SUBARTICLE

Biography of Noether

Clarissa Ai Ling Lee

Novel developments in physics usually begin with a speculation. The speculation ranges from a prediction based on a simple hypothesis, right through to the development of models, narratives, and prototypes of myriad possibilities. Some of the better known speculations emerge from thought experiments such as the Schrödinger Cat paradox and Einstein's Twin Paradox, each having played important roles as narratives of indeterminacies and what-ifs, each with experimental counterparts through the double slit experiment, the determination of the lifetime of particles traveling at near the speed of light, and more generally, how time is transformed between different frame of references.

Accompanying Materials

Methodology & Intellectual Context
(https://adanewmedia.org/2013/11/issue3-lee/)

Biography of Noether
(https://adanewmedia.org/2013/11/issue3-lee-accomp1/)

Biography of Goeppert Mayer
(https://adanewmedia.org/2013/11/issue3-lee-accomp2/)

On Speculative Science Fiction
(https://adanewmedia.org/2013/11/issue3-lee-accomp3/)

Epilog
(https://adanewmedia.org/2013/11/issue3-lee-accomp4/)

Emmy Noether and her far-reaching scientific contribution to the theory of invariance are important for grounding the ontology by which speculative physics theories are able to take place; and for providing the platform for epistemological explorations. The development of the theory of invariance resulted in paradigm-shifting implications in physics, from relativity to quantum field theory. In fact, without the mathematical developments that she had pioneered, many media-celebrated physical objects, such as the Higgs Boson, would have looked very different, or possibly not have been predicted in the way they were. Her theorem, transforming between paths of actions, energy, and invariant framework, as well as finessing the connection between classical and quantum mechanics, enables what would have been considered 'illegal' actions under classical theory to become quantum-mechanically feasible.

Noether took the mathematical analytics of Euler, Lagrange, and Hamilton, and produced, from them, geometrical analytics that were sublimated and transformed through group theory and complex numbers. These functionals rendered hitherto inexplicable physical phenomena logical through the development of new mathematical operators. Even as new developments in variational calculus have brought about short cuts for determining whether a particular mathematical embodiment of a physical action conforms to the symmetry of invariance and extremum (representing geometrical paths of minimum or maximum points in the curves of a graph), the foundation of her work in itself remains unquestionable in its technical promise and application. The symmetry is represented by a physical object, which, after rotation within the framework, could not be discerned as any different in terms of its positioning and physique. Among the functions used to describe the mathematical ontology of the object are dependent and independent variables, which play important roles in determining the level of perturbation the functions are able to endure, and therefore in shaping their constraints and contingencies.

Through the process of rotation and transformation of spatial coordinates (and the substitution of mathematical representations of the physical processes), the question asked becomes: has mathematics been normalized so that some order of terms can be cancelled or factored out of the equations? The normalization of terms becomes a method of trimming the edges by coupling together the long-bit strings of spaghetti-like functionals, the folding in of terms to produce more elegant representations of equations then used to demonstrate whether the physical action under examination is feasible. This means that one has to consider the possibility of extrapolation from a single dimensional character to the multi-dimensional, requiring stripped-down and idealized entities that were used for testing the mathematics to be restored to their full-bodied version, then subjecting the rigorous proofs to the ultimate test of physical fit and fitness.

Therefore, the importance of Noether's mathematical work has to do with its deployment for grounding theoretical problems in the 'new' physics of her day, and even the new physics of today. Her textual articulation of the mathematics is not particularly visual but still models, through abstract notations, the algebraic-geometrical structures that would drive the highly mediated object-oriented age of today's physics and of the mathematical sciences in general. The study of such a development opens up a line of communication that extends into consideration of the development of a highly visual media culture that is layered over, and bound together, through the application of the algebra of Noether, and her successors, for organizing data structures and categories.

Having worked closely with mathematicians such as Hilbert, Klein, Minkowski, and Schwarzschild, Noether was already familiar, by the time she developed her famous theorems, with problems facing the development of the multi-dimensional post-Newtonian physics, and had worked on the problem of energy conservation in Einstein's theory. This work was drawn from two theorems that came out of her 'habilitation' submission[1] in Göttingen, thus providing the tools for dealing with problems of conservation in the move from flat space-time to curved space time, through the symmetry group of finite and infinite dimensions. The theorems also allow for the reconstitution of conservation laws and identities, the latter known as the equality between functions differently defined but all adding up to describe the same qualities and quantities. Could Noether have foreseen the computational robustness of her theorem in the twenty-first century from her position in the early twentieth century?

Noether came of a long line of mathematical women whose earliest contributions had been as unsung agents of change pushing mathematical boundaries, either through intuitive insights or from seeing through the chaos to connect pieces of the mathematical puzzles coherently. Needless to say, one of the luminaries is none other than Countess Ada Lovelace. Noether and Lovelace were involved in the production of pure mathematics with almost immediate application to physics and computing respectively, even if the applications required some translation work from pure mathematics to computable algorithms. But many of the early contributions of mathematics provided by female mathematicians (most, being self-taught, had the privilege of private tutoring, and/or direct epistolary contact with famed mathematicians of their time) tended to be obscured by the fact that the theorems they developed are named for their *pater familia*, once again allowing patrilineal dominance to usurp their contribution, lending weight to the familiar assumptions that female mathematicians are exceedingly scarce historically. Noether was a case in point: I knew of her theorem long before I discovered that the person behind it was a woman, if only because the production of scientific discourse elides the social conditions and origins of the discourse.

Ada Lovelace was a different story, since everyone knew her as the woman mathematician who gave a 'voice' to Babbage's calculating machine, and who had also the honor of having a programming language named for her *first* name, which is therefore, *her* personal name. One other famous female Neo-Platonic mathematician we refer to by her first name is Hypatia, whose fame, sadly, did not preclude the preservation of her writings in mathematics and philosophy.[2] While one might argue that ignoring the gender of the mathematical exponent speaks to the quality and therefore, the success of women, as equal participants in a highly abstract field, and supposedly giving lie to the idea that high-level cognitive functions are differentiated by gender, it also becomes a convenient excuse for 'forgetting' that the female mind matters, and that the assimilation of her contributions have been highly disadvantageous to her recognition, and therefore, her agency, turning her accomplishments by virtue of social conditions into exceptions.

Noether's theorem did for developments in relativistic quantum mechanics what James Clerk Maxwell's equations did for the classical field of electromagnetism.[3] While Maxwell's geometry provided the first level of unification for electricity and magnetism, Noether's insight into the algebraic potentiality in geometry enabled the reconceptualization of field potentials in particle physics. There is an interesting twist to the story: prior to Maxwell's formulation of the electromagnetic field, the constitution of electricity and magnetism had been viewed as micro particles because of the materialist-atomistic view. Charge, both positive and negative, playing an important role in the particle-field representations, was also part of this atomic-materialist quilt. This materialization was later reincarnated in the form of the conservation of charge density in both continuum and discrete representations of quantum mechanics, therefore taking on mathematical import in the envisioning of the probabilistic density of particles with wave-like characteristics. Hence, the story of the charge, presented through Lagrangian mathematics as a protagonist in classical and quantum physics, now becomes an integral representation of finiteness in mathematical physics and exists in the dual factions of the particle and the field.

However, by the early twentieth century, the Maxwellian presentation of field had been replaced by a particle outlook because of developments in atomic and nuclear physics, such as the discovery of the electrons, protons, and neutrons. Later, there were also other experiments performed during the early years of the quantum theory conceptualization that led to the particle-wave duality debate Karen Barad discusses in chapter seven of *Meeting the Universe Halfway*. Even the early development of quantum electrodynamics, a precursor to quantum field theory, was very much centered on the concept of the particle. Therefore, it appeared that field theory, which Noether's theorem captures so elegantly, was, at that time, relegated to the back burner. This changed again in the 1960s when it became clear that field theory was needed to deal with the development of increasingly complex sets of new 'particles' that were being predicted and then discovered. The emphasis on the particle had brought about a number of unsolvable problems, such as that involving symmetry breaking of the unified forces and even the particle-wave paradox.[4] Noether's work on group theory, which had been so essential in the early days to the development of Einstein's Special Relativity, now returned for the development of an axiomatic approach to quantum field theory, which is another way of saying, without going into technical detail, that it is a first principle/axiomatic approach to quantum field theory developed through abstract algebra.

However, there was a period in the 1920s and 1930s when her work elicited only marginal interests from the mathematical community, mainly because she was not into publicizing her own work (Byers 954-55), given the pressures of self-effacement, promoted as an ideal in scholarship by ignoring power and social differentials. That said, her work has been intrinsic to unifying the various disparate disciplines of mathematics, and even played a small, yet unfinished, part in the creation of the theory of everything whereby the mathematics she had developed are applied to the study of gravity and gravitons.[5]

Footnotes (returns to text)

1. The *habilitation* operates like a postdoctoral examination that endows on you the recognition of being a full member of the academy (who can supervise PhD students) once your post-doctoral work submitted for that purpose is accepted and approved by a committee of specialists in your field at the university where you seek the *habilitation*.
2. It was serendipitous that I came across Margaret Alic's 1986 *Hypatia's Heritage: A History of Women in Science from Antiquity through the Nineteenth Century*. The work concentrates mostly on the contribution of women in the western worlds (we do not know what women in other non-Western civilizations did, so more work has to be done in this area) and ends sometime in the late nineteenth century, so women such as Noether and Goeppert Mayer, and their female contemporaries, are not part of the story. For more contemporary stories, though different from Alic's work, one might want to check out the recently published ***A Passion for Science: Stories of Discovery and Invention*** (http://findingada.com/book/) (edited by Suw Charman-Anderson) published in conjunction with the *Ada Lovelace Day* celebration. In reading about the backgrounds of these other women who preceded them, some of who we might have known by their last names having seen those referenced in mathematical papers, we come to appreciate the difficulties and gumption required to do what they did. Of course, class is also part of the story, for one does not hear of a countrywoman deciding suddenly that she wanted to do mathematics. It would have bordered on the miraculous had she succeeded. Ada Lovelace's story is told alongside that of French Sophie Germain and Russian Sofia Kovalevsky (nee Korvin-Krukovskaya) in the book.
3. Scientist-mathematician-philosopher James Clerk Maxwell, was interested in working out a more mathematically logical way for speculating on the formation of laws on electricity. His earlier work contains a geometrical outlook that conformed to the more dominant mathematical discourse of his time that privileged geometrical thinking over analytical subtleties. However, his later work, built on a

mechanical viewpoint that drove the dynamical model that led to the formation of his four famous equations of electromagnetism, was on modulating electrical forces and the displacement of electrical current. See “On Faraday’s Line of Force” in Thomas K. Simpson’s 1997 *Maxwell on the Electromagnetic Field*.

4. For a serious discussion on the conceptualization of the particle, one can read Gordon Fraser’s *The Particle Century,* published by the Institute of Physics. For more popular accounts, one can check out Robert Gilmore’s *Alice in Quantumland*, Lisa Randall’s *Warped Passage*s and *Knocking on Heaven’s Door*, and Frank Close’s *The Infinity Puzzle: Quantum Field Theory and the Hunt for an Orderly Universe.* All the popularizers above are physicists. Also, one might be interested in journalist John Gribbin’s *In Search of Schrödinger’s Cat: Quantum Physics and Reality* which will help explain the world in which physical paradoxes exist(Gribbin is a physicist turned science writer).
5. If you are interested in the kind of developments that Noether’s theorems have engendered, check out a rather comprehensive and thoughtful overview of it in Dwight E. Neuenschwander (2011)’s *Emmy Noether’s Wonderful Theorem*, Baltimore: John Hopkins University Press. For a very short biography of Noether, there is Nina Byers’s (1996) “The Life and Times of Emmy Noether: Contribution of Emmy Noether to Particle Physics” in *History of Original ideas and Basic Discoveries in Particle Physics*. Eds. Harvey B. Newman and Thomas Ypsilantis, NATO ASI series, New York: Plenum Press, 945-64. There is also a German biography of Emmy Noether by Auguste Dick, translated by H.I. Blocher, tersely titled *Emmy Noether: 1882-1935*, Boston: Birkhäuser, 1981. This biography contains her list of publications, the students she supervised, and her obituaries. However, there are no references to the papers and materials that would have aided in the writing of the biographical parts. Much of the childhood material could have been obtained through interviews, though not explicitly stated as such. The **German Wikipedia entry on the author** (http://de.wikipedia.org/wiki/Auguste_Dick) describes her as an Austrian historian of mathematics and professor.

Clarissa Ai Ling Lee (https://adanewmedia.org/author/clarissalee)
Clarissa Ai Ling Lee is ABD in the Program in Literature at Duke. She works at the intersection of comparative media studies and science studies. Her dissertation is currently titled Speculative Physics where she attempts to demonstrate that epistemic versatility and

inspiration can be found in the transdisciplinary practices of physics and literature. She blogs at modularcriticism.blogspot.com and scandalousthoughts.wordpress.com. She tweets as @normasalim.

Ada: A Journal of Gender, New Media, and Technology
ISSN 2325-0496