Some Facts about Students' Development of Next Generation Science Knowledge

"The students, from the Academy of the Americas, a public school a few miles from downtown [Detroit], are being asked to do the painstaking work of science, in an unlikely setting. It's part of a curriculum and professional-development program called BioKIDS, which seeks to build students' skill in complex scientific reasoning. The approach goes well beyond fostering students' knowledge of science facts and concepts, to place a heavy emphasis on the more difficult work of having them devise scientific arguments based on evidence. In other words, it's the work that actual scientists do." (Cavanagh, 2009)

This quote is from an *Education Week* article that profiled the work of the *Center for Essential Science (www.essentialscience.umich.edu),* led by Dr. Nancy Butler Songer. Songer is a Professor of Science Education and Learning Technologies in the School of Education at the University of Michigan and the Director of the *Center for Essential Science.* Songer has a program of research directed to foster and evaluate the development of Next Generation Science Knowledge (Lead States, 2013) with urban 4-12th grade students. Two major awards from the National Science Foundation support this research.

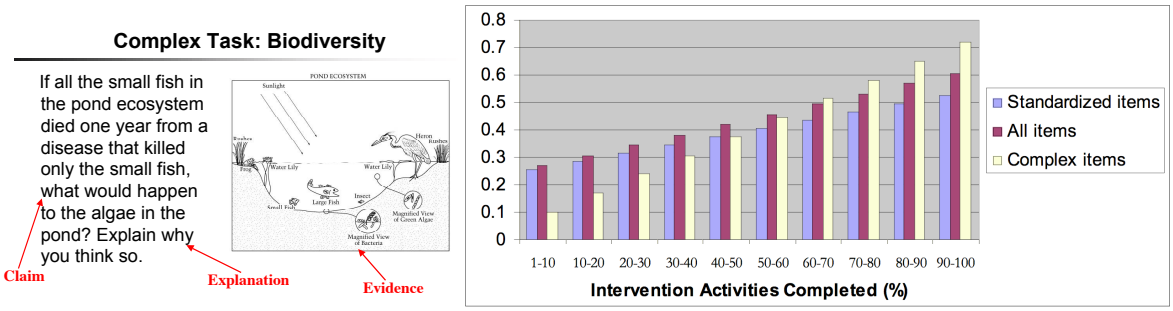
What is Next Generation Science Knowledge (NextGenSci)?
In 2013, new national science standards were released called the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). These standards draw on fundamental research on how children learn science and how scientists develop and use scientific knowledge for critical thinking and the development of deep conceptual understandings of disciplinary core ideas (NRC, 2012, NGSS Lead States, 2013). A key feature of NGSS is the nature of the knowledge underlying the standards. NGSS emphasizes three dimensions of science knowledge that are fused or inextricably linked with one another: science and engineering practices, disciplinary core ideas, and crosscutting concepts. In instruction and assessment, NGSS states that the disciplinary core ideas and crosscutting concepts should be taught concurrently and *through the science and engineering practices*. For several years, Songer and her team have developed and evaluated 8-week curricular units for 4-6th grade students that foster the development of ecology and biodiversity knowledge through the practices of data collection, data analysis, explanations, and argumentation.

What Do Students Learn With A Curricular Program Focused on NextGenSci?
Songer's team also produced an assessment system to evaluate NextGenSci knowledge development. The assessments provide evidence of both declarative knowledge and NextGenSci higher-order thinking, such as scientific explanations about the biodiversity of the schoolyard based on relevant evidence of animals collected in different schoolyard locations.

One study evaluated the science knowledge development of approximately 1800 Detroit Public School sixth grade students working with 22 teachers. Detroit students have nearly three times the average poverty rate of the state of Michigan (70% free/reduced lunch as compared to 27% state average), and 94% are ethnic minorities. In this study, the Detroit teachers were asked to teach eight weeks of ecology and biodiversity. Teachers were provided with professional development and support for two sets of materials covering the same content in ecology and biodiversity: The district approved textbook (Textbook) or *The Center for Essential Science* program that teaches science content through the practices of data analysis, the construction of explanations, and argumentation (NextGenSci). Results show pre-post achievement gains relative to the percent NextGenSci curriculum activities used (e.g., 0% intervention indicates the teacher used the Textbook for the full 8 weeks).

A sample NextGenSci task from U.S. Department of Education's National Assessment of Educational Progress (NAEP) and results are presented below. On overall achievement, students who received the full 8 weeks of instruction with our NextGenSci curricula had an effect size gain of 0.34 SD ($p<0.001$) when compared to students who did not participate in our program. On standardized items that measured factual knowledge of science, both Textbook and NextGenSci students made significant improvements even as the gains of the students who had the full 8 weeks of NextGenSci instruction were significantly better (effect size of 0.27, $p<0.05$). Achievement differences were most pronounced on NextGenSci complex items that asked students to, for example, develop a claim and explanation based on evidence (see figure). On these items, gains were substantially higher (effect size of 0.62; $p<0.001$) for students who completed our full program.

We conclude that student achievement on NextGenSci complex tasks is highly dependent on how much of the intervention curriculum a student has completed. Students who have no involvement with the program gain, on average, only one-tenth of a standard deviation on complex tasks throughout the 8 weeks. Students who are exposed to the intervention start with small gains but demonstrate sizeable gains by the end of the program. **These results suggest that NextGenSci knowledge is a slow developing ability that needs cultivation over an extended period**.



Sample Task and Achievement by Percentage NextGenSci Activities by Item Type (N =1885)

Increased Time, Systematic Guidance and Revisiting and Deepening Understandings
Our results support the view that developing NextGenSci knowledge involves focused time on topics, systematic guidance in developing more complex ideas, and an ability to revisit and deepen understandings in a systematic manner. As referred to in the *Education Week* article referenced above, our results suggest that the development of NextGenSci knowledge requires students to go beyond memorization of facts to the development of arguments backed by evidence, and to rehearse learning content through the practices over time and topic. Our units contain many supports to guide students in developing arguments and analyzing scientific data. By providing this guidance over multiple weeks, students in several studies consistently realize significant gains on standardized and NextGenSci complex tasks as compared to students who use more traditional, text-based resources and pedagogy.

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National Research Council (2012) *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington DC: National Academy Press
NGSS Lead States (2013) *Next Generation Science Standards: For States, By States*. Washington D.C.: The National Academies Press.