Future Visions for the study of Group Learning with Complex Systems Models: The role of multimodal data in group learning analysis

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Abstract: I propose how I will go about studying collaborative learning using multimodal data analytics. I will use a multimodal data analysis method to develop learning traces in physical spaces. I will use the system to study users playing a game about ants in both a museum, and a classroom. These methods of analysis let us evaluate open-ended learning. This beginning should be useful as schools move towards implementing more open-ended learning and project-based curricula. To conduct this kind of work I will use a mixture of qualitative coding and learning analytics to study collaboration. It seems this approach can have some impact as we develop more collaborative learning systems that share powerful ideas through mediating tools, like tabletop games and other new technology.

The Vision

I take the perspective that learning is always mediated by tools, peers and adults. Using multimodal data analytics, I plan to develop integrated tools to conduct learning research in person to person interaction with technology for learning. Specifically, I will use mutimodal data analytics, and qualitative methods to evaluate open-ended, complex systems learning in two contexts: museums and classrooms. Participants will explore several means of adapting ants’ behavior with a program to better get to know the complex systems of ant colonies. I selected ants to teach complexity, because my research up to this point shows they are useful means to teach complexity (Martin, Pierson, Sengupta, 2018; Martin, Horn and Wilensky, 2019). In that work, students have used a blocks-based system over one year to program ant colonies and learn ecology (Sengupta et al., 2015), and they switched their schemas, coming to understand how self-organized, unintelligent, systems can organize whole colonies of hundreds of individuals with no one in control. As a result, I will investigate how students learn in groups around an extension of my earlier ant game as a test case. This environment will serve as a testing ground for cross MMLA. To conduct this investigation, I suggest we continue to develop and deploy two novel means of analyzing these learning environments, computer augmented ethnography (Martin, Wang, Bain & Worsley, 2019), and Constructivist Dialogue Mapping (Martin, Horn & Wilensky, 2019). One focus of this work will investigate the role of emotion in learning using affective state tracking. Because earlier work has shown it may be a key element (D’Mello and Graesser, 2012) when studying learning.

Education, in many ways, is a way of thinking about how individuals approach tasks, creativity, learning, communication, teamwork, grit or resilience among many other potentially meaningful potential outputs of education. In other words, the values we place on the educational endeavor often determine what we look for as outputs. This often confines reform to data points we normally collect in education: grades, teacher perception of students, student perception of teachers, attendance, comparative growth. These measures are a result of our instruments of measurement. If we look at different measures, that is, if we change our educational values to understand people construct themselves and their interaction types in context, to find what each student is doing in relation to their peers and teacher in a particular space, we can find how people learn through their performance as an individual and in a sociotechnical system. Currently, it is hoped that this information can be gathered through several sensors and then synchronized using methods of big data and computational field methods.

This direction I envision for cross MMLA is important today, as we need better evaluation methods for open-ended learning environments. Highly successful programs of learning are moving towards constructionism. Singapore, Finland, and South Korea have transformed their economies over the last 50 years through education. They have focused on teacher-led instruction, and now all perform extraordinarily on the Programme for International Student Assessment (PISA) (World Bank, 2018). But each of them now wants more from their students than good performance; they want critical thinkers (Economist, 2018). Each in their way is bringing open-ended, project-based constructionist (Papert, 1980) learning into their curriculum through introducing powerful new learning tools (Papert and Wilensky, 2010). But they want means to evaluation these
systems impact on learners. Therefore, I want to test the technological tools that go into these constructionist-based learning environments. I will demonstrate complexity learning across two contexts and provide comparisons: First, I propose to place complexity science learning with ants in a museum to study the use of these systems in an informal learning setting. Second, I will co-design a classroom space with a teacher to develop a demonstration of the use of an open-ended learning game for formal learning in a middle school classroom. In each of these environments I will use two novel analysis methods I have been developing and publishing on, which I will describe below. The joint comparison of these two contexts will provide useful comparison of the use of MMLA instrumentation in a formal and an informal learning environment. From this perspective, and using my previous work, I envision investigating the following three questions:

- **Question I:** Does Constructionist Dialogue Mapping show students’ elaboration of complex systems in an open-ended, collaborative learning task?
  - **Subquestion:** Can this process be used to evaluate learning in open-ended learning tasks with groups of students?

- **Question II:** Based on the theory that when people are emotionally stimulated they learn more, can we identify windows of learning through association with affective states?

- **Question III:** If students learn during these short interactions, and we can identify windows of learning through affect tracking in an automated way, what role does discussion serve in mediating this multi-touch interactive table top interaction?

I will situate this investigation in the literature of four theories: (1) Constructivist theory, where a learner’s mental model drives his or her construction of understanding and internal cognitive structures (Piaget, 1983). (2) Constructionism, a method of learning through doing. Constructionist learning environments weave together the themes of redesigning education systems and empowering learners (Papert, 1986). (3) Complexity Education, where people have argued learning complexity is difficult, for instance Thinking in Levels (Wilensky, 2006), and even incommensurable (Chi et al., 2012). (4) Technological Mediation, Tools Mediation and Learning, Where as shown in Figure 1, learning happens between an individual, a mediating object, peers and teachers (Vygotsky, 1978). This means that thought results from action in the world. This action then takes place in a wider social circle of figure 1, of practice affinity, demographic and the media (Brofenbreuner, 1977).

As a result of this literature I imagine two means to measure learning in designed, “open” environments. As shown in Figure 1, I will study learning as social process, affected by the tools participants use in the wider social context.

![Analysis Pipeline](image)

**Figure 1.** Tools, peers, parents, and teachers scaffold learning in a wider sphere of influences.
The Method

To study open-ended, mediated learning I will implement a two-phase study design. The program analysis pipeline will follow Figure 1, focusing on learning at the center, seeing it as mediated by peers, the game, parents, teachers and other scaffolds. I will view these interactions affected by wider social aspects, such as demographics, the media climate, genre, learners affinity membership and practices of where the learning happens. I analyze this data using the pipeline outline in figure 2 to extract learners concepts as they develop and the co-occurring affective states. In the first phase I will extend the work of the pilot at the Field Museum to test Ant Adaptation (Martin and Wilensky, 2019; Martin, Horn and Wilensky, 2019) with Multimodal sensors inside of museums.

Visitors will explore the Ant Adaptation collaborative tabletop game in an open-ended learning activity in museums. This investigation will explore different aspects of colonial life, foraging, competition, and the interaction between individual agents and the colony’s success. This implementation will allow me to investigate how to use collaborative analytics to students collaboratively progress through a museum or classroom exploration, and the role emotion plays in that exploration. The affective component is key, because learning happens most felicitously when memory is engaged by emotion.

![Figure 1](image1.png)

**Figure 1.** An example of a graphic representation of the program analysis pipeline.

As shown in Figure 2, in both phases I will use the following analysis pipeline. I will use Social Signal Interpretation (SSI) (Wagner, Lingenfelser, Baur, Damian, Kistler, & Andre, 2013) to collect synchronized video, and audio data. I will process this data into transcripts for Constructivist Dialogue Mapping and individual videos of participants for affective state detection in FACET. In phases 1 and 2, I will use Empaticas to monitor proxies for biological engagement, heart rate and skin conductivity.

**Long term Goal and Projected Impact of this Work**

Outcomes improve when students engage with powerful ideas (Papert, 1980) through mediating objects (Vygotsky, 1978), such as well-trained teachers and refined education technology to explore ideas, discuss their meaning, and learn self-regulation and move towards higher goals. At our best, we can leave our children inspired to recreate the world in amazing new ways. At our worst, we can enforce our children to reproduce the worst aspects of society. In this work, I want to build on the semi-structured play spaces I have been designing, in order to explore this healthy middle ground, where students feel empowered to take action through collaborative learning with a learning too. This work will be an exploration of how thinking about ants can allow students to play in a system, where they need to come to grips with complexity, through understanding computer science concepts and apply emergence to meet their goals with the system of interaction, that is between them, the computer and their teammates. I will conduct these studies in both informal and formal learning environments, because I do not recognize the arbitrary distinction between them. I will a) demonstrate their feasibility across this arbitrary boundary, and b) discover the differences of implementation. I will use an
iterative co-design approach, building off the technologies and protocols I have used in the earlier ant simulations. I will evaluate the approaches success through qualitative coding using my variety of concept mapping, and multimodal learning analytics to investigate their affect and embodied understandings throughout the activities. This work is motivated through my earlier work.

References


