REVIEW

A review of Melanie Mitchell's MOOC "Introduction to Complexity"

MICHELLE E. JORDAN
Arizona State University (USA)

By inviting the perspectives of complexity researchers who are normally outside of the *Complicity* milieu and outside of education to questions in education, editor Barnard Ricca hoped to provoke new insights and create new avenues of inquiry into the relationship of complexity and education (Ricca, this issue). I was looking for much the same when I registered for Melanie Mitchell's MOOC, *Introduction to Complexity*.

Mitchell's Massive Open Online Course (MOOC) is a boon to the extended complexity community and to the educational complexity community. This online course was designed to offer a broad overview of the sciences of complexity as practiced by scholars in biological, physical, computational, and social science disciplines. Hosted by Complexity Explorer and funded by the Santa Fe Institute (SFI) and voluntary donations, the course is free and open to anyone. Offered periodically, it first ran in the spring of 2014 with 3, 993 students enrolled from around the world. It was offered again in the summer of 2014 and the most current iteration is scheduled to begin on September 29, 2014. There are no course prerequisites. The website suggests a commitment of 3 to 6 hours a week, which pretty well reflects my participation. Those wishing to receive a certificate of successful completion must average at least 70% on a set of ten end-of-unit tests. The course is self-paced in that participants can access all materials throughout the course; however, all tests must be completed by the course end date. Although you must sign up to access tests and the discussion forum, most course content is archived and accessible to anyone.

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How the Course is Structured

The course is structured into 11 sections, one per week as follows:

1. What is Complexity?
2. Dynamics and Chaos
3. Fractals
4. Information, Order, and Randomness
5. Cellular Automata
6. Genetic Algorithms
7. Models of Biological Self-Organization
8. Models of Cooperation in Social Systems
9. Networks
10. Scaling in Biology and Society
11. Wrapping Up; Virtual Field Trip

Each section is sub-divided into a series of short (7 to 20 minutes) video-recorded mini-lectures. Sections are often accompanied by ungraded activities, self-check quizzes, experiments, or homework with worked examples scaffolded through video-recorded explanations. NetLogo – a simulation and programming platform – is used extensively throughout the course to illustrate core ideas. Readers unfamiliar with agent-based modeling in general or NetLogo in particular need not worry about getting lost, as excellent tutorials walk the learner through step-by-step instructions for accessing and manipulating the models. One of the delights of the course for me was that each section invariably ends with a "guest spot", a recorded interview of a prominent complexity scientist about her or his work and views of the field as they relate to that section's topic (e.g., Mark Newman, physics and complex systems, University of Michigan; David Krakauer, theoretical biology, University of Wisconsin; Stephanie Forrest, computer science, University of New Mexico). Finally, each section is accompanied by a diverse set of optional readings. These range from popular press books (e.g., Duncan Watts, *Six degrees: The science of a connected age*) and online articles/resources (E. Yong, How the science of swarms can help us fight cancer and predict the future, Wired, 03.19.13; www.fractal-explorer.com/), to classic articles by influential 20th century scientists/mathematicians (e.g., W. Weaver, Science and complexity. American Scientist, 36: 536-544, 1948) and technical discussions of nonlinear models (e.g., M. Feigenbaum, Universal behavior in nonlinear systems. Los Alamos Science, 1, 1980, pp. 4-27).

For those who wish to receive a formal certificate of completion of the course and/or check their understanding of course concepts, each section is followed by a multiple-choice test with machine grading. From an instructional/pedagogical standpoint, this may be the weakest aspect of the course. The test questions are almost invariably aimed at the knowledge level, requiring only regurgitation of information with little inferencing or checking for transfer. This is not surprising or unusual in MOOC environments (Sandeen, 2013; Yin & Kawachi, 2013). And perhaps this type of evaluation best meets a need to make as large a number of people as possible feel as confident as possible about their basic understanding of complex systems, a goal to which I am not opposed.

Finally, the course website hosts an online forum for learners to post questions/answers and discuss the course material with the instructor, teaching assistants, and/or other students.

In my experience, the discussion was largely limited to addressing pragmatic concerns associated with the course structure and problems using the course platform. Little was explicitly done to provoke interdisciplinary and transdisciplinary exchange of ideas. In future instantiations of the course, such conversation might be facilitated through well-timed, thought-provoking questions that cross disciplinary lines - particularly if these were of a theoretical or philosophical nature. Such efforts might be most effective if advanced by the course facilitators, but course participants could also intentionally perturbate the conversational system. In the future, SFI hopes to use the course forum to help organize local "Meetups" for course participants who would like to meet in person, a practice that might also facilitate idea exchange and knowledge building.

What the Course Covers and Some Things It Does Not Address

The course is best described as a high quality tutorial in the general area of complexity. There is a strong connection to Mitchel's 2009 book, *Complexity: A Guided Tour*, with which many *Complicity* readers are familiar. It should be no surprise then that Mitchell's course adheres to a postpositivist, or what some might call a critical realist approach to complexity (Byrne & Callahan, 2013; Cochran-Smith et al., 2014), if not explicitly, then leastwise by virtue of the topics it privileges.

The first section of the course, *What is complexity?*, overviews common structures of complex systems and how such systems form, evolve, and exchange information. It surveys the core disciplines of complexity (i.e., dynamics, information, computation, and evolution), identifies the goals of complexity scientists (i.e., developing mathematical and computational tools to inform cross-disciplinary insights and advancing a general theory of complexity), and reviews methodologies of the field of complex systems research (i.e., experimental, theoretical, and computer simulation).

Sections 2 (*Dynamics and Chaos*), 3 (*Fractals*), and 4 (*Information, Order, and Randomness*), explore visual and mathematical representations of complexity that inform understandings of a wide range of biological, social, and technological systems. Learners are introduced to dynamics: science of how things change, iteration, nonlinear interactions, sensitive dependence on initial conditions, Shannon's information theory, and self similarity across scales.

Sections 4 (*Genetic Algorithms*) and 5 (*Cellular Automata*) describe idealized models of evolution and adaptation in complex systems, bringing together ideas on dynamics, information, and evolution from previous sections. The use of these simulation and computational modeling tools are illustrated and ascribed to solving real-world problems such as designing parts of aircraft, optimizing assembly line scheduling, detecting fraud, and generating computer animation for films.

In its examples and concerns, the first half of the course privileges natural sciences over social sciences. It was in the second half of the course that I found ideas most immediately salient to my thinking about learning, teaching, and educating. Section 6, *Models of Biological Self-Organization*, presents idealized models of self organization in biology, society, and economics to illustrate how complex scientists build simple models to gain insight about behaviors of complex systems such as flocking and schooling, synchronization, foraging, task allocation, clustering, and decision making. Section 7, *Models of Cooperation in Social Systems*, was perhaps my favorite. Mitchell organizes this section around the question: "How is it that intrinsically selfish individuals living in a society or any kind of social group learn, or find a way to cooperate in order to increase the benefit for all members of the group?" After presenting the well-known Prisoner's Dilemma and El Farol models, Mitchell interviews Brian Arthur (first director of SFI economics program), to gain further insight into this question. The next two sections, *Networks* and *Scaling in Biology and Society*, survey a diverse array of biological and social systems at multiple levels of organization (e.g., neural network of C. elegans, food webs, metabolic networks, city populations, airline routes, internet paths, bank network). Expanding on earlier themes, Mitchell describes common properties in the structure, evolution, and dynamics of diverse systems and considers some implications for nature, technology, and society.

Section 11 wraps up the course with a virtual field trip through the physical grounds and social networks of the Santa Fe Institute, putting a human face on that institution by touring the work spaces and lunchroom, interviewing SFI professors and graduate students in formal and informal settings. These interviews help give embodiment to the field of complexity science; these are real people doing real research and they occasional stop for lunch.

By this point, it is likely readily apparent to many *Complicity* readers some of the issues absent from *Introduction to Complexity*. For instance, there is little to no consideration of philosophical perspectives. Participants will not encounter Moran, Cilliers, or Doll, nor will they grapple with ontological, epistemological, or axiological diversity. This is not a complaint, simply recognition of a constraint in the instructor's intent. Melanie Mitchell is trying to help people understand basic concepts in complexity science as practiced by researchers associated with SFI. *Complicity* authors are often trying to help people teach better, learn better, and live more effectively in the complex systems they comprise and inhabit, to respond to complexity in ways other than avoiding or trying to control it. This MOOC might offer opportunities to gain insight about these kinds of issues, but to obtain them you will need to extrapolate far beyond the ideas as presented.

What This Course Can do for Educational Scholars and What It Probably Won't Do

I would liken this course to a 101 undergraduate level basic intro course in complexity. It is likely most useful for satisfying one's curiosity about what is complexity and helping people take first step into the deep end of understanding fundamental concepts that undergird the field. This is obviously helpful for people who are just getting a feel for the potential of the area. Thus, graduate students might find this course more helpful and interesting than more experienced researchers. Likewise, instructors teaching complexity will likely find this MOOC a helpful way to review material and develop ideas for instruction.

Nothing will surprise you here if you are already familiar with the general complexity field, but that does not mean that the course will not be useful for experienced educational complexivists. For instance, if you've ever hoped to develop a more integrated perspective on complexity concepts you originally learned in a fragmented fashion and to re-imagine how your current and future work might fit in that perspective, this is a course for you. If you've ever wanted to improve your understanding of the basic computational and mathematical tools of complexity science, this is a course for you. Complexity theory is seductive. However, the energy it takes to make the next steps to rigorous understanding is too easy to avoid. This course will enable people who have been attracted by the discipline of complexity to deepen their understanding of the basic foundations of complexity theories and models and therefore, be better able to use them in their work. Thus, this course is for those of us whose initial forays into the field of complexity produced large gains in understanding but are now feeling a need to make rigorous methodological progress (See Ricca, this issue).

By inviting the perspectives of complexity researchers who are normally outside of the *Complicity* milieu and outside of education to questions in education, the editor hoped to elicit new insights into the relationship between complexity and education and create avenues of inquiry within complexity and education. I invite *Complicity* readers to take Melanie Mitchell's online course, *Introduction to Complexity* – and to discuss it with friends and colleagues - as an additional, different opportunity to accomplish these goals. I also urge them to do so for another reason: So that we as the *Complicity* community and we as educational researchers will be better equipped to contribute to the extended complexity community. Guevara (this issue), suggested that "as scientific disciplines are increasingly mingled in modern scientific work, a common language will certainly facilitate the communication between different disciplines and presumably increase their contribution to society." To make progress with evolving solutions to problems we currently face and to successfully re-imagine transformative possibilities for the future, educational researchers need to be in interdisciplinary and transdisciplinary conversation with people who share root metaphors. But, as some in the complexity-education community pointed out, it is also incumbent upon us to reciprocally contribute to theories of complexity.

With these ideas in mind, I suggest that educational scholars who decide to register for *Introduction to Complexity* approach in three ways suggested by Ricca (this issue):

- Take the usual analytical approach: What is the content, argument, etc.?
- Approach them as a collection: What are the relationships among the ideas that might provide insight into the metaphors we share within the *Complicity* community and within the Complexity community?
- Inform your personal agenda: How does this article help me sharpen my own work as an educational researcher and as a complexivitst?

Possible Extensions

Introduction to Complexity is only the first of several online courses offered through www.complexityexplorer.org. The Santa Fe Institute has been busy developing a number of other free online courses including:

- Nonlinear Dynamics: Mathematical and Computational Approaches by Liz Bradley
- Mathematics for Complex Systems, by Melanie Mitchell
- Information Theory and Network Biology by Hector Zenil and Narsis Kiani
- Introduction to Dynamical Systems and Chaos by David Feldman
- Agent-Based Modeling in NetLogo by Uri Wilensky

Researchers of complexity in education might also find Scott Page's (University of Michigan) MOOC, *Model Thinking,* useful [www.coursera.org/course/modelthinking]. This 20-section course is developed around the idea that "We live in a complex world with diverse people, firms, and governments whose behaviors aggregate to produce novel, unexpected phenomena. We see political uprisings, market crashes, and a never ending array of social trends. How do we make sense of it?" Page presents "a starter kit of models" representing complexity in economics, political science, business, and sociology. *Section 2: Sorting and Peer Effects*, covers famous models of relational interdependencies by Schelling and Granovetter. *Section 3: Aggregation*, describes models of how individual preferences can be rational, but the aggregates need not be. *Section 7*, *Tipping Points*, applies a percolation model from physics to banking and examines a model of diffusion and recovery associated with the spread of diseases. *Section 12: Coordination and Culture* and *Section 14: Networks*, may be of particular relevance for *Complicity* readers, as they most closely pertain to understanding the kinds of social systems of interest to educational researchers.

Finally, a number of syllabi of complexity courses offered around the world are available online nowadays, a number of which the Santa Fe Institute has compiled at http://www.complexityexplorer.org/explore/syllabi (Note: most are by professors in U.S. universities). Like Mitchell's Introduction to Complexity MOOC, many of these courses focus on natural systems, taught in physics, biology, and computer science departments. However, a fair number focus on complex social systems, for instance, Duncan Watts' (Columbia University, Sociology) Networks and Complexity in Social Systems [www.columbia.edu/itc/sociology/watts/w3233/]. Two syllabi not yet listed on complexity explorer, but potentially useful to Complicity readers are Robert Axelrod's (University of Michigan) Complexity Theory in the Social Sciences [www-personal.umich.edu/~axe/]. Robert Goldstone's (Indiana University, psychology and director of the Percepts and Concepts Laboratory) course, Complex Adaptive Systems, [http://cognitrn.psych.indiana.edu/rgoldsto/complex/p747description.htm] is also quite useful, concentrating on "fundamental commonalities" across apparently dissimilar systems in psychology, computer science, economics, and neuroscience, among others. Goldstone has generously posted many resources related to his course.

References

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