Penn GSE
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DeTECT: Developing Teachers' Epistemic Cognition and Teaching Practices for Supporting Students' Epistemic Practices with Scientific Systems

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Project Goals

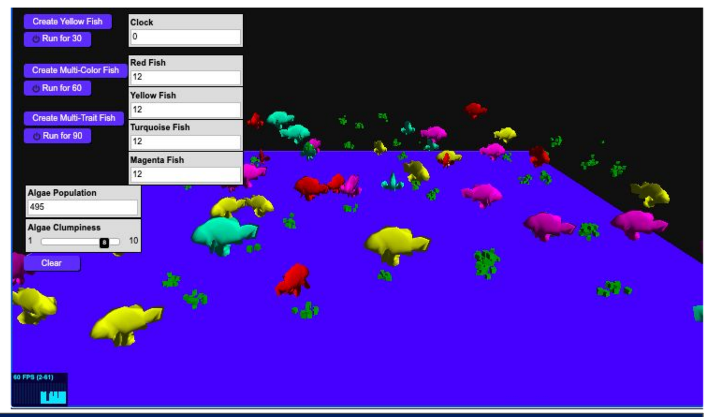
DeTECT aims to develop students' epistemic cognition and increase their interest and skills in investigating and evaluating scientific phenomena through improved epistemic performance. We use the Apt-AIR framework (Barzilai & Chinn, 2018) to specify what students and teachers need to know to promote growth both in science knowledge and in ways of knowing. It therefore provides a means to improve students' grasp of science practices.

To accomplish this goal, we are constructing, delivering, and pilot testing a high-quality teacher professional development program using computer-supported complex systems curricula that promote teachers' ability to recognize and strategize ways to develop and improve students' epistemic performance.

Context

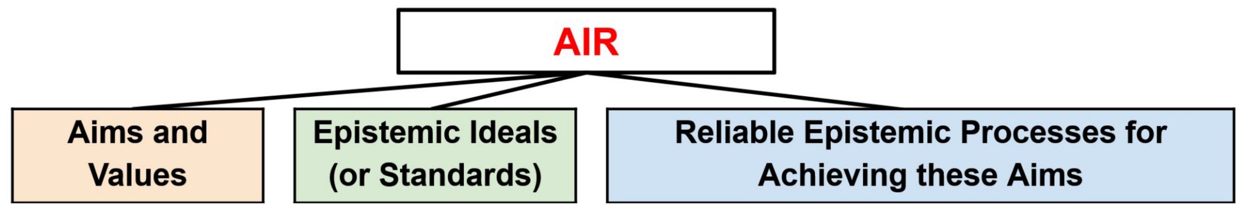
This project applies the BioGraph complex systems curriculum (Yoon et al., 2022) to support teachers as they engage their students with authentic scientific and epistemic practices. The curriculum utilizes agent-based simulations to guide small groups of students through lessons about five different biological phenomena: evolution, sugar transport, gene regulation, enzymes, and ecology. Within each lesson, students develop and test their own hypotheses, collect simulated data, and engage in scientific argumentation with peers. Within DeTECT, 14 high school science teachers from India, Kenya, and the US participated in multiple workshops over two years to examine epistemic practices in science classes and to adapt the existing BioGraph curriculum to promote greater opportunities for students to engage in apt epistemic practices. More information about the adaptations to the curriculum can be found in the PD section of this poster.

BioGraph



Theoretical Framework

The project used the AIR model as a framework for epistemic practices. This model describes epistemic practices as a combination of three epistemic components: Aims, Ideals, and Reliable Processes.



- Epistemic **A**ims are goals to construct or refine knowledge
- Epistemic **I**deals are the criteria by which the achievement of an epistemic aim is measured
- **R**eliable epistemic processes are the methods used to reliably achieve an epistemic aim while meeting epistemic ideals

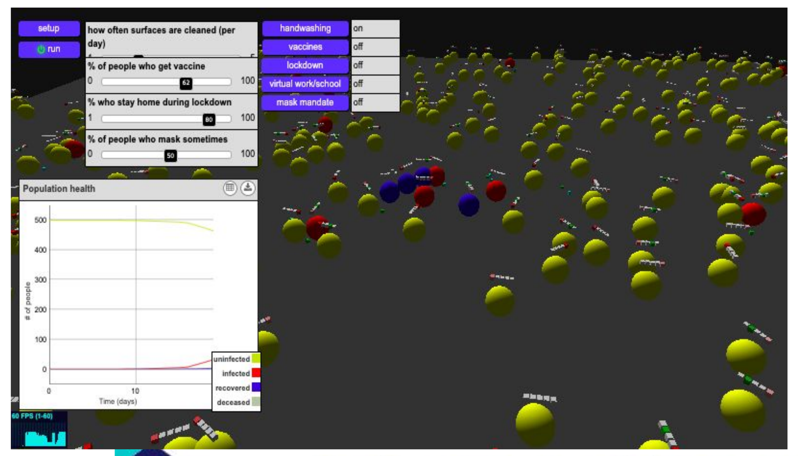
The three components of the AIR model are additionally crossed with five aspects of engagement to form the Apt-AIR framework. These aspects are described here as:

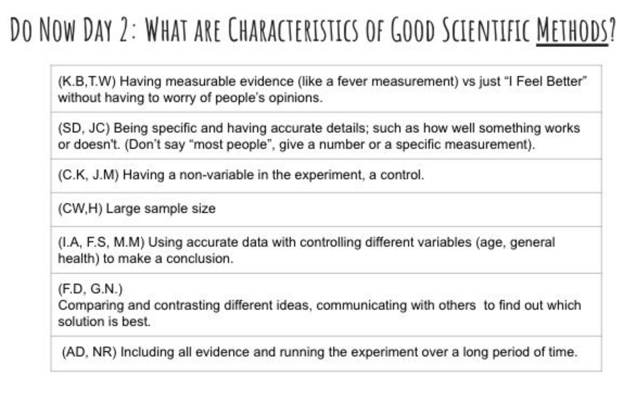
Cognitive	Use of reliable cognitive processes to achieve valuable epistemic aims that meet appropriate ideals
Metacognitive	Metacognitive skills as well as metacognitive understanding of appropriate aims, ideals, and reliable processes
Social	Participating in collaborative epistemic performance with an awareness of the role of social processes in producing knowledge
Caring	Positive affect and attitudes towards pursuing and achieving apt epistemic performance
Adaptive	Adjusting aims, ideals, and reliable processes to meet the demands of diverse contexts

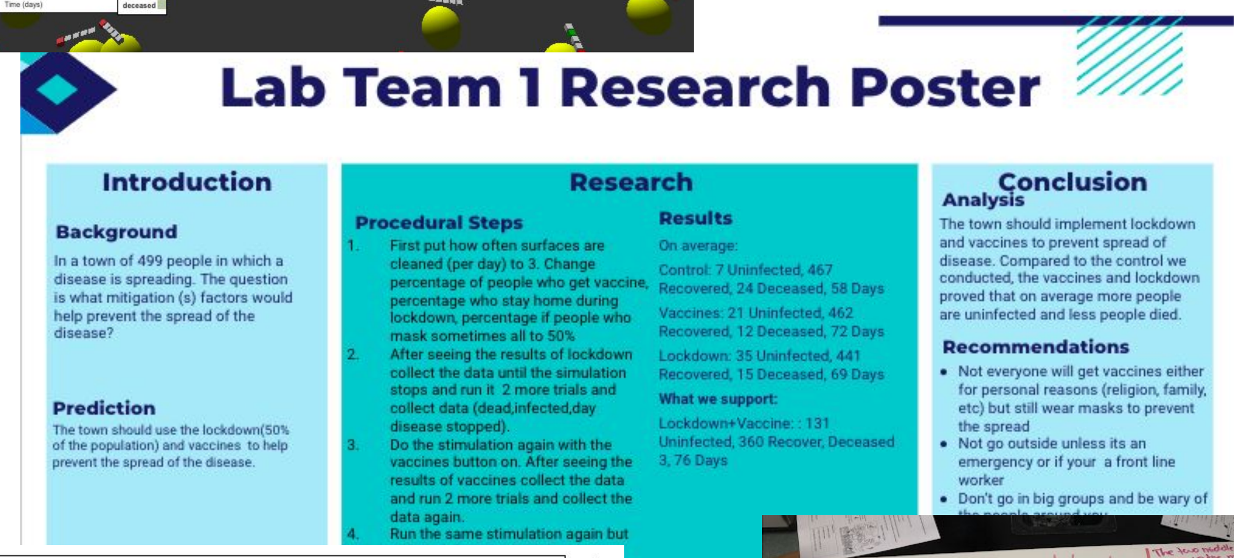
Epidemic Unit

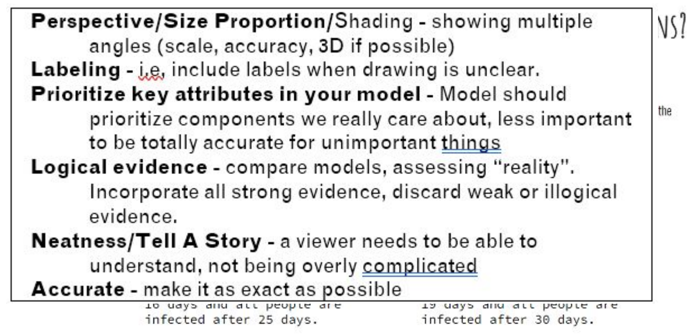
In addition to the previously existing BioGraph curriculum, for DeTECT, we created an new unit called the "Epidemic Unit" based on the viral spread of disease and our global experiences in the COVID pandemic. Consisting of 8 lessons, it was designed to support student understanding of epistemic practices of modeling scientific phenomena and their translation to evaluating a recent socioscientific issue.

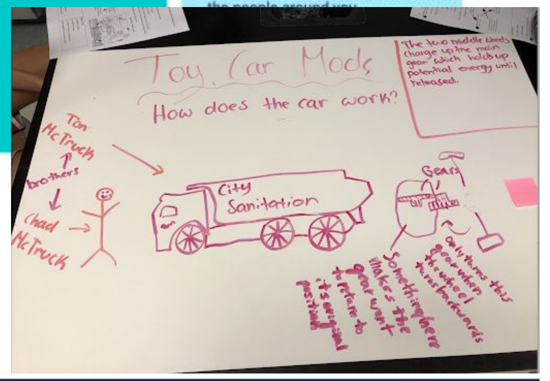
Lesson 1: Students create criteria for evaluating scientific models as a class.
Lesson 2: Students negotiate criteria for scientific practices.
Lesson 3: Systematic planning, carrying out experimental designs and showcasing designs for peer critique.
Lesson 4: Carry out revised experimental designs and develop scientific arguments.
Lesson 5: Compare class data to identify tenets that warrant productive disagreements.
Lesson 6: Revise and carry out experimental designs.
Lesson 7: Share results and scientific methods used to arrive as posters for peer review.
Lesson 8: Create a tweet to communicate findings.











Professional Development (PD)

During the summer of 2021, 8 high school biology teachers (Cohort 1) participated in a two-week DeTECT PD workshop. This workshop had two primary aims: (a) introducing teachers to the concepts of epistemic practices, why they are important, and how they may manifest in the classroom; and (b) collaboratively modifying the BioGraph curriculum to better promote opportunities for epistemic practice instruction. The modifications made to the curricular units broadly fell into three categories: (a) the inclusion of "epistemic callouts" for teachers to highlight potential moments for epistemic instruction; (b) increased connections to socio-scientific issues; and (c) increased opportunities for students to share, justify, and act on their own reasoning and cognitive processes. In the following school year, the teachers implemented the revised units and reflected on further adaptations that can be made. During the summer of 2022, Cohort 1 returned to participate in a one-week workshop to reflect on the previous years implementation and further adapt the existing curricular units (including the newly developed epidemic unit, described above). During this workshop, additional and more robust "epistemic callouts" were included throughout the lessons, and connections to SSIs and opportunities for students to share, justify, and act on their own reasoning and cognitive processes were made more robust. 6 new high school biology teachers (Cohort 2) then participated in a one-week PD workshop that aimed to again introduce teachers to epistemic practices and their manifestation in the classroom. During this workshop, Cohort 2 was also introduced to the revised BioGraph curriculum and the novel epidemic unit. Both cohorts of teachers then implemented the revised curriculum in the following school year.

Enhancing Epistemic Performance in the Classroom

Teacher Epistemic Moves

This paper analyzed the moves that teachers used while implementing the epidemic unit to develop an Apt-AIR based method of analysis that defines teacher epistemic moves. The preliminary analysis identified little justification/prompts for justification for epistemic aims and ideals, as well as less coverage of caring and adaptive aspects than other aspects. This analysis allows for investigation of opportunities for refinement of lesson plans and teacher innovations that could support student apt epistemic performance.

Navigating Epistemic Complexity

The paper examined teacher strategies that lend to navigating an epistemically complex learning environment in a science classroom. A case analysis of a teacher's implementation of the epidemic unit demonstrates the use of the following strategies:

Strategy #1: Highlight uncertainty within epistemic practices to normalize scientific iteration.

Strategy #2: Allow student choice while maintaining an invisible authority on epistemic criteria.

Strategy #3: Normalize the act of making incorrect predictions as something scientists do.

Student Implementation Experience

We collected pre- and post-implementation experience data from students using a 50-item survey instrument. An exploratory factor analysis found that students demonstrated significant growth in the following factors: (a) engaging in empirical investigations in class; (b) connecting science reasoning to everyday life; and (c) using modeling practices to learn about science. Early qualitative analysis of two teachers' implementation video suggested significant qualitative differences in the instructional practices of teachers whose students exhibited the largest and smallest growth in the surveys.

Project Challenges & Design Principles

Based on a review of the science education, epistemic performance, and teacher professional development literature, we aim to address seven overarching educational challenges (ECs) with corresponding design principles (DPs). (See Yoon et al, submitted).

Educational Challenges

EC#1: Seeing the scientific system in all its complexity
EC#2: Science denialism
EC#3: Misinformation foment
EC#4: Primacy of scientific concepts over scientific practices
EC#5: Curricular coherence (of high school Biology)
EC#6: The steep curve of teacher knowledge and practice
EC#7: Lack of useable PD

Design Principles

DP #1: Promote learning through modeling complex systems.
DP #2: Anchor learning in complex socioscientific issues curriculum.
DP #3: Emphasize epistemic performance of science.
DP #4: Prioritize scientific *practices* over science concepts.
DP #5: Align PD with teachers' existing curricula.
DP #6: Develop high-leverage epistemic teacher moves and routines.
DP #7: Co-design PD with teachers.

Understanding Why Science is Trustworthy

The overarching goal of DeTECT is to enable students to become scientifically literate adults who can interact with science proficiently to solve problems and make decisions on issues that matter to them in their lives. In an age of science denialism, it is important to support students in understanding why science is generally trustworthy. Yet science is quite obviously "messy"– uncertain, evolving, emotional, sometimes affected by bias, and social. How can such messy scientific practices yield knowledge worthy of trust? Our epidemic unit is designed to help students begin to understand this. Here are a few examples (our complete analysis is in Chinn et al., in press).

- Students develop class lists of ideals for good models, thus seeing how shared norms that include ensuring that models fit as much evidence as possible lead to more trustworthy models.
- Students engage in evidence-centered social critique of each others' models, thus developing an appreciation of the role of social critique in improving scientific ideas.
- Students critique and improve their own empirical methods, so that they can see how knowledge is improved through improving methods used to generate knowledge.
- Students learn different ways of resolving scientific disagreements to appreciate that disagreements are a means to advance science.

Our ultimate goal is to enable students to use these understandings to engage with socioscientific questions that matter to them, so that they can use science to improve their lives.

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