The Understandings of Consequence Project:
Research Overview

The curriculum materials and the pedagogical approach that grew out of the Understandings of Consequence Project, the *Causal Patterns in Science and Beyond* series, is the result of over ten years of research on student learning funded by the National Science Foundation. This document explains the research behind the program in accessible terms. If you would like more in-depth information or further details on the methodologies involved, we encourage you to visit our research page on the Project Zero website where you will find links to the research studies and specific references for the work.

The work started as a set of research questions. It aimed to address the following puzzles/challenges:

- A long history of research on misconceptions (or alternative conceptions) showed that students typically struggle with fundamental science concepts.
- Our observation in classrooms revealed that despite "best practices" teaching and highly dedicated teachers, students still reverted to nonscientific explanations.
- Even "everyday" scientific concepts assume an extensive repertoire of causal models. In addition, students are being asked to reason about an increasingly complex and global world.
- Students appeared to have limited knowledge about the nature of causality (although developmental research shows that they have more than expected based upon their ideas in science class!) and little opportunity to learn about it.

<u>Do limited notions of causality contribute to students' misunderstandings of everyday science concepts? Will teaching causal patterns enhance their understanding?</u>

<u>Are there ways to teach the patterns and features of causal complexity for today and tomorrow's world in the context of today's curriculum?</u>

Main Research Findings

1. Students often framing the underlying causality in science concepts differently than scientists do.

2. Opportunities to learn the underlying causal patterns improves students' understanding of the science concepts.

3. While explicitly unpacking the causal patterns improves the learning of all students, lower level achievers often improve the most.

4. Learning causal patterns in one topic can transfer to other topics, particularly when teachers engage students in thinking about connections.

Overview of *The Understandings of Consequence Project* Research Phases:

There have been three research phases to date:

- Phase 1: Investigated students' assumptions about the nature of causality within and across different science topics.
- Phase 2: Tested targeted interventions <u>in the context of</u> students' science learning designed to impact how students structured the causality inherent to particular levels of explanation.
- Phase 3: Investigated whether gains, such as those found in phase two, would transfer to new learning.

Phase One Studies:

We interviewed students in the context of their science learning…

- …through open-ended interviews and tasks designed to reveal how they structured concepts.
- …within a number of topics including simple circuits, ecosystems, electricity, density, pressure, force and motion, and evolution.
- …from third through 11^{th} grades.

Phase One Findings:

- Students make assumptions about the nature of causality that influence their ability to learn science concepts. (See list of default assumptions.)
- Students' tend to assimilate information about complex concepts into simpler causal structures thus distorting the information.
- This was so for both "everyday science" and for complex science concepts.
- This was so before, during, and after learning.

Phase Two Studies:

Across topics and grades, we worked with our teacher collaborators to develop curriculum that would teach the underlying causal patterns in service of the science. We compared the performance of students in classrooms with three different approaches

1. Causal Activities (RECAST) and Discussion
2. Causal Activities (RECAST) Only
3. Best Practices Control Group

All classes used "best practices" science units that included:

- extensive modeling by students.
- evaluating evidence.
- Socratic discussion.
- dynamic computer models.
- attended to students' evolving models.

But some added causal activities or causal activities plus causal discussion.

Phase Two Findings:

Across most topics, introducing RECAST activities significantly benefited student performance.

- For some topics, RECAST activities alone were not enough to make a difference and there was significant benefit to adding explicit discussion of the causality. The activities can be sufficient to learn less complex patterns and causal discussion appears necessary when the patterns are most counterintuitive.
- RECAST activities plus discussion benefited students across different achievement levels on topics with difficult causal concepts. Low achievers (as defined by their teachers) made the most dramatic gains.
- Effect sizes varied across topics depending upon the complexity of the causality to be grasped (higher effect sizes with more difficult forms) and depending upon other sources of difficulty.

Phase Three Studies:

Phase Three investigated whether learning about the underlying causality could make a difference beyond the concepts for which it was taught—would it transfer to new learning? We asked:

1. Does learning about causal patterns transfer between topics when the causal patterns are the same (for instance, many density and air pressure concepts have an underlying relational causality)?
2. What about when they are different? Might students begin to notice other forms of causality by comparison?
3. Are there any ways that it might help them generally in future learning (such as encouraging them to think more deeply, or by offering ideas about what it means to learn well, etc.)?

Phase Three Findings:

- There was some transfer of learning even without any special support when the causal patterns were the same.
- When teachers supported transfer (for example, by asking students, "Are there any other places where you might have seen this causal pattern?" Or "Think about your thinking, what kind of causal pattern are you using?"), there was a good amount of transfer when the causal patterns were the same and even some when the patterns were different.
- Good results were obtained when students worked with materials that helped them to think about the transfer of causal patterns, but that teacher support and discussion was even better.
- There was evidence that students were better prepared for learning in a general sense, but it was inconclusive in this study.

Our work is on-going. Check back on our project page on the Project Zero site to hear about new research that we are involved in and for a link to the *Causal Patterns in Science* Website.