathematics. What are the intuitions at work in thought experiments? Are they useful and legitimate? The range of answers is broad; some defend intuitions in the strong sense, others take intuitions to be nothing but prejudices that should be tossed out in favor of the real empirical study of nature and the mind. Brown 2010 defends a very strong form of intuition, of which Brendel 2004 is more critical. DePaul and Ramsey 2002 contains a useful variety of views. The literature on intuition is very extensive and diverse. The PhilPapers: Intuition bibliography and Pust 2017 will be useful places to start. Recently, there have been experimental challenges to the use of intuition and thought experiments in philosophy (see Experimental Philosophy).

Brendel, Elke. "Intuition Pumps and the Proper Use of Thought Experiments." *Dialectica* 58 (2004): 88–108.

Discussion of proper conditions for the use of intuition in a thought experiment.

Brown, James Robert. *Laboratory of the Mind: Thought Experiments in the Natural Sciences*. 2d ed. London: Routledge, 2010.

Argues for intuitions in a Platonistic sense. Defends the view that we can perceive some laws of nature, which are taken to be relations among properties (which are abstract entities). Originally published in 1991.

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dePaul, Michael, and William Ramsey, eds. *Rethinking Intuition: The Psychology of Intuition & Its Role in Philosophical Inquiry*. Lanham, MD: Rowman & Littlefield, 2002.

A now-classic text with a variety of accounts of intuition on display.

Grève, Sebastian Sunday, ed. PhilPapers: Intuition.

A collection of almost six hundred articles on intuition edited by Sebastian Sunday Grève.

Pust, Joel. "Intuition." In *The Stanford Encyclopedia of Philosophy*. Edited by Edward N. Zalta. Stanford, CA: Stanford University, 2017.

A periodically updated resource that summarizes philosophical views on the nature, content, and epistemic uses of intuition.

Imagination and Literary Fiction

Novels and other forms of fiction (plays, movies) seem to have a lot in common with thought experiments. They have a narrative structure that we can easily imagine and visualize. Are they in fact thought experiments, or is the similarity superficial? What are some of the special features they might have in common? Utopian novels (More's *Utopia*, of course) and dystopian novels (Orwell's *Nineteen Eighty-Four*, Atwood's *The Handmaid's Tale*) seem obvious candidates for being thought experiments. But what about other novels such as those by Jane Austen, George Eliot, or Henry James? Camp 2009, Davies 2007, and Elgin 2007 explore the relation between thought experiments and literary fictions and metaphors. Oatley 1999 explores the idea of fiction as a simulation. Swirski 2007 is a book-length study of many aspects of thought experiments and literature, while Macho and Wunschel 2004 is a collection of articles discussing thought experiments in philosophy as well as in science and literature. Bornmüller, et al. 2019 is a collection of papers that explicitly tries to compare thought experiments and fiction. Imagination seems to be at the heart of our interaction with fiction. Liao 2019 provides a comprehensive and periodically updated overview of the philosophy of imagination. Arcangeli 2010 emphasizes the importance of this connection for epistemology of thought experiments. Stuart 2019 distinguishes between conscious and unconscious imagination and discusses how both of these play (different) epistemological roles in thought experiments.

Arcangeli, Margherita. "Imagination in Thought Experimentation: Sketching a Cognitive Approach to Thought Experiments." In *Model-Based Reasoning in Science & Technology*. Edited by Lorenzo Magnani, Walter Carnielli, and Claudio Pizzi, 571–587. Berlin: Springer, 2010.

Points out the importance of having an account of imagination for doing epistemology of thought experiments, and makes several very useful distinctions.

Bornmüller, Falk, Johannes Franzen, and Mathis Lessau. *Literature as Thought Experiment?* Munich: Wilhelm Fink Verlag, 2019.

Sixteen chapters focused on the consequences of Elgin's statement that we learn from fiction the same way we learn from thought experiments.

Camp, Elizabeth. "Two Varieties of Literary Imagination: Metaphor, Fiction, and Thought Experiments." *Midwest Studies in Philosophy* 33.1 (2009): 107–130.

Discusses different forms of imagination in literary fiction with particular emphasis on fictions and metaphors.

Davies, David. "Thought Experiments and Fictional Narratives." *Croatian Journal of Philosophy* 7 (2007): 29–45.

Explores a number of views of thought experiments in the sciences and then compares them with works of fiction, noting important similarities and differences.

Elgin, Catherine Z. "The Laboratory of the Mind." In *A Sense of the World: Essays on Fiction, Narrative and Knowledge*. Edited by John Gibson, Wolfgang Huemer, and Luca Pocci, 43–54. New York and London: Routledge, 2007.

An examination of similarities and differences with an emphasis on how thought experiments both in science and in literature can lead to understanding.

Liao, Shen-yi. "Imagination." In *The Stanford Encyclopedia of Philosophy*. Edited by Edward N. Zalta. Stanford, CA: Stanford University Press, 2019.

An overview of the philosophy of imagination, focusing on contemporary issues.

Macho, Thomas, and Annette Wunschel, eds. *Science and Fiction: Über Gedankenexperimente in Wissenschaft, Philosophie und Literatur*. Frankfurt: Fischer Verlag, 2004.

A collection of articles on thought experiments in science and philosophy as well as on literature (in German).

Oatley, Keith. "Why Fiction May Be Twice as True as Fact: Fiction as Cognitive and Emotional Simulation." *Review of General Psychology* 3 (1999): 101–117.

Claims that fiction is a kind of simulation of the world run in the mind and that the way we understand fiction is similar to the way we understand the world. Emotion is particularly important.

Stuart, Michael T. "Towards a Dual Process Epistemology of Imagination." *Synthese* 2019.

Argues that dual systems models of cognition can and should be applied to imagination, and considers the consequences of this for the epistemology of thought experiments.

Swirski, Peter. *Of Literature and Knowledge: Explorations in Narrative Thought Experiments, Evolution, and Game Theory*. London and New York: Routledge, 2007.

A wide-ranging, book-length study of thought experiments in literature.

Skepticism about the Epistemological Efficacy of Thought Experiments

A significant minority of philosophers are deeply mistrustful of thought experiments. The focus of this distrust is usually intuitions (see Intuition and Experimental Philosophy). It is important to note that most of the critique is aimed at philosophical thought experiments, especially in ethics, personal identity, and philosophy of mind. It is very seldom aimed at thought experiments in physics (though see Duhem 1906 and Meinong 1973). Dancy 1985 and Wilkes 1988 argue that thought experiments are too strange, contrived, or abstract to decide issues in ethics, personal identity, and philosophy of language. Hempel 1965 argues that some uses of thought

experimentation are acceptable, though not to provide evidence. Bokulich 2001 argues that insofar as our intuitions are reliable because they are the product of evolution, thought experiments should not be trusted when applied to very un-intuitive systems, like quantum mechanics. Peijnenburg and Atkinson 2003 argues that philosophical thought experiments often produce contradictory conclusions, or they beg the question. Thagard 2010 and Thagard 2014 argue that thought experiments in philosophy are misleading or harmful. Wilkes 1988 distinguishes thought experiments in science from those in philosophy, rejecting the latter, while Hull 2001 argues against the use of thought experiments specifically in philosophy of science. For replies to some of these criticisms, see Replies to the Skeptics.

Bokulich, Alisa. "Rethinking Thought Experiments." ***Perspectives on Science*** **9.3 (2001): 285–307.**

Argues that our intuitions are only reliable for the kinds of systems our intuitions evolved to deal with. Thus, thought experiments about how many hotdogs we can eat are okay, but thought experiments about quantum superposition might not be.

Dancy, Jonathan. "The Role of Imaginary Cases in Ethics." ***Pacific Philosophical Quarterly*** **66 (1985): 141–153.**

Argues that thought experiments are not reliable in ethics.

Duhem, Pierre. ***La théorie physique son objet et sa structure*****. Paris: Chevalier & Rivière, 1906.**

The first skeptic about thought experiments explicitly so called.

Hempel, Karl. ***Aspects of Scientific Explanation*****. New York: Free Press, 1965.**

Argues that thought experiments cannot be used in place of empirical evidence.

Hull, David. ***Science and Selection: Essays on Biological Evolution and the Philosophy of Science*****. Cambridge, UK: Cambridge University Press, 2001.**

Contains two earlier essays, "A Function for Actual Examples in Philosophy of Science" (1989) and "That Just Don't Sound Right: A Plea for Real Examples" (1997), that present a strong case against the use of thought experiments as evidence or as tools of persuasion. He argues that thought experiments damage philosophy of science by stifling innovation, distracting from the real issues, and peddling in incoherent cases. Worst of all, there are no standards for evaluating thought experiments.

Meinong, Alexius. "Das Gedankenexperiment." In ***Über die Stellung der Gegenstandstheorie im System der Wissenschaften*****. Edited by Rudolf Haller and Rudolf Kindinger, 273–283. Graz, Austria: Akademische Druck und Verlagsanstalt, 1973.**

Argues that "an experiment that in fact does not exist at all, can neither prove nor teach anything." Originally published in 1907.

Peijnenburg, Jeanne, and David Atkinson. "When Are Thought Experiments Poor Ones?" ***Journal for General Philosophy of Science/Zeitschrift für Allgemeine Wissenschaftstheorie*** **34 (2003): 305–322.**

Argues that thought experiments in philosophy tend to be worse than thought experiments in science because of the different ways these disciplines interact with empirical evidence.

Thagard, Paul. ***The Brain and the Meaning of Life*****. Princeton, NJ: Princeton University Press, 2010.**

Argues that thought experiments should never be used as evidence, while allowing that they may be used in science to inspire new hypotheses.

Thagard, Paul. "Thought Experiments Considered Harmful." ***Perspectives on Science*** **22 (2014): 288–305.**

Updates his skeptical view on thought experiments in response to criticism.

Wilkes, Kathleen V. *Real People: Personal Identity without Thought Experiments*. Oxford: Oxford University Press, 1988.

Argues that typical thought experiments in the sciences work because they do not violate laws of nature, while thought experiments in philosophy of mind, such as people splitting like amoebas, often do violate such laws, making them unreliable.

Replies to the Skeptics

The papers in this subsection reply to the skeptics. Buzzoni 2018 argues (against tradition) that Duhem was really not a skeptic about Mach's notion of thought experiment. Cohnitz 2006 replies to Peijnenburg and Atkinson, arguing that thought experiments do not typically beg the question nor do they trade only on conflicting intuitions. Häggqvist 1996 reviews, analyzes, and argues against several important sources of skepticism about thought experiments. Stuart 2014 argues against the skepticism of Paul Thagard, trying to show that Thagard's own work in cognitive science can contribute positively to the epistemological debate about thought experiments (rather than supporting his expressed skepticism). Ylikoski 2003 argues that David Hull missed important roles played by thought experiments, and conditions for their use, that together allow Ylikoski to address Hull's worries.

Buzzoni, Marco. "Pierre Duhem and Ernst Mach on Thought Experiments." *HOPOS: The Journal of the International Society for the History of Philosophy of Science* 8 (2018): 1–27.

Presents historical evidence, suggesting that Duhem might not have been as skeptical about thought experiments as he is often portrayed.

Cohnitz, Daniel. "Poor Thought Experiments? A Comment on Peijnenburg and Atkinson." *Journal for General Philosophy of Science/Zeitschrift für Allgemeine Wissenschaftstheorie* 37 (2006): 373–392.

Criticizes the skepticism of Peijnenburg and Atkinson 2003 (cited under Skepticism about the Epistemological Efficacy of Thought Experiments).

Häggqvist, Sören. *Thought Experiments in Philosophy*. Stockholm: Almqvist & Wiksell, 1996.

Chapter 2, "The Case Against," is a very careful analysis of the skepticism of Wilkes and Dancy, as well as Jerry Fodor and W. V. O. Quine.

Stuart, Michael T. "Cognitive Science and Thought Experiments: A Refutation of Paul Thagard's Skepticism." *Perspectives on Science* 22 (2014): 264–287.

Presents a number of arguments against the skepticism of Paul Thagard.

Ylikoski, Petri. "Thought Experiments in Science Studies." *Philosophica* 72 (2003): 35–59.

Defends the use of thought experiments in philosophy of science against Hull's criticisms.

Experimental Philosophy

Thought experiments are a central part of the philosophical method, so criticisms of the use of thought experiments must be taken seriously. Perhaps the greatest modern challenge comes from what is called "experimental philosophy." Beginning roughly in the early 2000s, this movement has led to a methodological crisis that is still ongoing. Experimental philosophers present short thought experiments to people, collect the responses, and analyze the data statistically. Many of their results seem to show that the intuitions resulting from thought experiments are not shared among different groups of people, and they are influenced by irrelevant factors

including age, gender, culture, native language, level of education, and religious beliefs, as well as ambient sights, smells, and sounds. For instance, Buckwalter and Stich 2014 finds differences in the intuitions of men and women, while Nisbett 2003 finds differences between different cultures (though Knobe 2019 argues that experimental philosophy has found robust *similarities* in intuitions across demographic domains). For a general overview, see Knobe and Nichols 2017. Stich and Tobia 2018 provides an overview of the literature that ties it directly to thought experiments, and Ludwig 2018 provides a recent defense of the use of thought experiments in philosophy.

Buckwalter, Wesley, and Stephen Stich. "Gender and Philosophical Intuition." In *Experimental Philosophy: Volume 2*. Edited by Joshua Knobe and Shaun Nichols, 307–346. New York: Oxford University Press, 2014.

Buckwalter and Stich review empirical data suggesting that men and women do not have the same intuitions about many of the standard examples of thought experiments in philosophy. They conclude that intuition is not to be trusted as a reliable source of knowledge. They suggest it also explains the relatively small number of women in the discipline—women mistakenly think they lack philosophical ability.

Knobe, Joshua. "Philosophical Intuitions Are Surprisingly Robust across Demographic Differences." *Epistemology and Philosophy of Science* 56 (2019): 29–36.

Argues that intuitions about thought experimental cases are surprisingly robust across several demographic dimensions.

Knobe, Joshua, and Shaun Nichols. "Experimental Philosophy." In *The Stanford Encyclopedia of Philosophy*. Edited by Edward N. Zalta. Stanford, CA: Stanford University, 2017.

A periodically updated overview of work in experimental philosophy.

Ludwig, Kirk. "Thought Experiments and Experimental Philosophy." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 385–405. Abingdon, UK, and New York: Routledge, 2018.

Argues that experimental philosophy should not lead to general skeptical doubt concerning the use of intuition in philosophy.

Nisbett, Richard E. *The Geography of Thought: How Asians and Westerners Think Differently . . . and Why*. London: Nicholas Brealey, 2003.

Nisbett reports on his own empirical work claiming to show that Westerners tend to be more analytic in their thinking while Asians are more holistic. This difference, he claims, is evident in how people respond to some classic thought experiments, such as that of Galileo.

Stich, Stephen, and Kevin Tobia. "Intuition and Its Critics." In *The Routledge Companion to Thought Experiments*. Edited by Michael T. Stuart, Yiftach Fehige, and James Robert Brown, 369–384. Abingdon, UK, and New York: Routledge, 2018.

Summarizes the findings of experimental philosophy and criticizes certain uses of thought experiments in philosophy.

Miscellaneous and Amusing Pieces

There are a few light-hearted articles that also offer some insight into the nature of thought experiments. Learner 2011 is a sendup of Searle's famous Chinese Room thought experiment. A Fauxphilnews article, "Kripke Resigns as Report Alleges That He Faked Results of Thought Experiments," reports that Kripke faked his thought experiments. In case there is any chance of misunderstanding, it should be known that these are both jokes. Norton's Goodies include several examples that are fun to read, as is Munroe 2014. Six Famous Thought Experiments Explained Quickly is a series of animated videos that do what they promise.

Goodies.

John Norton, a major figure in debates about thought experiments, has a number of nice examples linked to his home page. They include short descriptions, and some are animated. Some favorites include “Ethics of Imaginary Cases,” “What If It Really Was Turtles All the Way Down,” and “Could You Really Build a Castle in the Sky.”

“Kripke Resigns as Report Alleges That He Faked Results of Thought Experiments.” Fauxphilnews.

A fake news report that claims Kripke has misrepresented the results of some of his famous thought experiments.

Learner, Berel Dove. “My Evening with Mr. Wang.” *Think* (Spring 2011): 83–93.

A dialogue between the author and Mr. Wang, the experimental subject of Searle’s Chinese Room thought experiment. Wang is organizing a union of thought-experimental subjects with the aim of ending the abuses they are often subject to and also to expose the fraudulent work of some thought experimenters.

Munroe, Randall. *What If? Serious Scientific Answers to Absurd Hypothetical Questions*. New York: Houghton Mifflin Harcourt, 2014.

Former NASA roboticist and creator of xkcd.com, this amusing book considers dozens of thought experiments, including what would happen if the earth suddenly stopped spinning but the atmosphere kept moving, if you threw a baseball at the speed of light, if everyone on earth got together and jumped up and landed at the same time, if you got a mole of moles together, and so on.

Six Famous Thought Experiments Explained Quickly.

An amusing short video of six thought experiments.

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