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The Big Sky Model: A Regional Collaboration for Participatory Research on Environmental Health in the Rural West

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Abstract

The case for inquiry-based, hands-on, meaningful science education continues to gain credence as an effective and appropriate pedagogical approach (Karukstis 2005; NSF 2000). An innovative community-based framework for science learning, hereinafter referred to as the Big Sky Model, successfully addresses these educational aims, guiding high school and tribal college students from rural areas of Montana and Idaho in their understanding of chemical, physical, and environmental health concepts. Students participate in classroom lessons and continue with systematic inquiry through actual field research to investigate a pressing, real-world issue: understanding the complex links between poor air quality and respiratory health outcomes. This article provides background information, outlines the procedure for implementing the model, and discusses its effectiveness as demonstrated through various evaluation tools.

Background

The Big Sky Model was developed among researchers from The University of Montana's (UM) Center for Environmental Health Sciences (CEHS) and the Department of Chemistry in collaboration with Big Sky High School located in Missoula, Montana. It is a four-pronged template that can easily be adapted to other regions of the country using the same or different environmental/health issues to get young students excited about science, and to extend learning from textbooks and lectures into real world research situations. The Big Sky Model:

1. Engages high school students in the measurement of local environmental hazards
2. Directly relates to human health issues
3. Utilizes hands-on, inquiry-based lessons and activities
4. Elicits findings which contribute to both university and regulatory databases

This four-pronged approach brings student-based scientific inquiry into the classroom, provides for mentoring opportunities as students work alongside university scientists, gives students real-world experience in systematic inquiry of problems relevant to their communities, and encourages youth to seek further education and careers in environmental and biomedical sciences.

The initial project began in 2004 when one high school junior designed a study to sample volatile organic compounds (VOCs) at the homes of 14 classmates as part of an independent

research project. The pilot project worked so well that it was expanded to two additional area high schools and a tribal college—Salish Kootenai College in Pablo, Montana—involving a total of 69 students by 2004-2005. The original Air Toxics Under the Big Sky program continued to provide the basis of a successful model for science teaching during the 2005-06 school year as it expanded to incorporate $PM_{2.5}$ (airborne particulate matter ≤2.5 microns in diameter) sampling within the students' homes to address residential home heating concerns, especially woodstoves, in the Missoula and Bitterroot valleys. Student participation increased to nearly 100 students. By the 2006-07 school year, the Big Sky Model was being used to teach more than 120 students at four Montana high schools and one tribal college in Idaho, Northwest Indian College's Distance Learning Center in Kamiah and Lapwai, Idaho.

Procedure

At its core, the Big Sky Model trains high school students to collect air pollution samples at their homes in collaboration with researchers from UM. High school and tribal college educators also receive professional development and act as partners in the program to further educate their students using classroom curricula on the science behind air pollution and associated health effects (see Figure 1).

Environmental Measurements

Early in the school year a UM researcher visits each of the participating schools to provide a presentation on air pollution, emphasizing why it is important to them. This presentation is followed by an equipment training session that demonstrates how to collect air pollutant samples, focusing on careful placement of equipment, proper calibration, logistics of transporting samples for analysis, and other quality control measures. Each home is sampled from 12- to 24-hour periods at least twice throughout the school year. Concentrations of VOCs, both inside and outside their individual residences, using customized kits containing low flow air sampling pumps (Model Number 222-3, SKC, Eighty Four, PA) and Carbotrap 300 sorbent tubes (Sigma-Aldrich, St. Louis, MO). These kits measure the concentrations of 53 VOCs, several of which are emitted from gasoline-powered automobile exhaust, and are listed on the United States Environmental Protection Agency's list of 189 hazardous air pollutants. Many of these toxic air pollutants are known or suspected to cause adverse health and environmental effects, notably benzene, toluene, and naphthalene. Concentrations of $PM_{2.5}$ --generally referred to as “fine” particles—have been implicated in human health effects (Dockery *et al.*, 1993; Heath *et al.*, 1995; Pope1 *et al.*, 1995; Pope2 *et al.*, 1995; Schwartz *et al.*, 1996; Laden *et al.*, 2000; Pope, 2000)—are also measured within students' homes and schools. Two different kinds of $PM_{2.5}$ samplers have been utilized in the program. These include filter-based samplers called Leland pumps/ Personal Environmental Monitors (SKC, Eighty Four, PA), and continuous $PM_{2.5}$ monitors called DustTraks (TSI, Shoreview, MN). Before sampling, the Leland Legacy pump/PEM samplers are fitted with a pre-weighed 37-mm $PM_{2.5}$ Teflon filter. After a 24-hour sampling period, the filter is then post-weighed to determine the collected $PM_{2.5}$ mass in the air during that 24-hour period. The DustTrak has no filter, and is able to continuously measure $PM_{2.5}$ mass (one minute interval averages) throughout the 24 sampling period. The electronic data files are easily downloadable, and are emailed to the UM researchers at the conclusion of each of the sample runs.

The exposed air samples collected from the VOC kits are returned to UM where the samples are analyzed and results are provided back to the students to allow them to interpret the raw air pollution data as part of classroom projects. Research questions that have been addressed by students include:

- Does the population in the home affect the amount of VOCs?

- Do room air purifiers have an effect on the amount of particulate matter found in indoor air?
- Does the age of the home itself affect the amount of VOCs?
- Is there a correlation between levels of VOCs found in indoor air and the proximity to high traffic roads?
- Does the location of the home affect VOC levels?
- Is there a correlation between the amount of particulate matter found in homes and the presence of pets?
- Does the type of heating used for the home affect air quality?
- Does it make a difference to a home's indoor air quality if it has a detached versus attached garage?

Health

Another important aspect of the Big Sky Model is to determine the health effects of children exposed to air toxics and $PM_{2.5}$ in the indoor environment. Before students begin sampling, they must first take home a description of the project to be read and signed by a parent or guardian giving consent for household participation in the program. Accompanying this summary of the program is a brief questionnaire to be filled out by the students. This questionnaire is used to obtain information on potential sources of air toxics and $PM_{2.5}$ inside their households, such as the types of chemicals stored in their attached garage or carport, whether new carpet had been installed, the age of their home, and how their homes are heated (woodstove, natural gas, propane, etc.). The questionnaire also asks optional health questions concerning the presence of asthma or allergies among family members, and whether or not anyone smokes within the household. Because this consent form contains personal health information, it receives annual review and approval by UM's Institutional Review Board; however, answering the health questions is strictly voluntary for the student.

Education

The Big Sky Model presents multiple opportunities to teach scientific principles—chemistry, physiology, geospatial learning, and environmental health—while students conduct participatory research working alongside scientists in laboratories and in their own communities. Science learning opportunities and activities include:

a) Researchers in the Schools Program

Atmospheric chemistry is the major focus of student research, training, and outreach efforts. Air pollution is commonly viewed as an urban phenomenon with less attention given to the kinds of exposures prevalent in rural environments or problems with indoor air quality. Students in these mostly rural, underserved communities soon realize that their training can lead to a better understanding of the sources and variations of air pollutants within their valley communities and home environments. To present a bigger picture of the various approaches to a problem like air pollution, UM researchers from different disciplines volunteer to go into the schools and present lectures on other areas of research being conducted at UM. An environmental epidemiologist might visit one of the high schools to talk about the health effects of air toxics exposure, while an immunologist can address how pollutants impact the body at the cellular level. Scheduling of the visits is coordinated through the Education and Outreach Office at UM-CEHS in conjunction with the teachers at each school.

b) Field Trips to University Campus

Field trips to the collaborating university are also a significant component of the Model's learning opportunities, serving both as a college recruiting tool and as means to offer advanced science activities using high tech laboratory equipment. As a college recruiting tool, the field trips are used to promote joint research projects between UM and high school teachers/students while familiarizing the students with research facilities and broadening their outlook on post-secondary options.

c) Science Symposium

At the end of the school year, a symposium is held at UM as a forum for the students to present their findings to the other participating schools, UM faculty, and staff from interested local and state agencies. The symposium begins with participants learning about global or regional air pollution issues via an authoritative keynote speaker before moving onto highlighting the students' work. Groups of four to five students take turns sharing their PowerPoint presentations and fielding questions posed by peers and a panel of judges representing an array of public figures, some of whom possess a science background. The judges come from diverse backgrounds and serve as a special guest audience panel to help steer discussion. A rubric is used to score each presentation and once the scores are tallied, a first place award is presented to the highest scoring team from each of the participating high schools. An environmental health fair held in conjunction with the symposium gives students an opportunity to display their posters alongside displays from health-focused organizations and local, state, and federal agencies. The media and public attention further augments the students' understanding of the role of science in our everyday lives, enhancing their sense of purpose and civic engagement within the larger community. Student PowerPoint presentations and pictures from the event are also posted on the UM-CEHS Website (see http://www.umt.edu/cehs/AirTox.html.

d) Curriculum Development

Two summer institutes have been offered to develop environmental health science education curriculum for the high school teachers' use. Workshop participants heard from experts regarding 1) differentiated instruction philosophy and strategies; 2) best teaching practices; 3) No Child Left Behind guidelines; 4) Science and Health standards; 5) effective curriculum components; and 6) cultural content consistent with Montana's far-reaching “Indian Education for All” law (MCA-20-1-501). Participating teachers have since been charged with the task of designing lesson plans and materials. Once the developed curriculum has been evaluated and quality is assured, CEHS will then disseminate these materials to schools interested in utilizing the Big Sky Model.

Evaluations

Evaluation of each of the education components of the Big Sky Model is ongoing. An independent science education evaluator tracks student outcomes and evaluates program efficacy using evaluation instruments to acquire formative and summative evaluations and solicit input from students and educators. This ensures that each activity meets aims and provides assessments of content and delivery. All survey data have been gathered anonymously; i.e., no individual is specifically identified. Preliminary analysis of the data show that student participation in our program leads to increased levels of interest in science.

The classroom presentations by UM researchers have had a dramatic and immediate effect on student interest. On a survey given to 28 high school chemistry students, 10 students indicated that before the presentation they were *not* excited about doing research on air toxics, while 14 were “sort of” interested and three were really interested. Following the presentation not a single student reported that he or she was not interested in doing research in this area. In fact,

16 students reported that they were "sort of" interested while 12 indicated that they were *really interested* in doing air toxics research. The data also indicate that the presentation also increased student interest in both science and science careers, seven out of 27 reporting increased science interest; five out of 28 reporting increased science career interest. One representative field trip involved student visits to the UM Human Performance Laboratory in which students were exposed to issues of air quality related to fire science, respiratory capacity, and human performance. Each station actively engaged students in testing, data collection, and discussions about these activities. For one group of 15 students the field trip to UM resulted in half of the group reporting an increased interest in science as well as in pursuing science careers. Every student that attended the field trip rated the experience as either good or excellent on a five-point scale.

The evaluation of the annual symposium examines the impact of the research program students were engaged in during the school year as well as the symposium experience itself. Data from a follow-up survey from the 2006 symposium clearly suggests that the preparing for and engaging in the symposium have had a significant impact on students. As a result of participating in the program, a third of the students reported that they were more interested in both science and in pursuing a career in science. This result is remarkable since the students that participated in the symposium entered the program with an already high level of science interest. Student comments about the impact on them are reflective of how powerful this type of event can be:

- [I learned] how much time and effort goes into big projects like this
- Just knowing what the other groups found, the effects and how much [air toxics] is really out there
- Knowing where a lot of these compounds come from and the health risks that come from them
- Knowing how much our involvement in this project effects our local community
- How important science is and how fun it is; that these projects have a huge impact within the science field and to later impact the world
- This experience with public speaking will have the greatest impact on my life; it also enforced my decision to go into a scientific field
- The continuation of the project as a whole will impact at least my next 2 years
- Seeing how much we can learn from a small effort by students to sample in homes
- The presentation on heating sources I will definitely think about when deciding on a heat source
- Science is so much more fun than ever
- The skills and learning to use the research equipment
- Science/chemistry is more fun than I thought it would be. Possible career!
- A renewed interest in chemistry and possibly studying at UM
- The activities I perform every day I will pay more attention to because I will think about VOCs more
- That working on science it is not as bad as people say
- The knowledge that there are people who are studying this type of thing and that they are working to better our world and control emissions

- I'm excited about future PM studies
- All people who are interested and work in the fields of chemistry and biology seem to love it
- You can't always be right
- I learned more about scientific research

Conclusion

The Big Sky Model consists of an effective set of teaching strategies and resources, which can solidify science career goals for those students who already have demonstrated an interest in this field. Moreover, the model has proven to be a viable approach for steering potential new recruits into environmental science study areas, thereby increasing the number of students involved in the science-career pipeline. The model's potential is multi-pronged and far-reaching: 1) As a model for chemistry teaching, the strategies and technologies presented are consistent with the region's environmental conditions, giving students an understanding of atmospheric chemistry that helps them collaboratively design basic exposure assessment studies; 2) As a workforce development model, classrooms have access to mentoring in applied science along with solid technology training. This provides avenues for continuing more intensive laboratory experiences, analytical work, and involvement in public policy and regulatory issues; and 3) As a model for student-led participatory research, investigations in mostly rural areas stimulate awareness and engagement in environmental public health issues affecting communities that may be geographically isolated and medically underserved.

Multi-stakeholder partnerships and collaborations continue to grow in this fourth year of the program. The program is now being replicated in additional high schools and tribal colleges in remote parts of the Rocky Mountain West. Sampling can also measure other air pollutants within the homes of students, including carbon monoxide, radon, and aeroallergens such as pollen. The questionnaire can be easily revised to elicit a more comprehensive picture of the health effects related to these environmental pollutants, by incorporating the sampling of pollutants from other media, such as measuring arsenic levels in local wells, streams, rivers, and lakes. We will also explore opportunities to include students from lower grades for a more extensive peer mentoring network (Blumenfeld *et al.* 1996: Voegel *et al.* 2004, 2005). The first steps toward this goal were taken when a high school student worked with local elementary school students to collect air samples at the bus/parent pickup areas at the elementary school during the 2005-06 school year. The potential for developing near-peer mentoring opportunities among middle school and high school students appears especially promising.

The Big Sky Model is part of a long-term project that will be built upon, improved, and expanded by future students during each new school year, and as new schools are added. It is the basis for fostering a long-term scientific collaboration between UM, regional high schools and tribal colleges, and has established students as regular and valuable contributors to the scientific community while exposing them to environmental issues involving chemistry, science, and health. An overall reduction in air pollutants both in the indoor and outdoor environments throughout the northern Rocky Mountains is anticipated as more and more students and parents are educated on the adverse health effects that can result from exposure to poor air quality. Through the sampling effort and results of the student questionnaires, a more comprehensive understanding of the sources of risk from air toxics and $PM_{2.5}$ will also emerge in our region, one that focuses on vulnerable populations in the homes of children, particularly during air pollution episodes with the greatest impact in our Northern Rockies region: winter thermal inversions and wild fire events. Campus-community partnerships in other regions of the country can use The Big Sky Model as a template to address the environmental pollutants of concern and associated health effects within their community.

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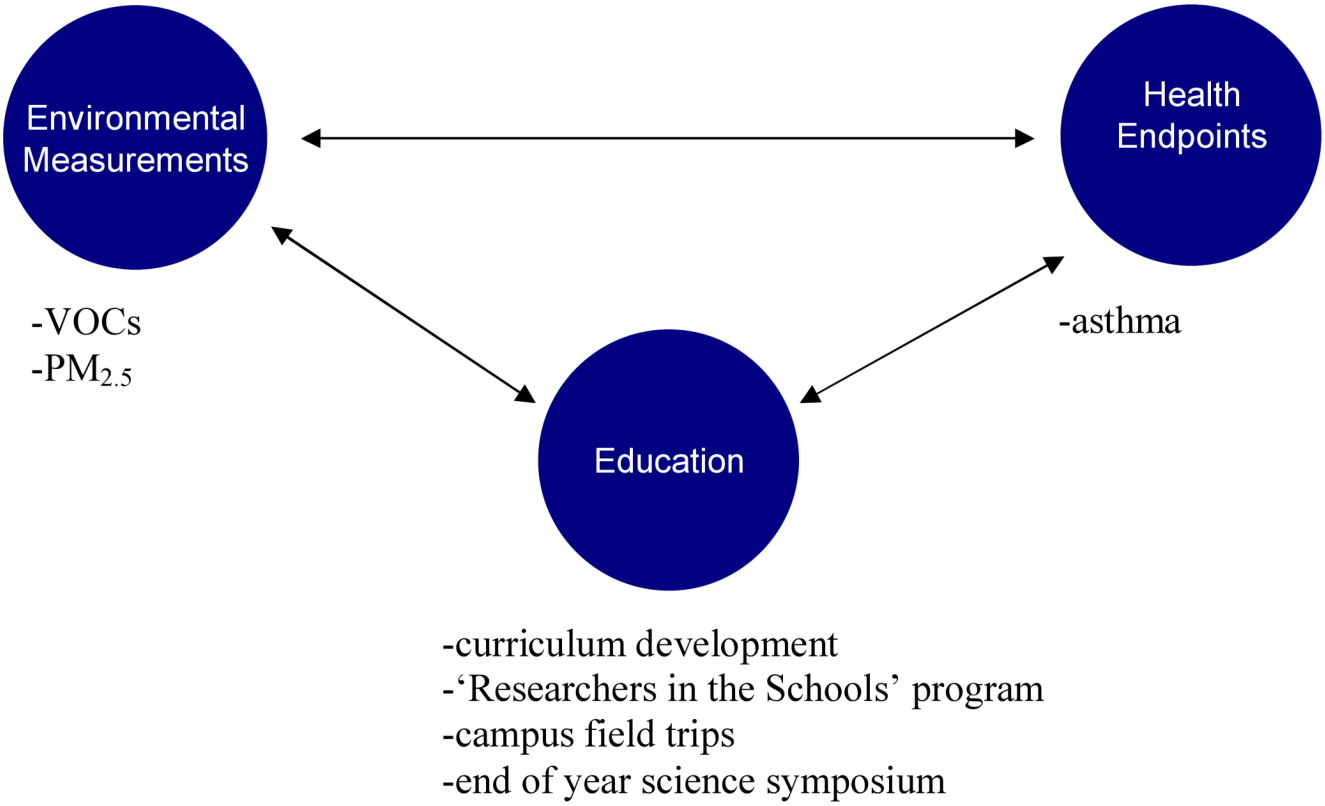

Figure 1.
The Big Sky Model for Integrated Science Learning