Benjamin C. Jantzen

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Current appointments

2018-present *Associate Professor of Philosophy*, Philosophy Department, Virginia Tech
2018-present *Associate Professor of Computer Science, by courtesy*, Department of Computer Science, Virginia Tech

Areas of specialization

Logic of Discovery; Philosophy of Biology; Philosophy of Physics; Philosophy of Science

Prior appointments

2011-2018 *Assistant Professor of Philosophy*, Philosophy Department, Virginia Tech
2015-2018 *Assistant Professor of Computer Science, by courtesy*, Department of Computer Science, Virginia Tech
2010-2011 Coordinator of Graduate Student Programs, Carnegie Mellon University

Education

2010 PH.D. in Logic, Computation, & Methodology, Carnegie Mellon University
2006 M.A. in Philosophy, Carnegie Mellon University
2003 M.S. in Physics, Cornell University
1999 B.S. in Biology, B.S. in Physics, with High Distinction and with Honors in Biology, The Pennsylvania State University

Grants & funding

2015-2020 B. Jantzen (PI), CAREER: Automated scientific discovery and the philosophical problem of natural kinds (NSF), $443,427

2019-2020 Katie Carmichael, Vanessa Diaz, Charlene M. Eska, Joseph F. Eska, Aarnes Gudmestad, Benjamin Jantzen, Tanushree Mitra, Robin Panneton, Natasha Staley, Kelly Trogdon, Abby Walker, Faculty Writing Group Grant (Virginia Tech), $2,000

2018-2019 Katie Carmichael, Vanessa Diaz, Charlene M. Eska, Joseph F. Eska, Aarnes Gudmestad, Benjamin Jantzen, Tanushree Mitra, Robin Panneton, Natasha Staley, Kelly Trogdon, Abby Walker, Faculty Writing Group Grant (Virginia Tech), $2,000

2017-2019 N. Abaid (PI) & B. Jantzen (co-PI), EAGER: Dynamical kinds in multi-agent systems: A philosophical understanding of collective behaviors (NSF), $123,691

2018 B. Jantzen (PI), N. Abaid (co-PI), A. Leonessa (co-PI), "Automated discovery of brain states from noninvasive EEG data," Data & Decisions seed grant (Virginia Tech), $25,000

2018 B. Jantzen (PI), CLAHS Grant-writing Incentive Grant (Virginia Tech), $5,000

2017 B. Jantzen (PI), CLAHS Grant-writing Incentive Grant (Virginia Tech), $5,000

2013 B. Jantzen (PI), CLAHS Grant-writing Incentive Grant (Virginia Tech), $5,000

2013 B. Jantzen (PI), Virginia Tech Mentoring Microgrant, $1,500

2012 B. Jantzen (PI), CLAHS Humanities Summer Stipend (Virginia Tech), $4,000

Fellowships & awards

2023 Virginia Tech Research and Innovation "Major Proposal" Award

2022 Longterm Participant, Causality Program, Simons Institute for the Theory of Computing

2010 CMU Graduate Student Teaching Award

2007-2010 CMU Philososphy Department Dissertation Fellowship

2004-2006 CMU Philosophy Department Fellowship

2005 Posner Internship at Carnegie Mellon University Libraries

1999-2001 NSF Graduate Fellowship competition Honorable Mention

1998-1999 Barry M. Goldwater Scholar (national award)

Publications

Journal articles & Book sections

forthcoming Jantzen, B. "Ad hoc identity, Goyal complementarity, and counting quantum phenomena,"in O. Bueno and D. Krause (eds.), *Individuals and Non-Individuals in Quantum Mechanics*, Synthese Library. http://philsci-archive.pitt.edu/18487/

forthcoming Jantzen, B. "Symmetry and Causation: A General Theory of Biological Individuality," *Minnesota Studies in Philosophy of Science*. http://philsci-archive.pitt.edu/17300/

2023 Aung, E., N. Abaid, B. Jantzen. "Recovery of dynamical similarity from lossy representations

of collective behavior of midge swarms," *Chaos* 33 (10): 103114. https://doi.org/10.1063/5.0146161

2022 Kannan, H., B. C. Jantzen, B. Mesmer. "A formal approach to identify inconsistencies in stakeholder needs in the context of systems engineering," *AIAA SCITECH 2022 Forum*, 1469.

2021 Jantzen, B. "Scientific Variables," *Philosophies* 6 (4):103. https://doi.org/10.3390/philosophies6040103

2021 Shea-Blymyer, C., S. Roy, *&* B. Jantzen. "A general metric for the similarity of both stochastic and deterministic system dynamics," *Entropy* 23 (9):1192. https://doi.org/10.3390/e23091191

2019 Kannan, H., G. V. Bhatia, B. L. Mesmer, *&* B. Jantzen. "Theoretical Foundations for Preference Representation in Systems Engineering," *Systems* 7, 55. https://doi.org/10.3390/systems7040055.

2019 Roy, S., M. J. Shirazi, B. Jantzen, *&* N. Abaid. "Effect of visual and auditory sensing cues on collective behavior in Vicsek models," *Phys. Rev. E* 100, 062415. https://link.aps.org/doi/10.1103/PhysRevE.100.062415

2019 Jantzen, B. "Dynamical symmetries and model validation,"in N. Fillion et al. (eds.), *Algorithms and Complexity in Mathematics, Epistemology, and Science, Fields Institute Communications* 82, https://doi.org/10.1007/978-1-4939-9051-1_6

2018 Hashimoto, A., N. Abaid, S. Roy, B. Jantzen, C. Shea-Blymyer. "Differentiation of collective behavior based on automated discovery of dynamical kinds," *Proceedings of the ASME 2018 Dynamic Systems and Control Conference*, DSCC2018-9139: 1-8.

2018 Roy, S. and B. Jantzen. "Detecting causality using symmetry transformations," *Chaos* 28 (075305): 1-11.

2017 Jantzen, B. "Entities Without Identity: A Semantical Dilemma," *Erkenntnis*. doi:10.1007/s10670-017-9958-3

2017 Jantzen, B. " Kinds of process and the levels of selection," *Synthese*. doi:10.1007/s11229-017-1546-1.

2017 Jantzen, B. "Cyberwarfare," in Joseph Pitt *&* Ashley Shew (ed.), *Spaces for the Future: a Companion to the Philosophy of Technology*, Routledge. (invited)

2017 Jantzen, B. "Dynamical Kinds and their Discovery," *Proceedings of the UAI 2016 Workshop on Causation: Foundation to Application* (http://ceur-ws.org/Vol-1792/paper2.pdf).

2016 Jantzen, B. "Discovery without a 'logic' would be a miracle," *Synthese* 193 (10): 3209–3238. doi:10.1007/s11229-015-0926-7 (First Online: 03 October 2015).

2015a Jantzen, B., D. Mayo, L. Patton. "Ontology *&* Methodology," *Synthese* 192 (11):3413-3423.

2015b Jantzen, B. "Projection, symmetry, and natural kinds," *Synthese* 192 (11): 3617-3646. doi:10.1007/s11229-014-0637-5

2014 Jantzen, B. "Piecewise Versus Total Support: How to Deal with Background Information in Likelihood Arguments," *Philosophy of Science* 81 (3): 313-331.

2012 Jantzen, B. "Peirce on miracles: the failure of Bayesian analysis" in Jake Chandler and Victoria Harrison (eds.), *Probability in the Philosophy of Religion*, Oxford University Press.

2011a Jantzen, B. "An awkward symmetry: The tension between particle ontologies and permutation invariance," *Philosophy of Science* 78(1): 39-59.

2011b Jantzen, B. "No two entities without identity," *Synthese* 181(3): 433-450. (First Online: 22 February 2010)

2009 Jantzen, B. "Peirce on the method of balancing 'likelihoods'." *Transactions of the Charles S. Peirce Society* 45(4): 668-688.

2008a Jantzen, B. and D. Danks. "Biological codes and topological causation." *Philosophy of Science* 75: 259–277.

2008b Jantzen, B. and T. Eisner. "Hindwings are unnecessary for flight but essential for execution of normal evasive flight in Lepidoptera." *Proceedings of the National Academy of Sciences* 105(43): 16636-16640.

2002 Koch, S. J., A. Shundrovsky, B. C. Jantzen, and M. D. Wang. "Probing protein-DNA interactions by unzipping a single DNA double helix." *Biophysical Journal* 83(2):1098-1105.

Books

2014 Jantzen, B. (2014), *An Introduction to Design Arguments*, New York: Cambridge University Press, ISBN 978-0521183031

Newspaper & magazine articles

2017 Jantzen, B. (Volume 1, 2016-2017), "How to use robot scientists to reimagine the world," *Illuminations*

2016 Jantzen, B. (1st Quarter 2016), "The philosophy of science," *The Philosophers' Magazine* 72:63-64

2015 Jantzen, B. (1st Quarter 2015), "The Fine Tuning Argument Unmasked," *The Philosophers' Magazine* 68:49-55

2006 Jantzen, B. (23 August, 2006), "Air displacement keeps butterflies, and other things, in the air," *The Ithaca Journal*

Broadcast media

2022 "What is the design evidence for God's existence?" interviewed for *Dini Cevalpar* (YouTube). https://youtu.be/-_9OKbylQjY

2020 " Philosophy and the Pandemic," interviewed by Robbie Harris, *Radio IQ* (radio). https://www.wvtf.org/post/philosophy-and-pandemic

2020 "Introduction to Design Arguments," interviewed by Shoaib Malik for *Academic Access* (YouTube). https://youtu.be/fKACzIocXjw

2016 "Algorithm of Discovery - Defining What Isn't," *Pulse of the Planet* (radio).

2016 "Algorithm of Discovery – A New Way of Seeing the World," *Pulse of the Planet* (radio).

2016 "Algorithm of Discovery – New Ideas From Computers," *Pulse of the Planet* (radio).

Technical reports

2003 Jantzen, B. C. and C. W. Henoch (2003). "A full-scale investigation of the wake produced by surface-piercing masts: Baseline measurements and verification of technique." NUWC-NPT Technical Memo 03-129.

2002 Jantzen, B. C. and M. Genco (2002). "A towing tank investigation of production of white-water wake by surface-piercing masts." NUWC-NPT Technical Memo 02-122.

Professional presentations

Peer-reviewed/Refereed

2023 "The relevance of natural kinds to the computational discovery of novel scientific variables," *AAAI Spring Symposium on Computational Approaches to Scientific Discovery*

2019 "Finding causation in time: background assumptions for dynamical systems," *CLMPST2019: 16th International Congress on Logic, Methodology and Philosopy of Science and Technology*, Prague, Czech Republic.

2019 (C. Davis and B. Jantzen) "Do heuristics exhaust the methods of discovery?" *CLMPST2019: 16th International Congress on Logic, Methodology and Philosopy of Science and Technology*, Prague, Czech Republic.

2019 "How to control with a model that can't predict," *American Philosophical Association (APA) 2019 Pacific Division Meeting*, Vancouver, Canada.

2018 (B. Jantzen and C. Davis) "Do heuristics exhaust the methods of discovery?" *PSA2018: The 26th Biennial Meeting of the Philosophy of Science Association*, Seattle, WA.

2017 "A brief and whiggish history of algorithmic discovery," *4th International Conference on the History and Philosophy of Computing, Brno, Czech Republic*

2015a "Natural kinds and automated scientific discovery," *15th Congress of Logic, Methodology and Philosophy of Science, Helsinki, Finland*

2015b "Dynamical kinds and the reliability of simulations," *Algorithms and Complexity in Mathematics, Epistemology and Science, London, Canada*

2014a "The Field Guide Approach to Teaching Argument Analysis," *AAPT session at the Eastern Division American Philosophical Association (APA) Meeting*

2014b "Why talk about 'non-individuals' is meaningless," *Philosophy of Science Association Biennial Meeting*

2013a "Dynamical kinds and ecological theory," *Biennial Meeting of the International Society for the History, Philosophy, and Social Studies of Biology (ISHPSSB)*

2013b "Symmetry, Dynamics, and the Levels of Selection," *International Conference on Evolutionary Patterns, Lisbon, Portugal*

2013c "Symmetry, Dynamics, and the Levels of Selection," *Philosophy and Theory in Biology Young Investigator's Symposium*

2012a "Piecewise Versus Total Support: How to Deal with Background Information in Likelihood Arguments," *Philosophy of Science Association Biennial Meeting*

2012b "Symmetry and Causation: A General Theory of Biological Individuality," *Philosophical Perspectives on Causal Reasoning in Biology, Part II, Minnesota Center for the Philosophy of Science*

2011 "The Spatial Objects Interpretation of Quantum Mechanics," *Boulder Conference on the History and Philosophy of Physics*

2010 "Comments on Nagelian reduction and mathematical assimilation," *10th Annual Pitt/CMU Graduate Student Philosophy Conference*

2009a "Quantum indeterminism and microevolution," *Biennial Meeting of the International Society for the History, Philosophy, and Social Studies of Biology (ISHPSSB)*

2009b "Peirce on miracles: the failure of Bayesian analysis," *Formal Methods in the Epistemology of*

Religion Conference

2009c "Background information as epistemic intervention: Comments on Matt Kotzen's 'Selection biases in likelihood arguments'," *Formal Epistemology Workshop*

2008 "Points and permutations," *Philosophy of Science Association Biennial Meeting*

Invited

2023 "Lost in the Tangled Bank: On Natural Selection and the Origin of Form," *Darwin Day in Iran, 2023* (virtual), Tardid School of Philosophy, Tehran.

2022 "Machines and ontological induction," *Philosophy of Science Meets Machine Learning, Max Planck Institute for Intelligent Systems*

2022 "A general metric of dynamical similarity: Overview of the dynamical symmetry approach to causal discovery," *Simons Institute Causality Program*

2021 "Mining the diversity of behavioral dynamics," *Bioinspiration & Biodiversity Workshop, Virginia Tech*

2020 "Two defeasible challenges for algorithmic scientific discovery" *ThoughtWorks Engineering for Research (E4R) Symposium, 3rd Edition*, Pune India [moved online due to pandemic], https://www.thoughtworks.com/engineering-research-symposium

2020 "The status and limits of scientific learning by machine," *Trust in Information Colloquium*, High-Performance Computing Center (Stuttgart) and Computational Science Studies (CSS) Lab (Aachen University), Germany [online]

2019 "A general metric for dynamical similarity," High-Performance Computing Center, Stuttgart, Germany

2019 "The challenges of automating science, or how to exceed your grasp with one hand tied behind your back," *CIN Workshop 2019 "Limits of Automatization"*, FORUM SCIENTARIUM, University of Tübingen.

2019 "Four perspectives on automated discovery." *79th Annual Meeting of the Academy of Management*, Vancouver, Canada [presented by video: https://youtu.be/E54E NILXp8]

2017 "A brief and whiggish history of algorithmic discovery," *STS seminar series, Virginia Tech*

2016a "Scientific variables: New answers, new questions," *Caltech*

2016b "Discovering Dynamical Kinds," *Mind, Technology, and Society talk series, UC Merced*

2016c "Automated Scientific Discovery," *Virginia Tech Carillion Research Institute*

2016d "Discovering Dynamical Kinds," *Causation: Foundation to Application Workshop, Uncertainty in Artificial Intelligence 2016*

2016e "How different can identity be?," *Society for Realist/Antirealist Discussion group session, APA Pacific 2016*

2016f "Discerning Dynamical Structure," *Dept. of Computer Science, Graduate Seminar, Virginia Tech*

2016g "The ethics integrative outcome," *Pathways Scholars working group, Virginia Tech*

2015a "Finding Natural Kinds," *Philosophy Colloquium, Virginia Tech*

2015b "An Introduction to Design Arguments," *Visible Scholarship Initiative, Virginia Tech*

2015c "Preparing the Broader Impacts Statement for Your NSF CAREER Proposal," *Panelist, Citizen*

Scientist Seminar, Virginia Tech

2015d "Causes, kinds, and variables: On the eve of revolution," *Department of Philosophy 30th Anniversary Celebration, Carnegie Mellon University*

2015e "Cyberwarfare: Conflict and control in a computerized world," *STS colloquium, Virginia Tech*

2015f "Robot scientists: Automated discovery of causal structures and inductively useful categories," *ECE colloquium, Virginia Tech*

2015g "An Introduction to Design Arguments," *ASPECT Books at Newman Library, Virginia Tech*

2015h "Integrative ethics beyond the case study," *Pathways Summer Institute, Virginia Tech*

2014 "Semantic Phenomenalism: What Mill meant, Helmholtz heralded, and Ayer almost got right," *University of Virginia*

2013a "The Argument Guide," *Panelist, Open Educational Resources & Innovative Learning Objects: Exploring Opportunities Workshop, Virginia Tech*

2013b "The Algebraic Conception of Natural Kinds," *Ontology & Methodology Conference, Virginia Tech*

2013c "Wigner's World: Natural Kinds Reconceived," *Faculty Keynote Speaker, Virginia Tech Graduate Philosophy Conference*

2006a "Biological codes," *Lunchtime Technical Talk Series (Naval Undersea Warfare Center, Div. Newport)*

2006b "Protean probability: How a mathematical theory of probability wrestled answers from randomness," *Posner Center of Carnegie Mellon University (at the opening of my exhibit)*

Other research

2016-2019 Team member, "A synthesis to identify how metacommunity dynamics mediate community responses to disturbance across the ecosystems represented in the LTER network" (NSF funded)

2016 Invited participant, Biological Collections as a Resource for Technical Innovation (NSF funded)

Teaching

Virginia Tech

Modern Logic & Its Development
Minds & Machines
Advanced Topics in the Philosophy of Science (graduate seminar)
Language and Logic
Symbolic Logic (core graduate seminar)
Reason and Revolution in Science
Philosophy of Biology (mixed graduate/undergraduate)
Philosophy of Mind
Knowledge and Reality

Carnegie Mellon University

Life, the Universe, and God (course creator)
Revolutions in Science
What Philosophy Is
Honors section of "What Philosophy Is"

Cornell University

Fundamentals of Physics II—Electromagnetism (lab instructor)

Service to the profession

Internal

2012-2020 Member, Graduate admissions committee
2012-2020 Senior Fellow, West Ambler Johnston Residential College (Virginia Tech)
2017-2019 Member, Strategic Planning Committee (Virginia Tech)
2017-present Manager, Digital Philosophy Lab
2019 Chair, Assessment committee
2018-2019 Invited member, Open Educational Resources (OER) Committee
2018-2019 Member, CLAHS Dean search committee (Virginia Tech)
2016-2017 Member, Intelligent Infrastructure and Human-Centered Communities (IIHCC) Faculty Design Team
2016-2017 Member, Data Analytics and Decision Sciences (DADS) Faculty Design Team
2017 Faculty liaison, Future Faculty Development Program (Virginia Tech)
2016 Participant, Pathways Rubric Development Workshop
2016 Member, Destination Areas Round Table
2016 Invited member, Smart Human Centered Infrastructure Steering Committee
2016 Panelist, NSF CAREER info session for pre-tenure faculty
2016 Panelist, PDI NSF CAREER award panel discussion
2014-2016 Virginia Tech Pathways Faculty Scholar
2016 Contributor, Open Education Week video testimonials
2012-2016 Member, CLAHS faculty council
2015-2016 Member, Faculty search committee (Virginia Tech)
2015 Member, CLAHS Summer Stipend review panel (Virgina Tech)
2014-2015 Member, Head search committee (Virginia Tech)
2013 Member, Faculty search committee (Virginia Tech)
2012-2013 Member, Faculty search committee (Virginia Tech)
2011-2013 Member, Library committee
2012 Usher at Virginia Tech University Commencement
2011-2012 Member, Graduate committee
2011-2012 Member, Faculty search committee (Virginia Tech)

2010 Assistant for the Carnegie Mellon Summer School in Formal Epistemology
2010-2011 Coord. of Grad. Student Programs, Eberly Center for Teaching Excellence (CMU)
2007-2011 Member, Faculty Teaching Evaluation Committee (CMU)
2007-2010 Teaching Fellow, Eberly Center for Teaching Excellence (CMU)
2007 Instructor and co-developer, Undergraduate philosophy writing workshops (CMU)
2007 Member, Graduate admissions committee (CMU)
2005 Member, Faculty search committee (CMU)
2005 Member, Selection committee for Ryan Award for Meritorious Teaching (CMU)
1999 Member, Search committee for Assoc. Dean of Schreyer's Honors College, Penn State

External

2021-2022 Guest editor, Philosophies Special Issue: "The Problem of Induction throughout the Philosophy of Science"
2016 Session chair, Biennial Meeting of the Philosophy of Science Association, Atlanta, GA
2013-2015 Guest editor, Synthese Special Issue: "Ontology & Methodology"
2003-2005 Judge, Office of Naval Research science fair outreach team
2001-2002 Instructor and course author, Graduate Student School Outreach Program, Cornell University
1999-2000 Mentor, Cornell "Microworld" high school teacher outreach program

Conference & workshop organization

2016 Creator, organize, instructor, "Philosophy & Physical Computing" graduate summer workshop
2012-2013 Conference Organizer for "Ontology & Methodology" at Virginia Tech
2007-2008 Chair, 10th Annual Pitt-CMU Graduate Student Philosophy Conference
2006-2007 Organizer, 9th Annual Pitt-CMU Graduate Student Philosophy Conference

Editorships

2021 Guest Editor, *Philosophies* SI: "The Problem of Induction throughout the Philosophy of Science"

Journal & Book Reviewing

Applied Sciences, Australasian Journal of Philosophy, Banisteria, Biomolecules, BioScience, British Journal for Philosophy of Science, Cambridge University Press, Ergo, Erkenntnis, European Journal of Analytic Philosophy, European Journal for Philosophy of Science, Fields Institute Communications, Foundations of Science, Journal for General Philosophy of Science, Mind, Minds and Machines, New Journal of Physics, Oxford University Press, Perspectives on Science, Philosophia, Philosophical Studies, Philosophical Transactions A, Philosophies, Philosophy of Science, Principia, Routledge, Southern Journal of Philosophy, Syn-

these, Systems Research and Behavioral Science, Transactions of the Charles S. Peirce Society, Teaching Philosophy, Theology and Science

Conference reviewing

2017 Southern Society for Philosophy and Psychology
2016 Neural Information Processing Systems
2013 "Ontology & Methodology," Virginia Tech (program committee)
2010 Canadian Philosophical Association Conference

Grant reviewing

2021 DDS, RFC 2021
2018 Data and Decisions, RFC 2018
2018 Israeli Science Foundation
2016 Open Education Initiative Faculty Grants
2016 National Geographic Society

Nonprofit & volunteer service

2022-present Founder and President of the Virginia Institute for Invertebrates (virginiainvertebrates.org)
2023-present Councilor (officer), Virginia Natural History Society (virginianaturalhistorysociety.com)
2020 - present Virginia Master Naturalist

Outreach

2021 "Is Beauty a Guide to Truth? A Physicist and a Philosopher discuss some Big Questions," *Veritas Forum, Bradley Study Center at Virginia Tech online event* (https://youtu.be/NKqxfsrfCRU)
2016-present Creator, administrator of "Robot Scientist," (annual event for early secondary school students), *Western Virginia Museum of Science, Roanoke, VA*
2017-2018 Coach, Harding Avenue Elementary Robotics Club (for children in 1st - 4th grade)

Dissertation

How Symmetry Undid the Particle: A Demonstration of the Incompatibility of Particle Interpretations and Permutation Invariance

Dissertation committee:
Mara Harrell (chair), John Earman (University of Pittsburgh), Jeremy Butterfield (University of Cambridge)

Prior scientific research experience

2004 *Johnson & Johnson Fellow in Chemical Ecology at Cornell University*:
collaborated with Thomas Eisner on a series of experiments involving insect flight

2003-2007 *Scientist at the Naval Undersea Warfare Center, Division Newport*:
managed research projects and conducted experiments in the hydrodynamics branch

1999-2003 *Graduate Research Assistant at Cornell University*:
worked with Michelle Wang in biophysics for two years managing a project intended to integrate molecular motors with nanofabricated devices; worked with Jane Wang in fluid dynamics for one year investigating insect flight (the subject of my M.S. thesis in physics)

2002 *Intern at the Naval Undersea Warfare Center*:
designed and executed a study of ship wakes using a small tow tank; worked with multiple teams in the department on a variety of naval systems projects

1999 *Trainee in the Educational Research in Radio Astronomy program*:
underwent two weeks of intensive training in techniques of radio astronomy at the National Radio Astronomy Observatory in Greenbank, WV

1997-1998 *Research Assistant at the Pennsylvania State University*:
performed independent theoretical investigation of butterfly flight mechanics and ran a variety of experimental systems in the laboratory of James Marden

1997 *Paleontology Field Assistant for the Royal Tyrrell Museum*
prospected, excavated, and prepared fossils at a remote Alberta site

Training and faculty development

2012-2013 Proposal Development Institute, Virginia Tech

2009 Geneva Summer School in the Philosophy of Physics