

The use of a theoretical lens to make sense of classroom video data – Exploring abduction on film

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Year 10 students explored natural selection through interacting with a set of purpose-built NetLogo models, a type of multi-agent based computer-modeling software. Tripod mounted cameras, web cameras and screen casting were used to record students' interactions with the software as well as their interactions with peers and teachers. This paper proposes the use of Magnani's (2001, 2009) abduction framework, specifically his notions of sentential, visual and manipulative abduction, to analyse and make sense of this rich and complex data set. Specifically, it enables a detailed exploration of students' reasoning with computational representations (NetLogo), something that has not been previously explored in detail with video data.

The difficulties of teaching and learning natural selection

The focus of the research addressed in this paper is on exploring the use of digital representations, in this case multi-agent based computer modelling software (NetLogo), by students (in year 10) to reason about natural selection as a complex systems phenomenon. In particular, investigating the specific affordances of this technology for students' reasoning about complex systems in science.

Natural selection is a particularly difficult scientific concept for students to comprehensively understand (Anderson, Fisher, & Norman, 2002; Dickes & Sengupta, 2012; Ferrari & Chi, 1998; White, 1997; Wilensky & Reisman, 2006). Research suggests that this is primarily because students do not understand the notion of a complex system, which is fundamental to natural selection (Centola, McKenzie, & Wilensky, 2000; Centola, Wilensky, & McKenzie, 2000; Chi, 2005; Chi, Roscoe, Slotta, Roy, & Chase, 2012; Dodick & Orion, 2003). In particular, many students believe that all systems must be deterministic and centralised, whereas complex systems are non-deterministic and decentralised (Resnick, 1991; Wilensky, 1993). If students can differentiate between a non-deterministic/decentralised system and a deterministic/centralised system then they can more productively explore the notion of natural selection.

NetLogo as a digital representation to explore natural selection

NetLogo (Wilensky, 1999) is a multi-agent based modeling software package that is designed specifically to allow simulation of complex systems. The software

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allows users to create and modify the variables that determine the behaviour of the individual components at the micro level as well as the variables that determine the role played by the environment (Blikstein & Wilensky, 2004; Levy & Wilensky, 2010; Wilensky & Reisman, 2006). The results of running the simulations are displayed in various forms (e.g. graphs, figures), which again can be modified, and which display the outcomes at the macro-level (Sklar, 2007). NetLogo is a digital representation because it has all the components of a representation stipulated by Peirce (1998b) (it operates within the triad of representamen, object and interpretant) and functions via a digital medium.

The software is low-threshold, high-ceiling and so while the software is easy to learn to use in order to perform basic functions, it can also be used to conduct complex investigations (Sengupta & Wilensky, 2011). It is possible to both modify existing models of complex systems and create entirely new models using the software (Blikstein & Wilensky, 2010). As such, NetLogo is ideally suited for use by students to reason, in a scientific way, about complex systems in a variety of different areas of science, including natural selection (Dickes & Sengupta, 2012; Wilensky & Reisman, 2006).

Students' reasoning

The reasoning that was conducted by the students when using NetLogo is conceptualised by the author according to Magnani's (2001, 2009) interpretation of Peirce's (1998a) notion of reasoning. Peirce (1998a, p. 11) understood reasoning as "the process by which we attain a belief which we regard as the result of previous knowledge." He proposed that while there are various forms of reasoning that it is the scientific method that enables the most productive reasoning (Peirce, 1992a). Peirce (1992b) identified three different forms of scientific reasoning: deduction, induction and abduction. But it is abduction, or hypothesis generation, according to Magnani (2001, 2009), which Peirce saw as the most important because it is the most generative of new understanding. The logic of scientific discovery, Magnani argues (2001, 2009), can be found in the notion of abduction. It is scientific reasoning, specifically abduction, conducted by students, which is the focus of this research. It is through abductive reasoning, the author argues, following Magnani (2001, 2009), that students can generate their own comprehensive understandings of natural selection.

Collecting & Managing Multiple Video Data Sources

How can students' use of NetLogo be captured in such a way that the rich data needed to explore students' reasoning about natural selection is made available? The data of most interest is not only the activity that is taking place on the computer screens, but also the interactions between the students and NetLogo, the interactions between the students as they use NetLogo (and refer to NetLogo) and the interactions between the students and the teachers (again in relation to the use of NetLogo). Peirce's (1998a) logic as semiotic (which explicitly links reasoning and representations, such that reasoning is a continues process of semiosis, or sign activity) plays out in each of these situations. All of these events involves multiple representations, each consisting of a complex array of interacting representamens,

objects and interpretants. All of this representational activity is relevant for investigating students' use of the NetLogo models to reason about natural selection, and so as much of this data as possible was collected.

The activity that was taking place on the computer screens was captured through the use of Camtasia Studio© (TechSmith, 2012), which has been shown to be the most effective screen capture software (Blevins & Elton, 2009; Carlson, 2009; Charnigo, 2009; Schnall, Jankowski, & St. Anna, 2005). Camtasia Studio© was also linked to webcams attached to the students' computers in order to capture the interactions between the students and NetLogo. This means that not only was the students' use of NetLogo captured (what was taking place on screen) but also the students' interactions with NetLogo (e.g. their gesturing at the screen as they used the software) was also captured.

In order to more comprehensively capture the students' interactions with NetLogo, as well as the interactions between the students and between the students and the teachers, two tripod-mounted cameras were also utilised. One focused on the teacher and other focused on the students. In addition, students' artifacts were collected (the students' projects they created using the iPad application Explain Everything ©) in order to capture additional representations that were produced by the students.

Once the video data was collected, as with all forms of data, it had to be managed in order to make it amenable for analysis. This was achieved through the use of Camtasia Studio© in conjunction with Studiocode© (which enables the tagging of events that occur in videos). Only recently has Studiocode© been used to explore the classroom (see Aranda et al. (2012), Tytler, Hubber, and Chittleborough (2010) and Xu, Tytler, Clarke, and Rodriguez (2012)).

The power of using Camtasia Studio© in conjunction with Studiocode© is that it enables the management of multiple sources of video data. The stacking of different combinations of the different video data sources (and their accompanying audio) means that multiple viewpoints of a single event are possible. In addition, it is possible to view multiple events occurring simultaneously. Thus it can be seen that through the use of both Studiocode© and Camtasia Studio© that multiple video data sources, and the relevant audio, can be turned into a data set that is useful for investigating students' use of NetLogo models to reason about natural selection.

Making Sense of All this Data

Yet, while the above approach provides a means of managing the video data, it does not address the analysis (i.e. coding) of the video data. This is a significant challenge because there is so much going on in the video data (a direct reflection of the complexity and dynamism of the classroom). Any coding of the video data must take into consideration: students, teachers, NetLogo models and students' artifacts. It is not sufficient to just focus on the discourse (involving students and teachers) because much that is going on visually in the video data is overlooked. The challenge is to take full advantage of the data available in the videos, and a key component of this is the visual data. What is needed is a way to frame the data so that we can account for both visual and auditory happenings.

The Affordances of Magnani's Abduction Framework

A possible solution to this problem may be found in Magnani's (2001, 2009) abduction framework (of cognition). As suggested above, Magnani (2001, 2009) identifies abduction as potentially the most important form of reasoning (the other forms of reasoning are deduction, in which the truth of the conclusion is guaranteed by the truth of the premise, and induction, which involves generalisations). This is because for Magnani (2001, 2009), following Peirce, it is abduction that is at the root of creativity in science; it is through abduction that scientists generate hypotheses to explain scientific phenomena. It is abduction that enables the generation of new scientific knowledge.

Magnani (2001, 2009) proposes that there are two distinct forms of abduction; selective and creative. Selective abduction is that which "merely selects from an encyclopedia of pre-stored hypotheses..." while creative abduction is "...abduction that generates new hypotheses..." (2009, p. 27). There are also two possible types of selective and creative abduction: theoretical and manipulative. So theoretical abduction may be selective or creative (although it is mainly selective) and manipulative abduction may be selective or creative (but more often than not it is creative) (2001, 2009). Theoretical abduction is abduction in which "...only inner aspects are at stake..." while manipulative abduction is "...thinking through doing..." (2009, p. 12). It involves "...the interplay between internal and external aspects..." (2009, p. 12) and is "...a kind of abduction, usually model based and so intrinsically 'iconic', that exploits external models endowed with delegated (and often implicit) cognitive and semiotic roles and attributes. ..." (2009, p. 58). Central to manipulative abduction are the "epistemic mediators" (2009, p. 2), which are objects in the environment (external to the individual) that are endowed with specific affordances (i.e. opportunities) for reasoning (including abduction).

Theoretical abduction includes what Magnani (2001, 2009) calls sentential and model-based forms. Sentential abduction is "...related to logic and to verbal/symbolic inferences..." (2009, p. 11) while model-based abduction is "...related to the exploitation of internalized models of diagrams, pictures, etc." (2009, p. 12). Model-based abduction can be further broken down into sub categories, one of which is visual abduction (2001, 2009). This is "...a special form of non verbal abduction, [and] occurs when hypotheses are instantly derived from a stored series of previous similar experiences. It covers a mental procedure that tapers into a non-inferential one, and falls into the category called 'perception'" (2009, p. 35).

Magnani (2001, 2009) provides a detailed description of sentential, visual and manipulative abduction. Sentential abduction consists of both verbal and written propositions (2001, 2009). Manipulative abduction, like visual abduction, is more complicated. It involves what Magnani (2009, p. 48) calls "templates of behaviour." These are ways of acting (some pre-existing in memory while others are created to address current needs) that "abductively enable a kind of epistemic 'doing'" (2009, p. 46). They include (as detailed in Magnani (2001, 2009)): attention to curious and anomalous phenomena, attention to the dynamical character of phenomena (not to entities and their properties); exploiting artificial apparatus to access previously hidden knowledge about phenomena; simplifying the reasoning task and redistributing effort across time; challenging/overcoming incomplete and inconsistent

information; controlling sense data to get various new kinds of stimulation; building external artifactual models to address current needs; using natural objects/phenomena as epistemic mediators (i.e. manipulating the natural environment in order to further understanding of the current situation); and executing various contingent ways of epistemic acting.

This epistemic acting consists of a number of different ways in which acting goes beyond the pragmatic. Including (as detailed in Magnani (2001, 2009)): looking at phenomena from different perspectives; checking the different information that is available in regards to the phenomenon of interest; reordering and changing relationships to evaluate what is going on in with the phenomenon of interest; comparing events as they transpire (in particular subsequent events); and finally choosing, discarding and imaging further manipulations.

As with manipulative abduction, Magnani, Cavite, and Mascara (2004) provide a detailed description of this cognitive construct. Visual abduction involves the individual experiencing an image that contains an anomaly, which triggers a process of image-based hypotheses creation (to explain the anomaly). The anomaly often concerns explaining (as detailed in Magnani et al. (2004): the absence of an object; why an object is in a particular position; and how an object can achieve a given task (interacting with other objects and moving around the image). The individual, in response to the anomaly and seeking an explanation for the anomaly, generates a series of possible explanations (or hypotheses) that are image-based.

This visual abduction involves both a spatial and a visual component (Magnani et al., 2004). The spatial component refers to “where an object is located relative to other objects” while the visual component refers to “what an image looks like” (Magnani, 2001, p. 99). The spatial component of visual abduction involves (as detailed in Magnani et al. (2004)): generating spatial representations from memory; composing and superimposing image representations; adding, deleting and moving parts of an image; focusing (and unfocusing) on parts of an image; rotating and scanning the image; and inspecting and retrieving spatial relations for an image. The visual component of visual abduction involves (as detailed in Magnani et al. (2004)): rotating the image (to alter the orientation); translating the image (to alter the location); and zooming the image (to alter the size of the image).

It must be stressed that while Magnani (2001, 2009) proposes that sentential, visual and manipulative abduction are distinct forms of reasoning, they never occur in isolation. Rather, abduction is multimodal and hybrid in nature; the sentential, visual and manipulative are interlinked and one entails the other. In this way, the reasoning of the individual is never just sentential, visual or manipulative; rather their reasoning simultaneously exhibits sentential, visual and manipulative components.

Applying the Abduction Framework to the Video Data

The author proposes that Magnani’s (2001, 2009) notions of sentential, visual and manipulative abduction might be useful for coding the video data. These categories (and their sub-categories, e.g. looking from different perspectives for manipulative abduction) provide a way of taking account of the visual and auditory happenings that form a part of the students’ use of the NetLogo models to reason about natural selection. But by no means do Magnani’s categories exhaust what it

means to reason when using NetLogo models. However, Magnani's framework does provide a valuable way to make sense of the video data.

By applying Magnani's (2001, 2009) framework to this video data, students' interactions with the NetLogo models and their interactions with peers and teachers, as well as the artifacts students produce, can be viewed as sentential, visual and manipulative abduction in action. The NetLogo models can be seen as epistemic mediators, offering students particular affordances for exploring natural selection. It can then be suggested that teachers must first work with the students to recognise the NetLogo models as epistemic mediators and only then can they work together to determine the particular affordances of the NetLogo models. Students can subsequently take advantage of these affordances to generate hypotheses (via sentential, visual and manipulative abduction) to explain natural selection. It can then be proposed that the NetLogo models are particularly useful epistemic mediators for the students to explore natural selection because they support students in the creation of hypotheses to explain natural selection (they afford abduction, in particular visual and manipulative abduction).

References

- Anderson, D. L., Fisher, K. M., & Norman, G. J. (2002). Development and evaluation of the conceptual inventory of natural selection. *Journal of Research in Science Teaching*, 39(10), 952-978.
- Aranda, G., Aubusson, P., Chittleborough, G., Ferguson, J., Hoban, G., Hubber, P., . . . Tytler, R. (2012). Enhancing the Quality of Science Learning Using a Representation-Intensive Pedagogy (National Ethics Application Form) (pp. 1-34).
- Blevins, A., & Elton, C. W. (2009). An Evaluation of Three Tutorial-creating Software Programs: Camtasia, PowerPoint, and MediaSite. *Journal of Electronic Resources in Medical Libraries*, 6(1), 1-7.
- Blikstein, P., & Wilensky, U. (2004). *MaterialSim: An Agent-Based Simulation Toolkit for Learning Materials Science*. Paper presented at the International Conference on Engineering Education, Gainesville, Florida.
- Blikstein, P., & Wilensky, U. (2010). MaterialSim: A Constructionist Agent-Based Modeling Approach to Engineering Education. In M. J. Jacobson & P. Reimann (Eds.), *Designs for Learning Environments of the Future: International Perspectives from the Learning Sciences* (pp. 17-60). New York: Springer.
- Carlson, K. (2009). Delivering Information to Students 24/7 with Camtasia. *Information Technology and Libraries*, 28(3), 154-156.
- Centola, D., McKenzie, E., & Wilensky, U. (2000). Survival of the Groupiest: Facilitating Students' Understanding of the Multiple Levels of Fitness through Multi-Agent Modeling - The EACH Project. *Interjournal*, 377.
- Centola, D., Wilensky, U., & McKenzie, E. (2000). *A Hands-on Modeling Approach to Evolution: Learning about the Evolution of Cooperation and Altruism through Multi-Agent Modeling - The EACH Project*. Paper presented at the Fourth International Conference of the Learning Sciences, Ann Arbor, Michigan.

- Charnigo, L. (2009). Lights! Camera! Action! Producing Library Instruction Video Tutorials Using Camtasia Studio. *Journal of Library & Information Services in Distance Learning*, 3(1), 23-30.
- Chi, M. T. H. (2005). Commonsense Conceptions of Emergent Processes: Why Some Misconceptions Are Robust. *Journal of the Learning Sciences*, 14(2), 161-199.
- Chi, M. T. H., Roscoe, R. D., Slotta, J. D., Roy, M., & Chase, C. C. (2012). Misconceived causal explanations for emergent processes. [Research Support, Non-U.S. Gov't]. *Cogn Sci*, 36(1), 1-61.
- Dickes, A., & Sengupta, P. (2012). Learning Natural Selection in 4th Grade with Multi-Agent-Based Computational Models. *Research in Science Education*, 1-33.
- Dodick, J., & Orion, N. (2003). Introducing Evolution to Non-Biology Majors via the Fossil Record: A Case Study from the Israeli High School System. *The American Biology Teacher*, 65(3), 185-190.
- Ferrari, M., & Chi, M. T. H. (1998). The nature of naive explanations of natural selection. *International Journal of Science Education*, 20(10), 1231-1256.
- Levy, S. T., & Wilensky, U. (2010). *Mining Students' Actions for Understanding of Complex Systems: Students' Explorations of Gas Models in the Connected Chemistry Curriculum*. Paper presented at the Annual Meeting of American Educational Research Association, Denver, Colorado.
- Magnani, L. (2001). *Abduction, reason, and science - Processes of discovery and explanation*. New York: Kluwer Academic/Plenum Publishers.
- Magnani, L. (2009). *Abductive Cognition - The epistemological and eco-cognitive dimensions of hypothetical reasoning* (Vol. 3). Berlin Heidelberg: Springer.
- Magnani, L., Cavite, S., & Mascara, P. (2004). Visual cognition and cognitive modeling. In V. Canton (Ed.), *Human and machine vision: Analogies and divergences*. New York: Plenum Press.
- Peirce, C. S. (1992a). Chapter 7 - The Fixation of Belief. In N. Houser & C. Kloesel (Eds.), *The Essential Peirce - Selected Philosophical Writings - Volume 1 (1867-1893)* (Vol. 1, pp. 109-123). Bloomington: Indiana University Press.
- Peirce, C. S. (1992b). Chapter 12 - Deduction, Induction and Hypothesis. In N. Houser & C. Kloesel (Eds.), *The Essential Peirce - Selected Philosophical Writings - Volume 1 (1867 - 1893)* (Vol. 1, pp. 186-199). Bloomington: Indiana University Press.
- Peirce, C. S. (1998a). Of Reasoning in General. In N. Houser, A. De Tienne, J. R. Eller, C. L. Clark, A. C. Lewis & D. B. Davis (Eds.), *The Essential Peirce - Selected Philosophical Writings - Volume 2 (1893-1913)* (Vol. 2, pp. 11-26). Bloomington: Indiana University Press.
- Peirce, C. S. (1998b). What is a Sign? In N. Houser, A. De Tienne, J. R. Eller, C. L. Clark, A. C. Lewis & D. B. Davis (Eds.), *The Essential Peirce - Selected Philosophical Writings - Volume 2 (1893-1913)* (Vol. 2, pp. 4-10). Bloomington: Indiana University Press.
- Resnick, M. (1991). Overcoming the Centralized Mindset: Toward an Understanding of Emergent Phenomena. In I. Harel & S. Paypert (Eds.), *Constructionism* (pp. 205-214). Norwood, NJ: Ablex Publishing Corp.
- Schnall, J. G., Jankowski, T. A., & St. Anna, L. A. (2005). Using Camtasia Studio© to Enhance Web Instruction Pages and Tutorials. *Journal of Hospital Librarianship*, 5(1), 77-81.

- Sengupta, P., & Wilensky, U. (2011). Lowering the Learning Threshold: Multi-Agent-Based Models and Learning Electricity. In M. S. Khine & I. M. Saleh (Eds.), *Models and Modeling - Cognitive Tools for Scientific Inquiry* (pp. 141-171). Dordrecht; New York: Springer.
- Sklar, E. (2007). Software Review: NetLogo, a Multi-Agent Simulation Environment. *Artificial Life*, 13(3), 303-311.
- TechSmith. (2012). Camtasia Studio (Version 8). Michigan, United States of America: Techsmith.
- Tytler, R., Hubber, P., & Chittleborough, G. (2010). *A Cross-National Study of Teaching and Learning in Primary Science Classrooms*. Paper presented at the Contemporary Approaches to Research in Mathematics, Science, Health and Environmental Education, Deakin University, Burwood, Melbourn, Australia.
- White, P. A. (1997). Naive Ecology: Causal Judgements about a Simple Ecosystem. *British Journal of Psychology*, 88(22), 219-233.
- Wilensky, U. (1993). *Connected Mathematics - Building Concrete Relationships with Mathematical Knowledge*. (Doctor of Philosophy Doctoral dissertation), Massachusetts Institute of Technology, Massachusetts Institute of Technology.
- Wilensky, U. (1999). NetLogo (computer software). Evanston, IL: Center for Connected Learning and Computer-Based Modeling, Northwestern University.
- Wilensky, U., & Reisman, K. (2006). Thinking Like a Wolf, a Sheep, or a Firefly: Learning Biology Through Constructing and Testing Computational Theories—An Embodied Modeling Approach. *Cognition and Instruction*, 24(2), 171-209.
- Xu, L., Tytler, R., Clarke, D., & Rodriguez, C. (2012). *The Value of Multi-Theoretic Analyses: Representational and Distributed Cognition Perspectives on a Classroom Sequence about Matter*.