4 Education and Public Outreach

Suzanne H. Jacoby, Kirk D. Borne, Julia K. Olsen, M. Jordan Raddick, Sidney C. Wolff

4.1 Introduction

Goals of the Education and Public Outreach (EPO) program include engaging a broad audience in LSST's science mission, increasing public awareness of scientific research, contributing to science, technology, engineering, and math (STEM) education, and enhancing 21st century workforce skills. LSST will contribute to the national goals of improving scientific literacy and increasing the global competitiveness of the US science and technology workforce. The open data access policy and survey operations mode of LSST facilitates the active engagement of a broad audience in many venues: in the classroom, through science centers, and in our homes, anywhere with access to the Internet. The LSST project will provide value-added products to enable both student and public participation in the process of scientific discovery. The LSST EPO program is well planned, tuned to our audience needs, aligned with national education standards, and integrated with the science mission of LSST. The program is organized around three main threads: 1) inquiry-based, scientifically authentic exploration in the classroom; 2) visualization of LSST data in science centers and on computer screens of all sizes; and 3) support of public involvement in activities that may be as simple as browsing through the data or as sophisticated as contributing to active research projects through Citizen Science opportunities.

4.2 National Perspective on Education Reform

Scientific literacy, defined as the "knowledge and understanding of scientific concepts and processes required for personal decision making, participating in civic and cultural affairs, and economic productivity," is a requirement in today's complex society (National Research Council 1996). Yet, only 28% of American adults currently qualify as scientifically literate; nearly 70% of Americans adults cannot read and understand the Science Times section of the New York Times (Miller 2007). Policy makers, scientists and educators have expressed growing concern over the fact that most people in this country lack the basic understanding of science that they need to make informed decisions about many complex issues affecting their lives (Singer et al. 2005).

The influential report "A Nation at Risk" investigated the declining state of the educational system in the US, identified specific problem areas, and offered various recommendations for improvement (Bell 1983). The report specifically documented the need for greatly improved science education in this country and galvanized the inclusion of the quality of education as a prominent element of the national political agenda. A succession of education reform efforts set forth to remedy the situation:

standards-based reform, the establishment in 1989 of National Education Goals, National Science Education Standards put forth by the National Research Council in 1996, and most recently the No Child Left Behind legislation. All have sought to standardize classroom learning goals, improve instructional methods, and enforce accountability.

Today, science education standards exist for content, teaching, and assessment, such as the National Science Education Standards (National Research Council 1996) or Project 2061 (American Association for the Advancement of Science 1994). Consistent with the "A Nation at Risk" report, expectations are defined for high school graduates, whether or not they plan additional education. These expectations include the ability to know, use, and interpret specific mathematical and scientific concepts, but also the ability to evaluate scientific evidence, understand scientific development, and participate in scientific practices and discourse. Beyond mere facts, it is these "habits of mind" that result in a scientifically literate populace, capable of participating in an increasingly complex global society.

In a changing world, new kinds of knowledge and skills are as valuable as core subjects. The 21st century worker must have strengths and attitudes dramatically different from typical workers of today, who were trained in the 20th century. In particular, three areas of proficiency must be addressed in preparing the 21st century workforce: core knowledge in science, mathematics, and other content areas; learning and thinking skills; and information and communications technology. Critical for workers of the future is the ability to incorporate high-level cognitive abilities with inventive thinking skills such as flexibility, creativity, problem solving, effective communication, and collaboration. The use of technology as a tool for research, organization, evaluation and communication of information is an integral aspect for the future workforce. It is skillfulness in both proactive learning and response to innovation that will separate students who are prepared for the work environment of the 21st century from those who are not. Scientific literacy, education reform, and workforce preparedness are all elements of the educational environment in which LSST is poised to contribute.

4.3 Teaching and Learning in the Classroom

LSST data can become a key part of projects emphasizing student-centered research in middle school, high school, and undergraduate settings. Taught in an exemplary fashion, using technology to its best advantage, students can participate in cutting-edge discovery with authentic classroom research opportunities developed through the LSST EPO effort. The LSST education program will design and develop a number of student research projects in conjunction with a teacher professional development program.

As described in "How People Learn" (Bransford et al. 2000), the goal of education is to help students develop needed intellectual tools and learning strategies, including how to frame and ask meaningful questions about various subject areas. This ability will help individuals to become self-sustaining, lifelong learners.

Engaging students by using real data to address scientific questions in formal education settings is known to be an effective instructional approach (Manduca & Mogk 2002). The National Science Education Standards (National Research Council 1996) emphasize that students should learn science through inquiry (Science Content Standard A: Science as Inquiry) and should understand the concepts and processes that shape our natural world (Science Content Standard D: Earth and Space Science). Students learn best if they are not passive recipients of factual information but rather are engaged in the learning process (Wandersee et al. 1994; Hake 1998; Prather et al. 2004; Duncan 2006).

Professional development, including the preparation and retention of highly qualified teachers, plays a critical role. The importance of teachers cannot be underestimated. The most direct route to improving mathematics and science achievement for all students is better mathematics and science teaching. In fact, "...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" (Carey 2004).

One goal of having teachers and their students engage in data analysis and data mining, is to help them develop a sense of the methods scientists employ, as well as a familiarity with the tools they use to "do science." The common lecture-textbook-recitation method of teaching, still prevalent in today's high schools, prevents students from applying important scientific, mathematical, and technological skills in a meaningful context. This model of teaching science is akin to teaching all the rules of a sport, like softball, to a child – how to bat, catch, throw, slide, and wear the uniform – but never letting the child actually play in a game (Yager 1982).

In order to support implementation of scientific inquiry in classrooms using public databases, the LSST EPO team is exploring the technological and pedagogical barriers to educational use of data mining and integrating that knowledge into planned professional development and classroom implementation modules. We refer to this effort as CSI: The Cosmos, capitalizing on public appeal of crime scene investigation television shows. We model a research question as a crime scene, with a mystery to be solved, and answers are found through clues mined from the database. Our goal is to develop a feasible plan promoting data mining as an instructional approach and successful classroom implementation, facilitating authentic research experiences using the LSST database. This approach provides an authentic experience of astronomy as a forensic (evidence-based) science. What is learned and what is known about our Universe comes entirely from evidence that is presented to us for observation through telescopes and preserved by us for exploration in databases. The CSI model of learning science resonates with the inquisitiveness of the human mind — everyone loves a good detective story.

The LSST EPO group has adopted the formal process of Understanding by Design (Wiggins & McTighe 2005) to facilitate the cohesive planning and implementation of LSST education for specific audiences. Experience shows that the most successful classroom research projects fall into two categories, both of which are natural outcomes of the LSST database:

1. projects that use the same analysis techniques with a changing data set, e.g., measuring lightcurves of a series of novae or supernovae, and
2. the classification or organization of large samples of a particular object type, such as galaxies.

Sample Learning Experiences being explored for formal settings are all aligned with NRC content standards for Earth & Space Science, Technology, and Physical Science. Those involving large number statistics and classification are aligned with mathematical content standards. All can be taught in an inquiry-based approach and supported with appropriate professional teacher development. These Learning Experiences include:

1. Wilderness of Rocks: Students classify asteroids (by rotation curve, light curve, and colors), make maps of their interplanetary distribution and orbital paths, and use colors to determine composition. Students also deduce the shape, orientation, and family membership (and possible binarity of the system) from LSST asteroid observations. Learning goal: to understand scientific classification and inference through synthesis of information; to understand the scientific measurement process, data calibration, and reduction; and to understand properties of primordial Solar System bodies. This broad area of investigation could be implemented at middle school, high school, or undergraduate levels.
2. Killer Asteroids: Students measure the locations of small Solar System bodies in multiple LSST images to calculate their orbital parameters and to see if a planetary impact is possible. If an asteroid will pass near a planet, the odds of an impact are also determined. Learning goal: to understand orbits, hazards from space, detection methods, and mitigation strategies.
3. Type Ia Supernovae in the Accelerating Universe: An analysis of Type Ia Supernovae light curves could be developed in partnership with the SDSS-II survey during the LSST construction phase. Students would monitor the images of $\sim$ several hundred nearby galaxies as measured by LSST, and try to find supernovae. This project is most appropriate for physics classes and astronomy research classes at the high school and undergraduate levels. Learning goal: to understand scientific data collection, and to understand fundamental physics as it applies to cosmology and stars.
4. Photometric Redshifts: Using optical colors from the LSST database, students apply the photometric redshift technique to measure the distance to high-redshift galaxies and to estimate their star formation history. Learning goal: to understand the concepts of photometric redshift, star and galaxy evolution, and model-fitting.
5. Galaxy Crash (Train Wreck): Using deep, wide surveys at many wavelengths, students track the rate of galaxy collisions as a function of redshift. While we can't watch individual galaxies collide and merge, we can use a wide survey to catch an ensemble of colliding galaxies in all stages of interaction in order to understand the processes of environment-driven galaxy-building and cosmological mass assembly. Learning goal: to understand galaxy evolution timescales and the concepts of dynamical evolution, hierarchical galaxy formation, and the development of the Hubble sequence of galaxies.
6. Star Cluster Search: Students search for overdensities of stars, to determine if a star cluster or star stream may be contained within the data. Students plot a simple H-R diagram and estimate the age of the star cluster or star stream (from the H-R diagram). If the overdensity looks promising, students can check lists of known clusters (e.g., WEBDA[1]) to determine other properties of the star system and to verify their age estimate. Learning goal: to understand the HR diagram, star formation in groups, stellar evolution, the difference between apparent and absolute magnitudes, gravitational clustering in astrophysical settings, and how to check online databases.

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[1] `http://www.univie.ac.at/webda/`

4.4 Outside the Classroom — Engaging the Public

The formal education system does not exist in a vacuum; students, teachers, and families are all part of the broader context in which we learn. Opportunities that exist for learning outside the classroom include Informal Science Education (ISE), Out-of-School Time (OST), and the world of Citizen Science, where non-specialist volunteers assist scientists in their research efforts by collecting, organizing, or analyzing data. More than a decade of research now shows that sustained participation in well-executed OST experiences can lead to increases in academic achievement and positive impact on a range of social and developmental outcomes (Harvard Family Research Project 2008).

Adults play a critical role in promoting children's curiosity, and persistence studies show that that one of the best indicators of likely success in the educational system (i.e., matriculation all of the way to graduation) is a home environment that is supportive of education (NIU College of Education, Center for Child Welfare and Education 2009). Engagement of parents in informal education, visits to museums and planetaria, and now Citizen Science can all help to create an environment that encourages young people to pursue challenging courses in math and science. As then-candidate Barack Obama said in his speech, "What is Possible for our Children" in May 2008, "There is no program and no policy that can substitute for a parent who is involved in their child's education from day one" (Denver Post 2008).

"Experiences in informal settings can significantly improve science learning outcomes for individuals from groups, which are historically underrepresented in science, such as women and minorities. Evaluations of museum-based and after-school programs suggest that these programs may also support academic gains for children and youth in these groups" (Bell et al. 2009).

Two concepts are under development to engage the interested public in LSST through the Internet outside of the classroom. It is expected that these public interfaces can provide a gateway to more formal activities in the classroom as described above, once interest is established.

1. Cosmic News Network (CN^2): A web-based news report on "changes" in the world of physics and astronomy; that is, a News, Weather, and Traffic Report of the Universe. Presented in the format of an online popular news source like cnn.com or msnbc.com, we will collect, organize, and present information on everything that could be reported as news in the Universe: phases of the Moon, eclipses, planet positions, satellite locations, the discovery of new asteroids, new Kuiper Belt objects, extra-solar planet transits, supernovae, gamma ray bursts, gravitational microlensing events, unusual optical transients, particle physics experiments, solar weather data, launches, comets, hot stories, and more. New media technologies will be used on the site, including an LSST blog and links to existing podcasts and video casts, RSS feeds and widgets of interest. Just as someone checks the morning on-line or on-paper news source to learn what happened overnight in the world, they would access the CN^2 web portal to learn about recent happenings in the Universe, including daily reports of the most significant LSST alerts and transient events.
2. LSST@HOME: A way for the general public or classrooms to adopt a piece of the celestial highway and call it their own. As in the public "Adopt-A-Highway" service along our nation's highways, individuals and organizations would register at no cost to be identified with a patch of the Universe. "Owners" of the patch can contribute their own inputs: images, links to other

> data and information resources for sources in the region, news events based in that region, tracks of asteroids that have passed or that will pass through the area, new measurements (astrometry, photometry, redshifts), links to related published papers, etc. These celestial patches may provide the starting point for robotic telescope observation requests for ancillary data on objects and/or LSST events within the region. We will develop a mechanism to collect, distribute, and archive all metadata about the adoptable, small parcels of the "LSST sky" (e.g., one square degree), including a table of historical VOEvents within the region. A user will be able to click anywhere on the LSST sky to learn about objects and discoveries within the selected stamp. Some users will be interested only in monitoring their patch of sky, while active users will be able to explore events and return their findings to the professional scientific community, for follow-up observations or publication. The gateway to the data can be provided through the World-Wide Telescope (WWT) or Google Sky interfaces. The LSST EPO Database would serve the cutouts. The VOEvent database would serve the alerts.

With survey projects like LSST (and its predecessors) on the sky, the role of amateur astronomers will shift away from discovery space into opportunities for follow-up and data mining. LSST saturates at magnitude 16, well within the reach of many well-equipped amateurs. Thousands of alerts per night will point to objects to be understood and monitored. Two windows of opportunity are particularly well suited to amateur observations: 1) following an object's brightness as its light curve rises above what LSST can observe and 2) filling in observations between LSST visits to increase time coverage of suitable objects. Working with the American Association of Variable Star Observers (AAVSO), pro-am collaborations and Citizen Science venues will be developed into partnerships that extend the scientific productivity of LSST.

4.5 Citizen Involvement in the Scientific Enterprise

Citizen Science is emerging as a popular approach to engaging the general public and students in authentic research experiences that contribute to the mission of a scientific research project (Raddick et al. 2009). Citizen Science specifically refers to projects in which volunteers, many of whom have little or no specific scientific training, perform or manage research-related tasks such as classification, observation, measurement, or computation. As reported at the Citizen Science Toolkit Conference held in Ithaca, NY, June 20th-23rd, 2007, successful Citizen Science projects are known to include authentic contributions to the field, not just "busy work," as well as validation for volunteer's effort. LSST recognizes the importance of Citizen Scientists in the astronomical endeavor and the vital contributions to research activities made by volunteers from the American Association of Variable Star Observers (AAVSO), NASA's Lunar Impact Monitoring project, and others.

Citizen Science is one approach to informal science education, engaging the public in authentic scientific research. Figure 4.1 illustrates design considerations for Citizen Science Projects, showing three overlapping circles: projects that people want to do, projects that people can do, and projects that scientists want done. A recent and highly successful astronomy Citizen Science project, Galaxy Zoo, sits in the sweet spot of the intersection of these three circles. Galaxy Zoo has involved more than 200,000 armchair astronomers from all over the world in classifying the morphology of galaxies

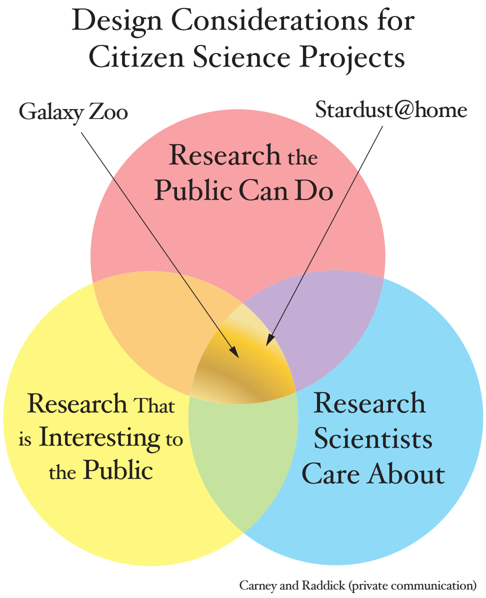

Figure 4.1: Citizen Science offers volunteers a fun and meaningful way to contribute to science. It offers scientific researchers the means to complete projects that are otherwise impossible to do on a reasonable time scale. The most successful projects maximize volunteer contributions and scientific value. Three overlapping circles symbolize design considerations for Citizen Science projects: Research the Public Can Do, Research that is Interesting to the Public, and Research that Scientists Care About. Finding out exactly why a particular project occupies one portion of the diagram over another is a key part of the research agenda for Citizen Science. In all cases, Citizen scientists work with real data and perform duties of value to the advancement of science.

from the SDSS, resulting in four papers published in peer-reviewed journals already (Land et al. 2008; Lintott et al. 2008; Slosar et al. 2009; Bamford et al. 2009). In the 18 months prior to February 2009, 80 million classifications of galaxies were submitted on 900,000 galaxies at galaxyzoo.org.

The Stardust@home project (Mendeź Bryan 2008) where volunteers pass a test to qualify to participate in the search for grains of dust in aerosol gels from the NASA Stardust Mission, has attracted smaller numbers of Citizen Scientists (24,000), perhaps because of the more sophisticated training and analysis required by participants, or perhaps because images of galaxies are inherently more interesting to the larger public than cracks in an aerosol gel. In all cases, Citizen Scientists work with real data and perform authentic research tasks of value to the advancement of science. The human is better at pattern recognition (Galaxy Zoo) and novelty (outlier) detection (Stardust@home) tasks than a computer, making Galaxy Zoo's galaxy classification activity and others like it good candidates for successful Citizen Science projects.

Within the realm of LSST, many Citizen Science projects are possible, including these proposed by the Science Collaboration Teams:

1. Galaxy Zoo Extension: Continue the Galaxy Zoo classification project with LSST data, adding billions of candidates to the sample. Extend classification categories to include low surface brightness galaxies and mergers. Put interacting galaxies in a sequence, and understand the timescales for the collision to produce detectable distortions in the galaxies and for

the eventual merger of the two galaxies. Explore how to use a large sample to probe changes over a Hubble time (Chapter 9).

2. Light Curve Zoo: Classify light curves generated from the automatically provided photometry of variable objects. Use trained human volunteers for the initial classifications (Chapter 8). The AGN group offers several suggestions (§ 10.8): Once a gravitationally lensed AGN has been identified via the presence of multiple images, one of the key projects would be to measure the brightness of the lensed images as the magnification caustics sweep across the accretion disk. These light curves will then be used in a sophisticated statistical analysis to infer AGN accretion disk sizes. One important and attainable project would be a study of the light curves of different classes of Active Galactic Nuclei, which are then used to model the differences due to obscuration and luminosity.
3. Lens or Not: Find new gravitational lens candidates via the Galaxy Zoo model. Human recognition of arcs, rings, and multiply-imaged sources can supplement the pattern recognition tools within the LSST image processing pipeline and aid in the discovery of rare unique objects. This investigation could be extended to the classroom by having students interactively model variables of mass, light, and placement to recreate the observed lensed candidates. (Chapter 12).
4. Human Computing: Label and annotate LSST images, along the lines of the Google image labeler (`http://images.google.com/imagelabeler/`) or the ESP Guessing Game (`http://www.gwap.com`) in which participants select words to describe and annotate each image; the most popular descriptors become part of the image header.

4.6 Diversity

A negative trend over the past 25 years is the increasing numbers of students – now nearly 1/3 – who do not graduate from high school (Greene & Winters 2005) and who therefore do not posses the minimum education required to be functioning Citizens and workers in a global environment. A disproportionate number of these students are from groups of ethnic and racial minorities, students from low-income families, and recent immigrants, all of whom have been ill-served by our educational system. The Greene and Winters study said: “the national graduation rate[2] for the class of 1998 was 71%. For white students the rate was 78%, while it was 56% for African-American students and 54% for Latino students.” Sixteen of the 50 largest school districts in the US failed to graduate more than half of their African-American students. All but 15 of the districts for which rates can be computed have Latino graduation rates below 50%. Minorities comprise the fastest growing segment of the US workforce, yet these are the same individuals most likely to be undereducated and consequently unqualified for positions in the science and technology fields. The statistics underscore the importance of diversity and inclusion, as aging baby boomers leave the workforce to an increasingly diverse pool of replacement workers.

LSST is well positioned to broaden participation of underrepresented groups in astronomy and physics with its open access policy and EPO plan integrating science and education. The data-intensive aspects of LSST includes research and education opportunities specifically in the contexts

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[2] Graduation rate is defined by the Manhattan Institute study to be: graduation rate = regular diplomas from 1998 divided by adjusted 8th grade enrollment from 1993.

of computer science, instrumentation, and the data sciences (Borne & Jacoby 2009). Thinking beyond the traditional types of students will open up a vastly larger pool of talent encompassing a diversity of disciplinary backgrounds and educational levels. LSST scientists and engineers throughout the project will partner with Faculty and Student Teams (FaST) from minority-serving institutions to develop long-term research and educational opportunities. This work builds on two years experience with NSF/DOE sponsored FaST teams at three LSST institutions: BNL (focal plane sensor development), SLAC (system calibration), and UW (variability detection sensitivity).

4.7 Summary

The challenge of today is not only to build excellence in students and teachers, but also to provide access to this excellence – quality education for all. To do this, we engage the entire community – students, teachers, parents, and the public – with pathways to lifelong learning. With its open data policy and data products that offer vast potential for discovery, congruence with educational standards, and relevance to problems that are inherently interesting to students, LSST offers a unique opportunity to blend research and education and to achieve the national goal of quality education for all students and enhanced scientific literacy for all citizens.

This engagement of the public in LSST-enabled formal and informal education is not entirely altruistic on our part. Full exploration of the LSST databases (to maximize specific scientific goals) is likely to require the engagement of large numbers of people outside the formal LSST project structure, and even beyond the traditional professional astronomy research community. By welcoming educators, students, and amateur astronomers to the LSST database, the doors will be opened wide to all. "And why not open the doors wide? It's hard to imagine that this data will ever get used up – that all the good discoveries will one day be wrung out of it – so the more minds working away at it, the better" (Becker 2009).

LSST is uniquely positioned to have high impact with the interested public and K-16 educational programs. Engaging the public in LSST activities has, therefore, been part of the project design from the beginning. This involvement and active participation will allow LSST to fulfill its public responsibility and extend its scientific potential – a truly transformative idea for the 21st century telescope system.

References

American Association for the Advancement of Science, 1994, Benchmarks for Science Literacy. Project 2061, Oxford University Press

Bamford, S. P. et al., 2009, *MNRAS*, 393, 1324

Becker, K., 2009, Old Data, Fresh Eyes. `http://www.dailycamera.com/news/2009/feb/13/science-old-data-fresh-eyes/`

Bell, P., Lewenstein, B., Shouse, A., & Feder, M., 2009, Learning Science in Informal Environments: Places, People and Pursuits. National Research Council, National Academy Press.

Bell, T. H., 1983, A Nation at Risk, The Imperative for Educational Reform. National Center for Excellence in Education

Borne, K., & Jacoby, S., 2009, The Revolution in Astronomy Education: Data Science for the Masses. ASTRO2010 Decadal Survey Position Paper.

Bransford, J., Brown, A., & Cocking, R., 2000, How People Learn: Brain, Mind, Experience, and School. National Academy Press

Carey, K., 2004, Thinking K-16, The Education Trust, 8, 3

Denver Post, 2008, Full text of Obama's education speech. Denver Post.

Duncan, D., 2006, *Astronomy Education Review*, 5, 70

Greene, J. P., & Winters, M. A., 2005, Manhattan Institute Education Working Paper. Manhattan Institute, from `http://www.manhattan-institute.org/html/ewp/08.htm`

Hake, R. R., 1998, *Am. J. Phys.*, 66, 64

Harvard Family Research Project, 2008. Harvard Family Research Project, from `http://www.hfrp.org/out-of-school-time`

Land, K. et al., 2008, *MNRAS*, 388, 1686

Lintott, C. J. et al., 2008, *MNRAS*, 389, 1179

Manduca, C. A., & Mogk, D. W., 2002, Using Data in Undergraduate Science Classrooms. Final report of the National Science Digital Libary Workshop

Mendeź Bryan, J. H., 2008, SpaceScience@Home: Authentic Research Projects that Use Citizen Scientists; in EPO and a Changing World, *ASP Conference Series*, C. Garmany, M. Gibbs and J. W. Moody, (editors), 389, 219

Miller, J., 2007, Scientific Literacy: How Do American's Stack Up? From `http://www.sciencedaily.com/releases/2007/02/0702181`

National Research Council, 1996, National Science Education Standards. National Research Council, National Academy Press

NIU College of Education, Center for Child Welfare and Education, 2009, Supporting Youth in the Middle and High School Years. From `http://www.cedu.niu.edu/ccwe/publications/`

Prather, E., Slater, T., Adams, J., Bailey, J., Jones, L., & Dostal, J., 2004, *Astronomy Education Review*, 3, 122

Raddick, M. J., Bracey, G., Carney, K., Gyuk, G., Borne, K., Wallin, J., & Jacoby, S., 2009, Citizen Science: Status and Research Directions for the Coming Decade. ASTRO2010 Decadal Survey Position Paper

Singer, S. R., Hilton, M. L., & Schweingruber, H. A., 2005, America's Lab Report: Investigations in High School Science. Committee on High School Science Laboratories: Role and Vision, National Research Council

Slosar, A. et al., 2009, *MNRAS*, 392, 1225

Wandersee, J. H., Mintzes, J. J., & Novak, J. D., 1994, Research on Alternative Conceptions in Science. Handbook of Research on Science Teaching and Learning, D. L. Gabel (Editor), New York: Macmillan Publishing Company.

Wiggins, G. P., & McTighe, J., 2005, Understanding by Design. Prentice Hall

Yager, R. E., 1982, What Research Says to the Science Teacher, Volume 4. National Science Teachers Association, p. 117