Abstract (APA)
The authors' ascertainable measurement of geological and cosmological teaching among the least understood and difficult-to-teach concepts in all of K-12 science education. To address this issue, a multidisciplinary team of geologists, astrophysicists, and educators from Western Kentucky University developed a series of professional development workshops for pre- and in-service middle grades teachers. The goals of these workshops were to (1) develop teachers' content understanding of important scientific concepts related to measurement of the universe, (2) develop teachers' appreciation of the inquiry-based approach and its potential to help them more effectively engage students about rates of change and the measurement of the universe; and (3) address those issues in a two-day format. Each workshop consisted of a blend of depth content discussions, hands-on activities, and classroom implementation formats. The teachers were provided with all the materials necessary to implement the lessons learned during the workshops as well as publications pertaining to deep time and evolution. Teachers were assessed prior to and immediately after each workshop and again one year later. The results of our evaluations showed that teachers were able to discuss how best to convey the content of the workshop to middle grades students. They were able to share content expertise and teaching experience, and were better able to discuss the scientific perspective deep time and of an ancient and evolving universe. The inquiry-based activities emphasized the methods by which scientists study cosmic distances, ages, and evolution. Our multidisciplinary team (including geologists, astrophysicists, and educators) has initiated a series of workshops to address these issues in Kentucky's public schools. The goal of the workshops is to provide clear, easy to implement curriculum materials to help middle grade science teachers explain to their students how we know the ages of the earth and the entire universe.

Introduction
In the United States today, evolution is under fire in our K-12 curricula. Recent attempts to revise how evolution is taught in US schools have not just with the theory of organic evolution but with current scientific theories about the age and evolution of the cosmos. Our multidisciplinary team (including geologists, astrophysicists, and educators) has initiated a series of workshops to address these issues in Kentucky's public schools. The goal of the workshops is to provide clear, easy to implement curriculum materials to help middle grade science teachers explain to their students how we know the ages of the earth and the entire universe.

Workshop Structure
During each workshop the teachers were introduced to a series of inquiry-based, hands-on activities designed to integrate thematic content from the life, earth, and physical sciences. Additional resources (various physics lab materials, earth materials kits, posters, CD-ROMs, etc.) and information were provided to allow each teacher to become familiar with the scientific perspective deep time and of an ancient and evolving universe. The inquiry-based activities emphasized the methods by which scientists study cosmic distances, ages, and evolution. Essential to the organization and delivery of each workshop was:

- The relative short duration of the workshop. Each workshop ran for four days. Our goal was to allow overburdened teachers to devote a substantive time to the workshop without imposing too much at any one point in their schedules.
- The emphasis on teams of pre- and in-service teachers. Teams were able to share content expertise and teaching experience, and they were able to discuss how best to convey the content of the workshop to middle grades students.
- The alignment with state and national science education standards. These included the National Science Education Standards and AAAS Project 2061.
- Pre- and post tests and knowledge surveys. These allowed for a quick assessment of workshop objectives and modification during the second year of delivery.
Student Understanding Through Professional Development Workshops For Teachers

Western Kentucky University, 1906 College Heights Blvd., Bowling Green, KY 42101, fred.siewers@wk.edu

Pre-Workshop Assessment
Age of the Universe
1. a) According to the predominant scientific understanding, how old is the Universe?
   b) What evidence supports this?
2. How do astronomers study the Universe?
3. In addition to planets and stars, what categories of objects make up the Universe?
4. a) How do objects in the universe form and change over time?
   b) What has caused (and continues to cause) these changes?
5. Why does the Sun look different from other stars?
6. Why do we use the distance light travels in one year to measure distance between stars?
7. Who is looking at a distant astronomical object like looking back in time?
8. a) What color are stars when we see a green star to be? List at least three factors.
   b) Why can’t the geometric/logic/geometric method of parallel be used to measure the distance to another galaxy?
9. a) What is the geometric/logic/geometric method of parallel used to measure the distance to the hithen galaxies.
   b) Consistently explain what must happen to create a rainbow.
10. Why is the age of the Earth pre- and post test assessment. The total number of points the participants received vs question number is plotted.

Age of the Earth Relative Time Pre-Workshop Assessment
1. a) How “complete” is the geologic record?
2. How are fossils used to date events in Earth history?
3. a) What are invertebrates?
   b) What types of invertebrates are recognized?
4. Describe the Law of Superposition
   a) In the time line below, position the following events in Earth history:
      i) extinction of Pangea
      ii) formation of rocks
      iii) extinction of dinosaurs

Age of the Cosmos
Question number
Results of the Age of the Cosmos pre- and post test assessment. The total number of points the participants received vs question number is plotted.

Field Trip: Geology of South Central Kentucky

Assessment and Evaluation
Immediate
Pre and Post tests
Ongoing
Implementing workshop materials in the classroom
1. Submission of an implementation plan by in-service participants
2. Assist with implementation
3. Observe implementation
Classroom visits to:
1. Observe the classroom environment
2. Assist with implementation of workshop materials
3. Assist in implementation of workshop materials

Successes and Challenges

A. Participants expressed appreciation for the theme of the workshop
1. Large amount of interest in how scientists determine geological and astronomical ages
2. Desire to understand evidence for evolutionary change in physical and biological systems

B. Inquiry-based presentation was successful
1. Selected workshop activities were successful
2. Chose to rely on established activities, rather than re-invent the wheel
3. Providing teaching materials is critical to the participants

C. The mixing of pre- and in-service teachers was deemed successful
1. In-service teachers have experience with classroom logistics
2. Undergrad, pre-service teachers at ease with content and full of enthusiasm

D. Target audience of middle grades science teachers was good choice
1. Science content for grades 5-9 even less frequently addressed by professional development opportunities
2. Interdisciplinary themes inspire enthusiasm and tend to match state/district directives for middle grade teaching

E. Participants expressed that the content matched standards

F. Scheduling difficulties
1. Scheduling around presenter and participant schedules is difficult
2. Order of presentation (astronomy vs. geology) appears not to matter
3. Two approaches were used, with good and bad points for each:
   i) four semi-continuous days (2004 June 3, 4, 7 & 8)
   ii) a pair of two-day sessions, separated by a week (2005 February 18 & 19 and 25 & 26)
4. Tendency by organizers to overschedule workshop days, providing more content than could be readily absorbed

G. Participant comfort level
1. Most teachers were comfortable with lowest level concepts
2. Presentation of evolution did not seem to be a big issue, all participants recognized it is a difficult issue

H. On-going assessment is difficult
1. All parties requested a respite immediately after workshop’s conclusion, but then got tied up with all other demands.
2. Long term evaluation requires substantial resources, which are rarely included in final budget

I. Successful Professional Development requires a serious investment of time and resources

J. Science teachers in rural schools tend to be either oversubscribed or uninterested.
   Teachers interested in content-rich professional development workshops are very often serving as coaches, club advisors, etc.

K. Despite the challenges of time and money, the workshops are worth doing and are beneficial to teachers

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