How Scientists Explain Research

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Problem

- How can you tell when a presentation of scientific research is good?
- How can you tell when it is poor?

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Presentation by a Science Graduate Student

This is a presentation to middle school students

- What is good about this presentation?
- What could be improved about this presentation?

<video>

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Problem

- Efforts by scientists to *communicate* the nature and results of scientific research are hindered by lack of training and emphasis on scientific communication to a general audience.
- Federal agencies have begun to place increased emphasis on scientists ensuring “broader impacts” of their research.
- A significant first step toward having broader impacts is understanding how to explain science effectively to a general audience.

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Context

- NSF GK12 project pairs science graduate students (fellows) with K12 science teachers.
- Fellows receive significant professional development training in pedagogical knowledge in the context of teaching middle school science.
- Fellows spend an entire school year working 10 hours per week in the classroom of a middle school science teacher in Boston, Dedham, or Milton.
- Science focus is on local Neponset River watershed.

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Research Question

- ***How do science graduate students improve in their ability to explain their own research to a general audience of non-scientists?***
    1. Characterize explanations of research by scientists to an audience of non-scientists
    2. Compare fellows pre- and post- fellowship year
    3. Compare to control group of non-GK12 fellows

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Value of the First Study

We developed a rubric to evaluate the quality of scientific explanations so that we could quantify the impact of the GK12 experience on science graduate students.

- Used as a training tool by scientists, the rubric holds the promise of assisting them in improving scientific communication and ultimately conducting scientific research more effectively.
- Used as a training tool in preparing science teachers, the rubric offers a mechanism for combining content knowledge training with pedagogical training.

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Approach to the Study (Methodology)

- We asked science graduate students *impromptu* to, “explain your own research to an audience of non-scientists in 3 to 5 minutes,” and we videotaped the presentations
- Three years of data - explanations prior to involvement in the GK12 program and after one year
- Sixteen science graduate students representing diverse cultural backgrounds in various stages of M.S. and Ph.D. programs

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Qualitative Method Applied

- Analysis of videos and transcripts developed inductively from the data
- Began with literature base, developed rubric to characterize scientific explanations
  - Similar cases with different outcomes – where do key causal differences lie?
  - Cases with same outcome – which conditions are common, which causes are necessary?
- Applied rubric to oral/visual presentations
- Transcribed and coded presentations for deeper analysis
- Validated analysis, reliability studies
- Looked to research literature to help interpret findings

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Research Base for the Initial Rubric

- Teachers with strong knowledge of their disciplines, and strong pedagogical practices, are more capable of using materials effectively (Cohen and Ball, 2003)
- Explaining science well (Chinn and Malhotra, 2002)
  - Involves cognitive properties that are elements of scientific inquiry
  - Science is taught more effectively when a science teacher has training as a scientist
- Clear evidence indicates content knowledge alone is not sufficient in teaching well (Darling-Hammond et al, 2005)
- Additional content knowledge required to teach a subject can be quantified (Ball, 2000)

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Research Base for the Initial Rubric

- Frameworks when explaining science
  - Scientists and the general public use same frameworks
  - Causal/mechanical, functional, and intentional

  (Grotzer, 2003; Gopnik and Meltzoff, 1997; Brewer, Chinn and Samarapungavan, 2000)
- Cognitive operations that scientists and the general public rely on as they attempt to explain phenomena that they do not yet fully understand
  - One must understand something before explaining it effectively (Keil and Wilson, 2000)
  - The ability to explain one's understanding is often a measure of whether or not the explainer has effectively learned it (Vygotsky, 1986)

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Research Base for the Initial Rubric

- Cognitive operations that science teachers use when explaining science to students effectively can be characterized as a set of concrete practices (Ogborn et al, 1996)
  - Create a need for an explanation by "transforming" what is familiar to students into something unfamiliar, often through the use of analogies and stories
  - Scaffold explanations so that they build on and connect to each other across various lessons
  - Rely on diagrams and gestures to aid in explanation

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The Rubric

The rubric runs parallel to what we know about effective science teaching – that it requires three kinds of knowledge

1. Science content knowledge
2. Pedagogical knowledge
3. Integration of content and pedagogy in the service of a clear explanation

The Rubric: 1. Science Content Knowledge

Factual knowledge and processes <u>and</u> how well that knowledge is understood in broader contexts. Assesses accuracy and depth, including how well the scientist portrays the overall organization of knowledge.

- Factual knowledge
- Evidence of organization of knowledge by the guiding principles of the discipline
- Ability to transfer knowledge to broader contexts

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The Rubric:
2. Pedagogical Knowledge

The knowledge and skill involved in explaining major concepts involved in the scientist's research. Assesses methods scientists employ to communicate their knowledge orally to an audience, with written media to support in real-time.

- Structure and balance of presentation
- Response to the audience
- Choice of language
- Technical skill of presentation and use of media

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The Rubric:
3. Integration of Content and Pedagogy

Assesses the ability to integrate content and pedagogy in the service of a clear, coherent, and engaging explanation of scientific research.

- Development of appropriate mental images to support explanation
- Tactical use of media
- Scaffolded explanation

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Findings

1. Effective explanation of science is developed in layers
   - When an explainer is strong in only one type of knowledge (content or pedagogy), there is a clear transition in the person's explanation
2. Only when both pedagogy and content are strong is a scientific explanation effective
   - Science explanations in this category exhibit development of powerful mental images, tactical use of media to support explanation, and scaffolded development of concepts
3. Presentation skills add an extra layer that can cause a good presentation (transcript) to fail (video) and a poor presentation (transcript) to appear to succeed (video)
4. Gestures sometimes reveal deep content understanding that the explainer is unable to articulate verbally

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Characteristics of Four Types of Explanations in Science

	Weak content knowledge (of own research)	**Strong content knowledge (of own research)**
Weak pedagogical knowledge	○ Unclear from start to finish.	○ Engaging introduction that relates to audience but is unrelated to research, or big picture about research that is not relevant to audience. ○ Clear transition to more complex scientific explanation inappropriate for audience.
Strong pedagogical knowledge	○ Strong introduction that establishes structure, and is engaging, clear, and relates the research to the audience. ○ Clear transition to explaining own science, unable to explain clearly.	○ Clear logical structure, story maintained throughout explanation. ○ Explanation scaffolded throughout. ○ No transition.

Findings in the Context of the Field

Effective teachers display three kinds of knowledge (Shulman, 1987)

- Pedagogical knowledge
- Content knowledge
- Pedagogical content knowledge (PCK)
  - Knowledge about how to teach a specific subject matter for improved understanding and learning

- PCK as a construct has "fuzzy boundaries" (e.g., Gess-Newsome, 1999)
- How does/can PCK develop? (van Driel et al, 1998; Loughran et al, 2003)
  - Through experience of teaching coupled with strong subject matter knowledge
  - Form of knowledge that can be developed alongside pedagogical knowledge and content knowledge

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Further Study

1. Apply rubric to large numbers of science graduate students to learn more about science explanation skills and strategies that scientists need most assistance in developing
2. Independently test for content knowledge, pedagogical knowledge, and pedagogical content knowledge to determine whether there is a correlation between performance in these and evaluation of science explanations using our rubric
3. More tests over time to further understand nature of the progression of GK12 fellows toward effectiveness in explaining science
4. Compare GK12 fellows with a control group of graduate students not in the GK12 program to assess impacts of GK12 program on improving scientists' ability to explain science to a general audience

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