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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

As an innovative community-based framework for science learning, the Big Sky Model is guiding high school and tribal college students from rural areas of Montana and Idaho in their understanding of chemical, physical, and environmental health concepts in the context of their own homes, schools, and communities. 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.

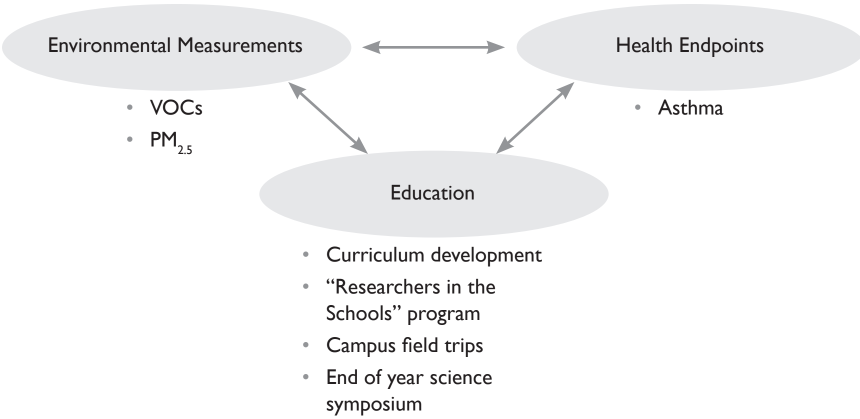
Background

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 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 that 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

Figure 1. The Big Sky Model for integrated science learning



real-world experience in systematic inquiry into 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 fourteen 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 2004–5. The original Air Toxics Under the Big Sky program continued to provide the basis of a successful model for science teaching during the 2005–6 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 the effects of woodstoves, in the Missoula and Bitterroot valleys. Participation increased to nearly 100 students. By the 2006–7 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 the students. 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 for 12-hour to 24-hour periods at least twice during the school year. Concentrations of VOCs, both inside and outside their individual residences, were tested 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 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, Pope, and Thun 1995; Pope et al. 1995; Pope, Dockery, and Schwartz 1995; Schwartz, Dockery, and Neas 1996; Laden et al. 2000; Pope 2000)* and 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 Legacy pumps or personal environmental monitors (SKC, Eighty Four, PA) and continuous $PM_{2.5}$ monitors called DustTraks (TSI, Shoreview, MN). Before sampling, the Leland Legacy pump samplers are fitted with a preweighed 37 mm $PM_{2.5}$ Teflon filter. After a 24-hour sampling period, the filter is postweighed 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-hour 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. Results are provided 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 on 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 has 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) presentations by researchers in the schools, (b) field trips to the university campus, (c) a science symposium highlighting the work of participating students, and (d) curriculum development in relevant fields.

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.

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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 a 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 and students while familiarizing the students with research facilities and broadening their outlook on postsecondary options.

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 on to 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 highes 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 Web site (see http://www.umt.edu/cehs/AirTox.html).

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 ensured, 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, so 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 3 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 indicate that the presentation also increased student interest in both science and science careers, with 7 out of 27 reporting increased science interest and 5 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.

"As a result of participating in the program, a third of the students reported that they were more interested both in science and in pursuing a career in science."

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 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 both in 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 personally 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 that 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 multipronged 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.

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Multistakeholder 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 2005–6 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 and 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 wildfire 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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• Earle Adams is a research assistant professor in the Chemistry Department at the University of Montana (UM) in Missoula. He has both a BS and an MS in chemistry, and received his PhD in analytical chemistry. Earle was the recipient of two postdoctoral fellowships: one for five years at Yale University School of Medicine and the second for two years at Grinnell College in Iowa. Earle serves as the departmental coordinator for technology and tribal outreach and is the primary contact

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- Dr. Andrij Holian is the director of the UM Center for Environmental Health Sciences and is the principal investigator on the Environmental Health Science Education for Rural Youth project. Dr. Holian received a PhD in chemistry from Montana State University in 1975. He held positions at the University of Pennsylvania and Villanova University before joining the faculty of the University of Texas Health Science Center at Houston in 1984. During his tenure in Houston, he became a full professor and assumed the director of research position for the Mickey Leland National Urban Air Toxics Research Center. In 2000 he arrived at the University of Montana to direct the newly established Center for Environmental Health Sciences within the Department of Biomedical and Pharmaceutical Sciences. His current immunotoxicology research focuses on developing treatments to prevent lung inflammation and fibrosis resulting from exposure to airborne particulates (asbestos, silicates, and urban dusts) and ozone.

- Dave Jones is a chemistry teacher at Big Sky High School in Missoula, Montana. He earned a BS in zoology and an MS in chemistry and has been teaching high school science for sixteen years. For the past five years Dave has been working closely with UM-based colleagues to design the air toxics high school research program out of a strong commitment to mentoring students in community-based science inquiry experiences. He has received numerous grants and awards for his efforts, notably from Toyota Tapestry, Toshiba America Foundation, Best Buy, and Vernier Technology. He was the 2005 American Chemical Society Northwest Regional Chemistry Teacher of the Year.

- Dr. Randy Knuth, president of Knuth Research, Inc. of Spokane, Washington, is the science education evaluation specialist for Air Toxics Under the Big Sky project. He has been actively involved in designing, implementing, and evaluating instructional systems for over two decades. Randy began his career in education as a high school teacher in Montana and completed graduate work in instructional technology and learning theory at Indiana University. This led to a research and development position at an educational research laboratory in Chicago where he developed instructional videos and Web sites, conducted research, and directed national projects. In addition to serving as the overall evaluator on the UM Environmental Health Science Education for Rural Youth program, Randy is involved with projects in the Northwest on geospatial science, biotechnology, health science, bullying prevention, and school-based mentoring.

- Nancy Noel Marra is the education coordinator for the Center for Environmental Health Sciences (CEHS) at the University of Montana. Nancy has been involved in the field of education for twenty-five years in many different capacities: classroom teacher, environmental education specialist, gifted education specialist, Teacher Expectations and Student Achievement facilitator, differentiated instruction trainer, and student teacher supervisor. Nancy serves as a school support team member for Montana's Office of Public Instruction. She has a master's degree in education and was a recipient of the Presidential Award for Excellence in Science and Mathematics Teaching in 1996.
- Diana Vanek is the outreach coordinator for the UM Center for Environmental Health Sciences and serves as co-investigator on the Environmental Health Science Education for Rural Youth project funded by a Science Education Partnership Award (NIH Grant #1R25 RR020432). The Big Sky Model is drawn from one of the four main subprojects under this grant. Diana has a bachelor's and a master's in anthropology, and has worked with advocacy, education, and workforce training programs serving disadvantaged populations in rural Montana communities. Her role at the UM CEHS involves promoting meaningful collaborations between university-based scientists and communities to enhance the public's role in identifying biomedical research priorities with the goal of improving environmental public health.
- Tony Ward is a research assistant professor at the UM Center for Environmental Health Sciences (CEHS). He is an atmospheric chemist and was instrumental in developing the protocols and standards involved in the Air Toxics Under the Big Sky program for the expanding network of participating high schools. He has both a BS and an MS in environmental science/industrial hygiene, and received his PhD in chemistry from the University of Montana. He held a postdoctoral fellowship in Andrij Holian's laboratory at CEHS before being promoted to his current research assistant professor position. His research focus is on air quality exposure assessment studies to determine the specific sources of air pollution in western U.S. communities.