The SEPUP Development Process: Design for Issue-Oriented Science

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The Science Education for Public Understanding Program (SEPUP) is based at the Lawrence Hall of Science at the University of California, Berkeley. It develops issue-oriented materials for use in grades 6-10 and has been supported by the National Science Foundation (NSF) since 1989. How does SEPUP develop its program materials? What does it mean to be "research-based?" What are the expectations of the National Science Foundation, which funds the instructional materials developed by SEPUP? How does the program gather information from teachers and students to support its ongoing evaluation of materials in development? What is the impact of SEPUP use on teachers and students? This paper will try to answer these and related questions.

About SEPUP

From very early on, SEPUP has used personal, societal, and environmental issues to frame the science content and process skills in its middle/high school science materials. Consider the following questions:

- Should you throw your old computer into the trash?
- How might the introduction of a non-native species affect a local ecosystem?
- Should you be concerned about genetically modified organisms in the food supply?

These are relevant questions, whether one is a student or teacher, an adolescent or an adult citizen. These are the types of personal and societal issues that SEPUP uses to engage students in the study of science. Students are provided with some evidence about the issue at hand, but they often realize that they have more questions than answers. These new questions are addressed in a series of science activities that introduce and teach relevant science concepts. Eventually, students apply their new science knowledge to re-considering the issue. SEPUP curricula do not advocate a particular position on issues, but encourage students to support their views with relevant evidence.

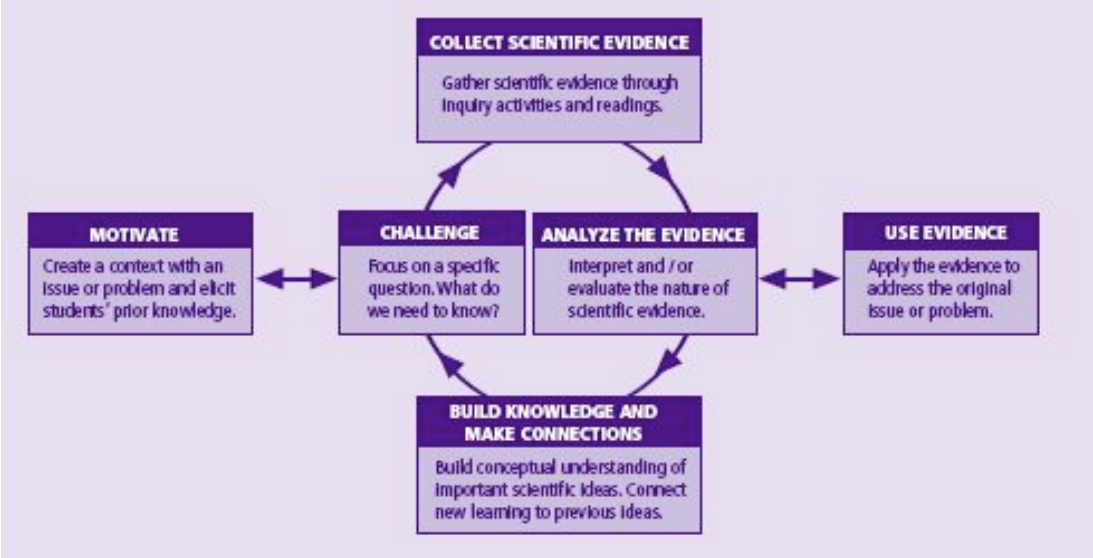
SEPUP designs curriculum using the best of research and practice. The staff first identifies research-based techniques that can help students learn. These techniques are integrated into the development of the curriculum, which is then trial-tested by classroom teachers and their students. Only after addressing the input of teachers, scientists, and other experts are the materials commercially published.

[1] The author was SEPUP Assistant Director from 1991-94, and a SEPUP instructional developer since 1986.

In all of its curriculum materials, SEPUP incorporates:

- Personal and societal issues to introduce science
- The role of scientific evidence and trade-offs in decision-making
- Different approaches to hands-on inquiry
- Age-appropriate teaching strategies
- Spiraling of key concepts and skills over time
- Assessments that are embedded in the curriculum
- 4-2-1 approach to cooperative learning
- Explicit connections to other disciplines, such as math and literacy

The following model summarizes the major elements in the SEPUP instructional design. This model has been strongly influenced by the learning cycle developed by the late Dr. Robert Karplus, professor of physics at UC Berkeley, and SEPUP founder Dr. Herbert D. Thier. Personal and societal issues can be incorporated into all aspects of this model. Most often, issues provide a context for introducing important science content (MOTIVATE). They are also used to assess students' ability to apply evidence (USE EVIDENCE)[2].



SEPUP materials also contain support for literacy and technology, and a nationally-acclaimed, embedded assessment component featured in such publications as *Knowing What Students Know* (2001a) and *Classroom Assessment and the National Science Education Standards* (2001b). Since it first began work in the late 1980s, SEPUP has received support from seven major grants from the National Science Foundation. These have all been through the Instructional Materials Division of the Education (IMD) of the Elementary, Secondary, and Informal (ESIE) Division of the Education and Human Resource (EHR) Directorate. A modern observer might remark upon the changes in education since the late 1980s. In the early days of SEPUP, the National Science Education Standards were little more than an idea gathering momentum among science educators, and NCLB, with its focus on accountability at the state and federal levels, would not become law for more than a dozen years.

[2] For more on the SEPUP curriculum design, see www.sepuplhs.org.

But the basic steps in the SEPUP development process, as outlined in *Developing Inquiry-Based Science Materials: A Guide for Educators*, by SEPUP founding director Herbert D. Thier, have not changed all that much. While we might now "begin with the end in mind," according to Grant Wiggins (1998) instead of "…thinking of cool science things to do with kids…" (Bybee, 2006), which recognizes an increased focus on outcomes, student achievement, and accountability, the basic steps in the process of developing SEPUP materials have not changed all that much over the years.

All SEPUP materials are:

- Authored by science knowledgeable master teachers, scientists, engineers and/or assessment experts;
- Piloted and nationally field tested with geographically and ethnically diverse student populations representing urban, rural, and suburban districts throughout the country;
- Subjected to external formative and summative evaluation and technical review; and,
- Revised based on the results of evaluation and technical review by master teachers, scientists, and engineers to ensure their scientific and educational integrity.

As mentioned previously, the use of issues provides a useful context for middle and high school students, helping engage them in what is for them the real reason to care about science. Less than 5% of all pre-college students will graduate from college with a degree in science or mathematics, so the use of relevant issues provides a context and motivation to engage all students in science. Thus the early development work involves the selection and definition of the relevant societal, personal, or environmental issues to be developed. Development of comprehensive (full year) materials, such as those materials produced with NSF funding, usually requires about five years.

Phase One - The early stages and local trials

Typically, after the development grant is funded (see Thier, 2001 for a discussion of the grant writing process[3]), SEPUP begins with a process of developing initial outlines, issues, and assessments for the courses. This process generally includes a development conference that includes scientists, classroom teachers, college science education faculty, and others. The following essential questions guide the development in these critical early stages where the issues are selected and initial approaches are suggested:

- Are the concepts age-appropriate and standards-based?
- What standards and concepts are most important?
- Does the issue use and apply rigorous science content?
- Is the issue motivating to students?
- Is the issue complex, i.e., does the decision making involve trade-offs?
- What approaches will best communicate this concept?
- How will the learning be assessed?

[3] NSF has very explicit guidelines for all its projects to make sure the grantees' work is grounded in research, including findings from cognitive science about how students learn and best instructional practices in the classroom to support them, along with making sure the materials are original, innovative and not something that the private sector might support, and aligned to NSES.

The outlines produced as a result of this process will include specific learning goals, a preliminary correlation to the NSES, and a brief description of each activity in the sequence. These outlines will be reviewed by a larger advisory group and revised if necessary. The outlines will be further developed into draft units and prototype kit materials within a nine-month period.

As part of this development, SEPUP staff at the Lawrence Hall of Science work in collaboration with teacher consultants, an expert advisory board, local pilot schools, and national field test districts. Specific learning goals are defined for each content standard and used to develop culminating assessments that will provide evidence to determine whether students have improved their understanding. Instructional activities are then developed to promote student learning. Students' work on embedded tasks, culminating assessments, and pre-/post-tests will be evaluated to determine whether learning goals have been achieved.

Following completion of the outlines and drafting of core activities, SEPUP developers typically teach the draft units in local classrooms in San Francisco Bay Area. These districts serve diverse student populations and include low and high performing schools as based on the California Academic Performance Index. Teacher comments and observations by project staff are gathered for use in revision of the materials. Typically, staff visits classrooms in pairs and alternate roles, one teaching while the other "scripts" or records a detailed log of the lesson.

Phase Two - National pilots

After initial local trials, and typically one to two years after the project begins, the materials are revised to prepare national pilot versions. This revision begins with the development of expanded descriptions of each NSES content standard addressed in the course in order to define specific learning goals. These descriptions are developed by project staff familiar with research on student learning in the different disciplines and experienced teacher consultants. These detailed descriptions of the learning goals are used to create an assessment framework and scoring guides. In the current high school project, this step is taking place in Phase I, before local trial teaching, according to the "backward design" process. This is generally followed by development of drafts of culminating assessments and several embedded assessments for each unit. The advisory board then reviews the expanded learning goals and the assessment framework, and changes are made where needed.

Sites are selected by a competitive application process based on commitment to teaching the program, providing administrative and professional support to participating teachers, and providing feedback and evaluation data. Sites are also selected to ensure diversity of students, teachers, and settings, including classrooms with honors students, English Language Learners, and special education students.

Teachers will receive professional development for teaching the materials during 3 to 5 day sessions at the SEPUP offices at the Lawrence Hall of Science before they teach the unit. These professional development sessions will be based on draft professional development materials co-developed and initially delivered by SEPUP. There are typically about 10-15 cooperating teachers in 2-3 centers who participate in the national pilots. The centers and teachers are selected by a competitive process and based on commitments to complete the materials and provide feedback and local dissemination. National pilots are small-scale efforts to learn as much as possible about the units before exposing them to a larger population of students. Recent pilot

and field test centers for SEPUP have included large school districts such as Akron, Brooklyn and Queens, Buffalo, Chicago, Louisville, Los Angeles, Seattle, and Winston-Salem/Forsyth County; smaller cities such as Iowa City, IA; Vista, CA, Spearfish, SD, and Huntsville, TX; suburbs such as Naperville, IL; and the Navaho Nation.

Phase Three - National field trials

SEPUP staff use feedback from teachers and project advisors to revise the units to produce national field test versions. National field-testing of the units typically takes place in approximately eight centers representing diverse student populations. A typical center will include a center director, usually the district science curriculum leader, and five classroom teachers. Of particular interest at this stage is the use of assessment system and multimedia components. Test item banks are reviewed and subjected to item analysis. Student scores are compared on a pre-post basis and individual items are reviewed for validity (is the item measuring the concept or skill it is supposed to measure?) and reliability (do the items distinguish students who know—and don't know—the material?).

As is the case in national pilots, participants are introduced to the course during a one-week summer professional development conference at the Lawrence Hall of Science and a three-day follow up during the academic year. Center directors provide additional professional development and support. Teachers provide regular feedback on specific activities and overall flow of each unit through SEPUP's online feedback reporting system. They also provide samples of student work and pre-/post tests. At the same time, experts in content and pedagogy also review materials are reviewed.

During the field test, teacher feedback and information from staff visits is reviewed. Essential questions at this formative stage include:

- Are the activities working as intended? If not, why not?
- Are the key concepts and process skills achieved?
- What material needs revision?
- Is the material scientifically accurate and free from bias?
- Can teachers easily teach the materials?

At the end of the year, developers analyze and summarize the full feedback from the field test sites and expert review to prepare the commercial version, as described below. Selected field test teachers join project staff in dissemination of the materials at national, regional, and state science teacher conferences and deliver summer professional development workshops in each field test district's region.

Phase Four - Peer review and commercial publication

The units are then prepared for commercial publication. Selected teacher leaders from the field test sites typically join the development team in Berkeley after the trials are completed to contribute to the revision for commercial publication and to development of the professional development and outreach plan. These field test center consultants review the revision plan and contribute to revision of the course and the professional development materials. The final product will be submitted to advisory board members and additional reviewers for content, teaching, and assessment review. A complete commercial version of the course will be available by the end of the fifth year of the project. In all stages of the multi-year process, the LAB-AIDS and SEPUP staffs work together to refine the kit materials that accompany the unit.

The professional development materials and routines are prepared by LAB-AIDS, the SEPUP publisher, so they can be delivered to teachers at workshops at state or national meetings, directly to school districts, and/or to pre-service and in-service teacher education providers. Publisher's consultants typically provide awareness workshops and teacher professional development for implementation.

Student impact research

The following papers describe *third party* efforts to understand the impact of SEPUP on teachers and students who use the program.

- Barter, A. (2005). *Issues and Earth Science Student Evaluation Report 2004-05*. Center for Research, Assessment and Evaluation, Lawrence Hall of Science, University of California, Berkeley.

  An evaluation of student learning with Issues and Earth Science, a middle level SEPUP earth science program. Pre- to post- student learning gains were statistically significant for all units; reliability estimates for the pre/post measures range from .73 to .82. Effect sizes ranged from .48 to .80 indicating moderate effect sizes for most units. Results suggest consistent evidence of the effectiveness of the curriculum.

- Draney, K. & Wilson, M. (1997, July). *Mapping student progress with embedded assessments: The challenge of making evaluation meaningful*. Paper presented at the National Evaluation Institute Workshop, Indianapolis, IN.

  Describes the development of psychometrically calibrated progress maps that describe student performance on embedded assessments in SEPUP's year-long course Issues, Evidence and You.

- Hill, Stanford (2005). *Report of pilot study on student impact of SEPUP in Winston Salem*. *In* D. Martin, S. Hill, J. Timmerman, and M. Ward. 2005. An NSF Urban Systemic Program in the Winston-Salem Forsyth County School District. Midpoint Review. National Science Foundation: Arlington, Virginia.

  Mean normal curve equivalent (NCE) scores of SEPUP and non SEPUP students taking the 2004 NC state 8th grade science assessment, a Stanford-9 based test were compared. It

was found that SEPUP students outperformed their non-SEPUP peers, and across all ethnic subgroups.

- Scott, G. (2000). *Integrated science study*. Science Teacher, 67 (6), 56–59.

  This paper reports on gains in student achievement as a result of a two-year integrated science sequence in Los Angeles Unified School District. In many of the participating schools, the integrated science sequence was based on two SEPUP courses: Issues, Evidence and You and Science and Sustainability.

- Siegel, M.A., & Ranney, M.A. (in press). Developing the Changes in Attitude about the Relevance of Science (CARS) questionnaire and assessing two high school science classes. *Journal of Research in Science Teaching*.

  This article describes the development of the Changes in Attitude about the Relevance of Science (CARS) questionnaire. This questionnaire was used to determine changes in attitudes toward science among students using the Science and Sustainability field test.

- Wilson, M., Sloane, K., Roberts, L., & Henke, R. (1995). SEPUP Course I, Issues, *Evidence and You*: Achievement evidence from the pilot implementation. (BEAR Report Series, SA-95-2) University of California, Berkeley.

  This report gives evidence of student achievement after using SEPUP's course, Issues, Evidence, and You. The pre-test and post-test results showed that the average SEPUP student showed improvement in providing evidence and using trade-offs in scientific arguments.

For a complete bibliography of SEPUP research (8 pp.), visit www.sepuplhs.org/research.

References

Bybee, R. (2006). Science Teaching the the 21st Century: Five Themes for Educational Leaders. A paper given at the American Museum of Natural History for Science Education Leaders in New York City Schools. Kendall Hunt, Dubuque, Iowa.

National Research Council (1996). National Science Education Standards. National Academy Press. Washington, D.C.

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Thier, H. (2001). Developing Inquiry-Based Science Materials: A Guide for Educators. Teachers College Press. Columbia, New York.

Wiggins, G. and McTighe (1998). *Understanding by Design*. Association for Supervision and Curriculum Development. Alexandria, Virginia.

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Appendix A

List of NSF-Funded SEPUP Instructional Materials Projects

SEPUP Modules (MDR-8751532, 1983-1995; and ESI-9730606, 7/1/98-6/30/03).

This program consists of twelve individual modules, designed for general use in grades 7-12, with each title requiring two to four weeks for completion. Each module includes a teacher's guide containing lesson plans, masters for student sheets and overhead transparencies, glossary, assessment, and solution prep pages. Complete kits are available for each title; each kit supports up to 160 students before refills are needed. Topics include groundwater pollution, chemistry of food additives, toxic waste disposal, environmental health risks, and others.

SEPUP Middle Level Programs (ESI-9553877, 4/1/96-3/31/01; and ESI-9252906, 10/15-92-9/30/00; ESI-0099265, 4/02-6/06).

The middle level comprehensive programs consist of *Science and Life Issues (SALI), Issues and Earth Science (IAES), and Issues, Evidence, and You (IEY)*. Each provides print materials and an equipment kit for up to 160 students (5 classes x 32 students each class). Each is available in complete form, or as "mega-modules," covering approximately nine weeks of study. The middle level programs provide complimentary, integrated coverage of the life and physical sciences. SALI units include: studying people scientifically, human body systems, cells and cell biology, genetics, ecology and evolution. IEY units include water quality and use, materials science, energy, and environmental impact. IAES topics include rocks and minerals, erosion and deposition, plate tectonics, weather and atmosphere, and earth and the solar system. All programs feature an authentic, embedded assessment system, developed in tandem with the instructional sequences, plus support for literacy and technology.

SEPUP High School Programs (ESI-9252906; 10/15/92-9/30/00).

Designed as an integrated high school environmental science course, the course, *Science and Sustainability*, can be also used to fulfill third-year graduation requirements for non-majors. Topics from the life, earth, and physical sciences are used to develop student understanding of major issues related to sustainability. Major unit titles include: Living on Earth; Feeding the World; Using Earth's Resources; and, "Fueling the World." A Companion book, the *Material World* (Sierra Club Press) details the everyday life of 67 families across six continents and helps to develop student understanding of sustainability. Complete material kits are available; strong links to technology are embedded in the program. As of this writing, work is beginning on a second NSF funded high school project with the working title, "Science and Global Issues."