EPO and the Big Education Reform Picture

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Abstract. This paper is a summary of the keynote talk delivered at the conference. I have tried to keep the sense of the spoken presentation. Some of the ideas are my own, some are borrowed from colleagues. The biases, and whines, are my own.

1. Introduction

There are three topics that I would like to talk about.

1. How can we realize our fantasy that someday every American will be literate in astronomy?
2. Some lessons I have learned that might be helpful.
3. How partnering with each other and other education experts is critical to achieving our goals.

To begin, there are some kudos to hand out. Understand that these are personal and I am sure that I am missing some very worthy folks, but some of us have done extraordinary things and should be recognized. First, I want to recognize Barbara Morgan, she, "paid the dues and got the views." Barbara persevered after the loss of the Challenger to become NASA's Teacher-in-Space this year. Had she not hung in there, there would be no Educator Astronaut program, a loss to the agency. We can (and should) expect great things from Barbara. Next, I want to recognize Jacqueline Barber, Isabel Hawkins, Greg Schultz and their colleagues at Berkeley and the Lawrence Hall of Science for setting an example of effective partnership. They assembled a number of NASA forums and education experts to produce *GEMS Space Science Sequence for Grades 3–5,* a terrific new curriculum for grades 3-5, soon to be followed by a grade 6-8 edition. These instructional materials responded to the challenge that I made a few years ago to produce something that incorporates the best of NASA's cutting edge research to help children learn grade-level appropriate ideas in astronomy in the time available.

By incorporating the latest findings from learning and cognitive science research and tackling a small set of important ideas they have produced a realistic and realizable curriculum. We would do well to become familiar with these materials and promote them to teachers and schools rather than trying to create something else. At the same time, we can learn from teachers and students using *GEMS Space Science Sequence for Grades 3–5* and provide feedback to Jacqueline Barber and her team.

Other kudos go to Tim Slater and the CAPER team and to Phil Sadler and others for helping us learn what we need to know and to Sidney Wolff and Andy Fraknoi for starting and sustaining the Astronomy Education Review. It will serve us all well to pay close attention to the growing quality and quantity of astronomy education research. Others are making huge contributions to public outreach: raising the interest in things astronomical. Neil deGrasse Tyson, Larry Krauss, and many others are providing an articulate public face for astronomy. Finally, the Astronomical Society of the Pacific and all of you in the EPO world are making a difference. It is an honor to be one of your peers.

2. A Challenge

A few years ago I was having a conversation about education with a friend who is a very accomplished astronomy researcher at a major American university. At one point while we were talking about the state of undergraduate education and teaching today's crop of students my friend said, "I would say that twenty percent of my students can learn on their own. All I have to do is order the book, show up, and give the tests." Then, amazingly, about five minutes later, as we were talking about students who go on to major in physics or astronomy, my friend said, "You know, I teach to the top twenty percent of my classes..." This conversation highlights one of the real challenges that the schools and universities are facing. Who is our audience and what are our goals?

In elementary schools, it is pretty clear that it is basic literacy and interest for all kids and all teachers. By middle school, there is usually some separation based on who is or isn't taking or succeeding in algebra. High schools cater strongly to those students (and their parents) who are striving to get into "good" colleges and universities. The majority of students in most schools, those who will drop out or find a job after graduation or even those who go on to a local community college, are tolerated by the system, but garner much less of the resources than their numbers (~80%) would suggest they should receive. Of course, there are exceptions, and there are always wonderful teachers whose heart and soul is dedicated to serving "the forgotten majority," but the system is not. In higher education it is not much different. We treat future majors differently than future elementary teachers, for example. There has been some wonderful work trying to optimize the economic model of huge classes (efficiency = students/faculty), but little work in trying to implement educationally sound models for those who need effective instruction most. In this area, community colleges are at the forefront because they can afford to teach smaller classes. The issue is teaching them well.

Then there is the general public, the great masses of adults and their children who primarily live near cities with museums, colleges or universities with astronomers on the faculty, or those connected to the Internet. And we need to be strategic about choosing our target audiences to maximize the impact of the resources that we are using. A small percentage of adults, teachers, and students are "space groupies" who will be thrilled with anything we do. The majority has other primary interests and commitments and must be convinced of the merit of our offerings. If we are serious about our fantasy, we cannot EPO just to the choir.

So the first challenge is to decide, are you focusing on contributing to the astronomical literacy of generic elementary, middle, or high school students, exciting highly capable students (including girls and under-represented minorities) who might become scientists or engineers, increasing the content knowledge of current or future teachers, increasing adult literacy or appreciation of NASA, or engaging our professional peers in rethinking teaching and learning? The second challenge is to set measurable goals and gather credible evidence of successes or failures. As scientists we owe the community more examples of thoughtful work and good research.

3. A Focus on Teaching

My own bias is that we will get the biggest bang for our buck by focusing on helping teachers become effective teachers of astronomy. As stated by the Education Trust in their Winter 2004 newsletter,

> "...teacher effectiveness is the single biggest factor influencing gains in achievement, an influence bigger than race, poverty, parent's education, or any of the other factors that are often thought to doom children to failure."

This is not a trivial undertaking. It starts in future teachers' homes and K-12 experiences, continues through their higher education astronomy classes and teacher training. It includes the resources and support that teachers receive in their school districts and buildings.

We should start by asking, what is effective teaching? This is a question that has a strong research base in science, if not specifically in astronomy. First, effective teaching engages students with relevant and important content. It takes place in an environment conducive to learning within the classroom, museum, or laboratory. It provides all students appropriate access to content, uses questioning strategies to monitor and promote thinking, and takes the time to help students make sense of the content.

Next we can ask what does it take to teach effectively? Teachers must have deep content and pedagogical knowledge. They need the best instructional materials available. Instructional materials are tools that enable a skilled practitioner to build a learning environment much like quality tools enable a skilled craftsperson to build a fine piece of furniture. Effective teachers have instructional flexibility, the skills to incorporate new research and adapt for their classroom context. New research is affirming the importance of participation in learning communities, teachers committed to improving their instruction by examining their students' learning collaboratively. This collaboration requires creative support by the administration and careful training.

4. Four Generations of Instruction and Instructional Materials

This is a brief diversion, because I think curriculum materials are such critical tools for teachers, and so much EPO effort has gone into preparing and disseminating materials. Since Sputnik, there have been many different changes proposed and implemented in instructional materials and materials in schools today reflect a broad spectrum of thinking about students and teaching. This simple model identifies four generations of materials, organized by the underlying instructional approach that reflects the belief of how students learn best.

Generation I: Stand and Deliver Students as empty vessels
The traditional textbook, full of wonderful information, skillfully organized, is still the most common instructional material used in higher education and high schools. It works well for those students who are already motivated self-learners. It works poorly for everyone else unless supplemented with effective instruction by hard working teachers. Every classroom should have one as an encyclopedia in case the Internet goes down.

Generation II: Activity Mania Students as born scientists
Science as Inquiry kits such as FOSS, STC, SEPUP and the materials designed in the 60's and 70's. These materials are in common use in many elementary schools, are gaining market share in middle schools, but rarer in high schools and higher education. They engage students in well-conceived activities that are connected to the big ideas of science though the connections are rarely made explicitly. The kits typically are motivating, and do a nice job of providing authentic experiences. There is little coherence in content among the kits, even those that deal with the same discipline like Earth Science, so there is little scaffolding of ideas from year to year. The kits are also generally weak in helping the teacher identify and address prerequisite knowledge or common student preconceptions. Assessments, both formative and summative, are also generally weak.

Generation III: Supported Teachers and Students
These emerging materials, often kit-based, incorporate the research from the past 15 or so years that has been synthesized by the National Research Council in books like *How People Learn* and *Taking Science to School*, and from physics and astronomy education research. Examples include *Interactions in Physical Science, Aries,* and *GEMS Space Science Sequence for Grades 3–5.* They supplement activities with support for the teacher and student to draw out and examine initial ideas in light of evidence, engage in thinking about phenomena scientifically, and confront their own learning. They generally lack any support for teachers to collaborate around student learning as a means to improve instruction for those students.

Generation IV: Collaborative Inquiry
All the properties of Generation III plus support for administrators and teachers collaborate to improve instruction (no materials yet).

The research is compelling that Generation IV instruction is effective for all students. Our goal in working with teachers then, is to help them deliver Generation IV instruction either by providing the professional development that will help them acquire the knowledge and skills to use their existing materials effectively, or developing new materials like *GEMS Space Science Sequence for Grades 3–5,* that will help well prepared teachers deliver Generation IV instruction with minimal professional development. In the long view, we need to work towards a time when new teachers graduate from our institutions with the knowledge and skills and expectations to find and use these materials well.

Realizing Effective Instruction for All Students Realizing effective instruction is more than providing teachers and students unlimited access to information. Access to information is critical, but information doesn't teach itself. That's why I am so skeptical of things like Google Sky and t he World Wide Telescope. (Though the WWT developer is making a concerted effort to learn about effective instruction and use the WWT as a tool for real learning.) When Carol Christian says "Sky in Google Earth will foster and initiate new understanding of the universe by bringing it to everyone's home computer," I have to disagree. Just like Google Earth is having minimal impact on students' abysmal understanding of geography, Google Sky will neither "foster" nor "initiate" increased student "understanding of the universe" unless it is incorporated into a sound instructional model. And that is hard to do, but it is what we should be working on. The question now is how can we realize Generation IV or effective instruction in every classroom? An interesting conversation to have with an elementary principal is to ask, "Are you committed to the goal that every lesson for every student, every day, every year, every subject be taught effectively?" Of course they are. But think about this from the elementary teachers perspective. They know that some are better at teaching reading, or science, or math than others, that some really don't know much about science or math, not because they are dumb or don't care, they have been and continue to be, poorly served by the K-16 system. So if you know that a certain third grade teacher, for example, is a poor science teacher, isn't there a moral responsibility to do something about it - now?

So the first step in realizing effective instruction is to agree to the shared vision outlined above, every student taught well all the time. There is no one best way to achieve this vision. There is one sure way not to, that is maintain the status quo. Here are some other steps. We can start with a collaborative professional development plan for existing teachers. Who needs to learn what to become more effective? One size never fits all. Schools can also engage in strategic hiring. Ask your district if they look at the math and science grades in the transcripts of new teacher applicants, then ask them if they might.

We can create, and schools can adopt and implement with adequate professional development and support, 3rd or 4th generation instructional materials. We can also support administrators, teachers, and students to be part of professional learning communities. It is critical to adopt Richard Elmore's Principle of Reciprocity that basically says there will be no unsupported mandates, but that real support merits accountability.

Some Reform Examples from the Field

Over the past four years, we have been working with about 150 schools and five higher education institutions in northwest Washington State in a Math and Science Partnership program funded by NSF. I hope these examples will show you what can be accomplished through intentional, research-based work. Our most important finding is that we can take average teachers and through carefully designed and implemented professional development help them to become effective science teachers.

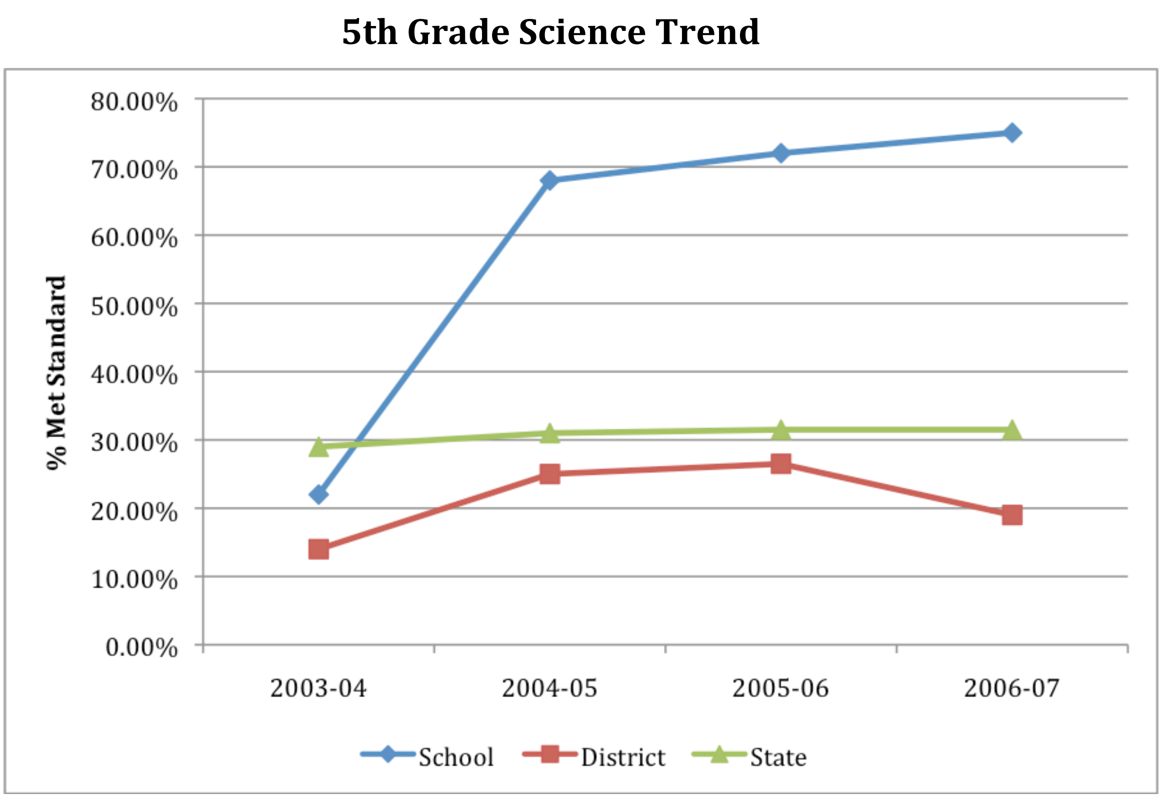

Figure 1. The percentage of Big Lake Elementary School students passing the 5th grade state science test by year compared to the state and district average.

One of the activities of the project is to work intensively with at least one teacher from each school, first to increase their capacity to teach effectively in their own classroom, then to help the teachers become leaders in facilitating instructional improvement in their buildings. Here are two examples from buildings that took the shared vision discussed earlier to heart. Both building restructured their teaching to meet the goal of effective instruction in all subjects for every student every year. In one case, the principal led the restructuring, in the other, the initial ideas came from the teachers, but in both cases the teachers and principals functioned as a team. We call this the "Collaborative Specialist" model because, it is not the typical "science specialist" model of an isolated teacher responsible for teaching a single subject like middle and high school. Rather, the teachers, two in one school and three in the other became collaborative teams that shared students and the responsibility for their learning. The principals were able to provide, through creative scheduling and at no extra cost, time everyday for the teachers to meet to discuss their students, their assignments, and their plans.

Big Lake Elementary School started their collaboration in the 2004-2005 school year following the first summer of intense professional development. Figure 1 shows how the percentage of the school's students passing the 5th grade state science test changed over time compared to the state and district average. Larrabee Elementary School began their model in the 2006-2007 school year. A similar jump in the passing rate on the 5th grade science test occurred (Fig. 2).

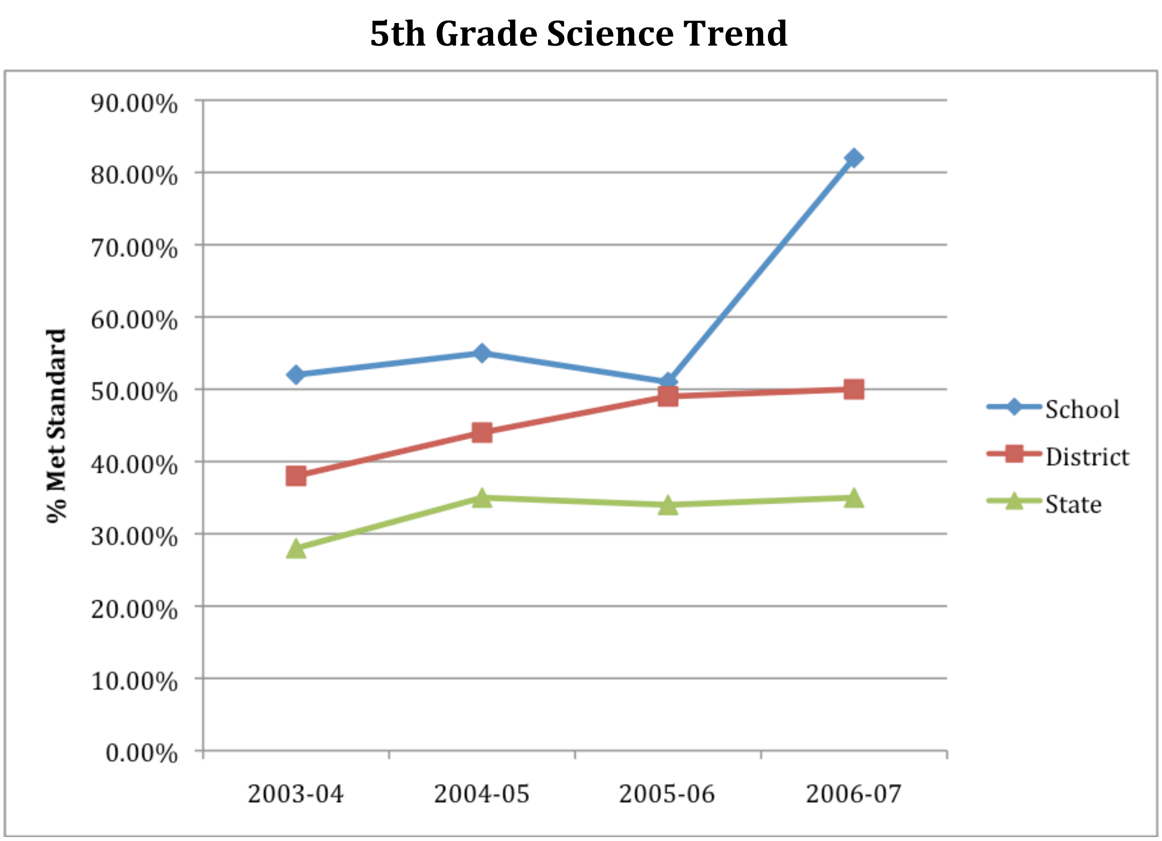

Figure 2. The percentage of Larrabee Elementary School students passing the 5th grade state science test by year compared to the state and district average. The jump in percentage for 2006w 2007 occurred when Larrabee used the collaborative specialist model.

Another example comes from the science content courses we designed for pre-service and in-service elementary and middle school teachers. Working with our partner science faculty in the community colleges, we developed a life and Earth science curriculum using the Physics and Everyday Thinking materials developed by Fred Goldberg and collaborators at San Diego State University as a template. The materials took two years to bring to the pilot stage and are still undergoing revision. They were taught in teams to approximately 150 in-service teachers during summer academies at Western Washington University by all of the twenty-five science faculty that are part of the project. For example, the first summer, the physics faculty led teams of biology, chemistry, and geology faculty. The next summer, the biologists were the lead instructors, followed by the geologists. The teachers not only learned science during these courses, they were intentionally engaged as partners in understanding the pedagogical approach and actively critiquing and providing feedback on the design. The courses are currently being taught on all five participating campuses to future elementary teachers. Results from pre- and post-tests and one-year delayed posttests are shown in figure 3. We would like to have a similar course in astronomy based on the common themes of the transfer and transformation of energy in interactions, but did not have the time or resources to develop it ourselves. Here is an opportunity to make a contribution.

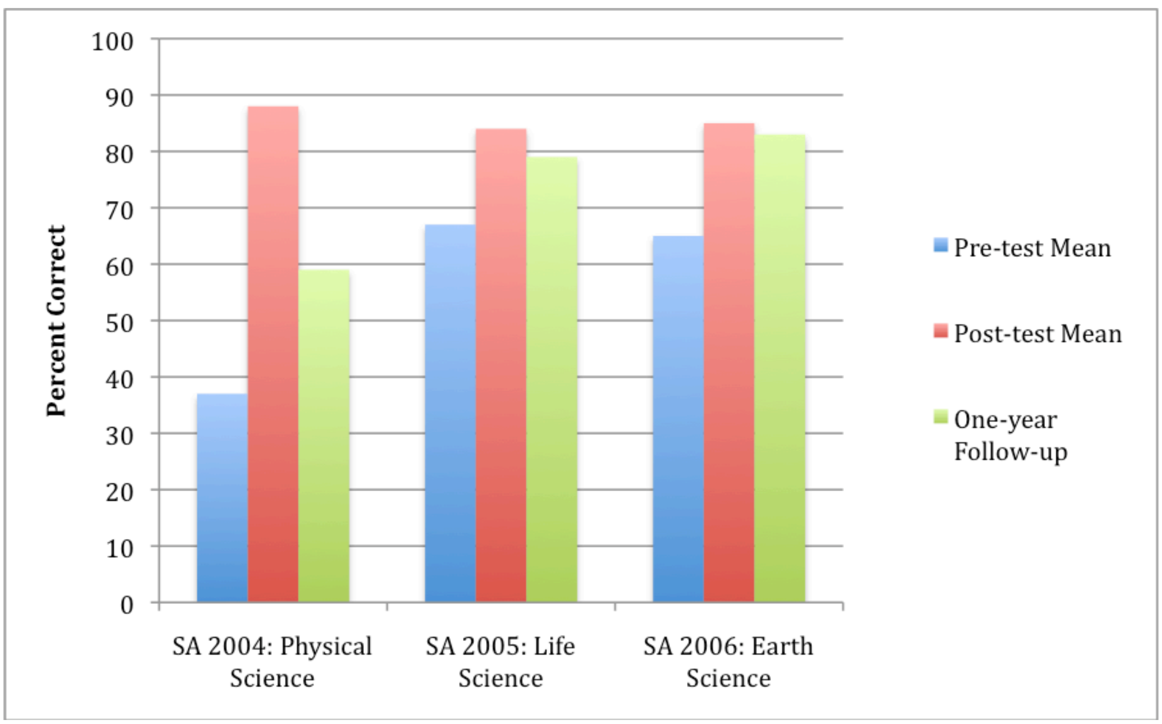

Figure 3. Results from pre- and post-tests and one-year delayed post-tests given to approximately 150 inservice teachers during summer academies at Western Washington University.

5. What Can EPO Do?

These few examples are not only a chance to brag a bit, they are intended to illustrate the key point of this presentation. To have the biggest impact we must partner: partner, partner! We can promote the use of materials like *GEMS Space Science Sequence for Grades 3–5* in schools where we work as part of a coherent curriculum. We can partner to design and deliver professional development to teachers using the new *GEMS Space Science Sequence for Grades 3–5* curriculum, even if we were not involved in the development. We can design, carry out and publish solid research on the materials and the implementation models and provide feedback. We can partner to design and implement a new course for future elementary teachers so they don't need to take Astronomy 101 with 500 of their closest friends. We can work with World Wide Telescope to help it realize its potential as an educational tool. No one institution or organization has all the knowledge and expertise they need to be successful. Only by working and learning together, by sharing our resources, and acknowledging our needs will we achieve our fantasy of universal astronomical literacy. I am optimistic that this powerful group of dedicated astronomy educators will make it happen. We are making a difference. There is still much to learn and do.