SCIENTIFIC LITERACY OF ADULT PARTICIPANTS IN AN ONLINE CITIZEN SCIENCE PROJECT

A dissertation

submitted by

Charles Aaron Price

In partial fulfillment of the requirements

For the degree of

Doctor of Philosophy

In

Education

TUFTS UNIVERSITY

February, 2011

ADVISERS:
Dr. Hee-Sun Lee (Chair)
Dr. Eric Chaisson
Dr. Danilo Marchesini
Dr. Tim Slater (University of Wyoming)

ABSTRACT

Citizen Science projects offer opportunities for non-scientists to take part in scientific research. Scientific results from these projects have been well documented. However, there is limited research about how these projects affect their volunteer participants. In this study, I investigate how participation in an online, collaborative astronomical citizen science project can be associated with the scientific literacy of its participants.

Scientific literacy is measured through three elements: attitude towards science, belief in the nature of science and competencies associated with learning science. The first two elements are measured through a pre-test given to 1,385 participants when they join the project and a post-test given six months later to 125 participants. Attitude towards science was measured using nine Likert-items custom designed for this project and beliefs in the nature of science were measured using a modified version of the Nature of Science Knowledge scale. Responses were analyzed using the Rasch Rating Scale Model. Competencies are measured through analysis of discourse occurring in online asynchronous discussion forums using the Community of Inquiry framework, which describes three types of presence in the online forums: cognitive, social and teaching.

Results show that overall attitudes did not change, $p = .225$. However, there was significant change towards attitudes about science in the news (positive) and scientific self efficacy (negative), $p < .001$ and $p = .035$ respectively. Beliefs in the nature of science exhibited a small, but significant increase, $p = .04$. Relative positioning of scores on the belief items did not change much, suggesting the increase is mostly due to reinforcement of current beliefs. The cognitive and teaching presence in the online forums did not change, $p = .807$ and $p = .505$ respectively. However, the social presence did change, $p = .011$.

Overall, these results suggest that multi-faceted, collaborative citizen science projects can have an impact on some aspects of scientific literacy. Using the Rasch Model allowed us to uncover effects that may have otherwise been hidden. Future projects may want to include social interactivity between participants and also make participants specifically aware of how they are contributing to the entire scientific process.

ACKNOWLEDGEMENTS

An incalculable number of people have supported me in this endeavor and I will certainly omit someone important to me. So I will limit these acknowledgements to those who have the power of retribution over me.

First, Hee-Sun Lee has made the experience more than I could have hoped for and dedicated far more time to my education than I had the right to receive. I will *always* be in her debt. Eric Chaisson has been both an advisor and a good friend, full of wisdom and humor. Tim Slater has provided both research expertise and also encouraged me to think about how research should be expressed into the real world. He is also responsible for my participation in the International Year of Astronomy committee that led to this project. Finally, I thank Danilo Marchesini for agreeing to dip his toes into the world of education research and insuring that this study, in the end, actually makes sense in the world of science. Thanks are due to Jennifer Borland and Grant Foster for technical advice. Finally, I'd like to thank Larry Ludlow for allowing me to join his psychometrics class and providing advice regarding Rasch analysis.

Next, I must pay respects to the taxpayers of the United States. The Citizen Sky project and much of my research tools and time are funded by the National Science Foundation through DRL award #0840188**.** However, that does not imply NSF support or endorsement of the views presented in this publication.

With that bit of pro forma rigmarole out of the way, I'd like to also thank my mother, Carol Price, for supplying me with astronomy magazines, books and posters when we couldn't always afford them. I'd like to also thank my father, Ron Price, and my stepmother, Beverly Price, for giving me my first telescope as a Christmas present and my family in general for supporting my astronomy hobby (a.k.a. habit).

I'd like to thank Arne Henden for introducing the idea of a PhD and supporting me professionally in every way possible. He was the first person who believed I could do this.

Most importantly of all, I thank my wife Erma Cuenca-Price for her support, optimism and willingness to put her goals on hold while I finish this program. Now it is my turn to support her so she can shine!

This dissertation is dedicated to Caroline.

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

SCIENTIFIC LITERACY OF PARTICIPANTS IN AN ONLINE CITIZEN SCIENCE PROJECT

CHAPTER 1. INTRODUCTION

A recent report sponsored by the National Research Council concluded that science learning in non-school settings is often overlooked, even though most people spend the majority of their lives out of school (National Research Council, 2009) and there is a strong correlation between informal science education and civic scientific literacy (Miller, 2004). Informal learning settings present opportunities to support lifelong learning (Dierking, Falk, Rennie, Anderson, & Ellenbogen, K., 2003; Falk, Stoksdieck & Dierking, 2007), engage populations typically underrepresented in science (Center for Informal Learning and Schools, 2005) and qualitatively affect personal relationships with science (NRC, 2009). The National Science Board has called for more informal science education opportunities (National Science Board, 2008). Citizen science, research collaborations between scientists and volunteers (Cornell, 2009), is an increasingly popular venue for informal science education (Cohn, 2008). Such projects are beginning to involve education as the primary goal or on par with the scientific goals of the projects (Silvertown, 2009).

Citizen science projects are quite popular and experiencing explosive growth (Hand, 2010). They offer a unique solution to many scientific problems that require voluminous contributions of the sort that cannot be easily automated. However, their impact on the world is not restricted to scientific advancement. They also have an impact on the participants of these projects, the vast majority of whom are not scientists by training. There is very little empirically based research about the type of impacts citizen science projects have on their participants.

I hope to add to the limited research pool by studying how participation in a citizen science project can be associated with the scientific literacy of its participants. First, I measure change in two aspects of scientific literacy: attitudes towards science and beliefs in the nature of science. Then, I measure change in competencies associated with science, as seen through online discourse. The citizen science project being studied here is Citizen Sky – an astronomical project focused on stars that change in brightness ("variable stars").

My main research question is:

- How does participation in a large-scale, online citizen science project affect the scientific literacy of its participants?

In support of that question, I ask the following sub-questions:

- How do attitudes towards science and beliefs in the nature of science change through participation in a large-scale, online citizen science project?
- How can competencies associated with science be observed in the discourse of an online citizen science project? And how do the competencies differ according to the structure of the forums? How do they change over time? And are there differences among groups posting to the forums?

Thanks largely to the Internet, it has become easier and more efficient to coordinate and train citizen scientists. At the same time, high profile successes (such as SETI@Home, The Christmas Bird Count and GalaxyZoo) have convinced more scientists that citizen science is a viable option to assist their

research. As opposed to being largely a public outreach gimmick, or a vital component of small, niche projects that rely on large numbers of data collectors, citizen scientists are now seen as capable volunteers who can contribute both materially and in terms of shared cognition.

The field of citizen science is heavily fragmented by discipline. Astronomers, ornithologists, oceanographers, meteorologists, etc. all run citizen science projects yet tend to report their results only to meetings and publications of their respective professions. There is no overall citizen science trade organization, regular conference or journal. The odd cross-disciplinary citizen science discussion has been attempted (Cornell, 2005), but they are usually invite-only and not consistent (the last was five years ago).

This is perhaps the main reason why there is little empirically based research on the effect citizen science projects have on their participants. The majority of publications that exist are self-reported studies that are mostly aimed to market individual projects to trade publications. Very few reach the level of, and are published in, peer reviewed research journals (Brossard, Lewenstein & Bonney, 2005; Trumbull, Bonney, Bascom & Cabral, 2000).

Another reason for this lack of research could be that the educational aspects of citizen science projects have historically taken back seat to the scientific goals. Most citizen science projects are run by scientists, not by educators. This is what partly gives citizen science its authentic charm, but the down side is very little interest in educational outcomes. Little is known about 1. How these projects are affecting their participants. 2. How the projects can be

better designed to increase science education outcomes and 3. Where the projects can best fit in the greater continuum of science education.

Fortunately, there is a movement afoot to professionalize citizen science. It is happening in many of the disciplines at once, but the main driver has been the National Science Foundation (NSF), which funds citizen science efforts through its Informal Science Education (ISE) program. Perhaps due to the potential for substantial funding through this program, citizen science projects have begun to enhance the educational components of their projects. At the same time, the informal science education (a.k.a. informal science learning, out-of-school learning, etc.) community has come to embrace citizen science as one of its own (National Research Council, 2009).

Various federal projects and initiatives came together in the late 2000's to make it an important era in citizen science. In 2007, the NSF-funded the creation of the Center for the Advancement of Informal Science Education (CAISE), an organization with a goal to coordinate informal science programs across disciplines and support their development and research. CAISE quickly established a citizen science inquiry group (Public Participation in Scientific Research [PPSR]), which was focused on ways to use citizen science to increase public scientific literacy and has made suggestions on how to measure that effect through rigorous research (Bonney, Ballard, Jordan, McCallie, Phillips, et al., 2009). Then, in 2009, the National Academies (with support from the NSF, the National Research Council and the Board of Science Education) published their report "Surrounded by Science: Learning Science in Informal Environments"

(National Research Council, 2009) which called for more citizen science programs and also has their own recommendations for assessing learning outcomes. With such high profile support, citizen science began to receive large-scale public recognition in mainstream science media circles, including a recent review article in Nature (Hand, 2010).

The CAISE report provides recommendations for research. The committee that prepared the report was chaired by Rick Bonney, a leader in citizen science through his 20+ years of work at the Cornell Ornithology Lab, one of the premier citizen science projects of the 20th century. The report suggests seven outcome measures for scientific literacy in citizen science projects (Table 1). This dissertation addresses all but two of those outcome measures. Web server statistics are used to describe how long people are involved in the project and how often they visit the project web site. An analysis of online discourse helps interpret what type of scientific learning is taking place in the project. Two pre- and post-tests on attitudes towards science and beliefs in the nature of science address issues of attitudes towards science and understanding the scientific process, respectfully. The two items the dissertation does not address is measuring change in participant scientific skill set and measurement of an increased interest in science as a career choice. Since the project is primarily a project for adults, this latter outcome does not apply.

Table 1
Scientific Literacy Research Outcomes from Bonney, et al. (2009)

Research Outcomes from Bonney, et al. (2009)	Measurement Tool

Duration of involvement by project participants	Web server statistics
Numbers of participant visits to project web sites	Web server statistics
Improved participant understanding of science content	Online discourse analysis (move down 3 rows)
Enhanced participant understanding of science process	Nature of science test (pre/post)/ Follow up interviews
Better participant attitudes toward science	Attitude (pre/post) test
Improved participant skills for conducting science	Online discourse analysis
Increased participant interest in science as a career	Not measured (adult science project)

This study contributes an important, early data point to this newly emerging field of citizen science education research. The field is starting to coalesce and mature and now has the mechanisms in place to support and disseminate empirically based research about itself. This study also describes a new approach to data collection (web-based pre- and post-tests, online discourse) and analysis techniques (Rasch analysis, interviews and discourse analysis in a mixed-methods design) that I have yet to find in another citizen science research project. Finally, the question it asks has yet to be formally asked in a comprehensive manner.

The dissertation opens with this introduction. The next chapter describes the context of the study in terms of the citizen science field, the Citizen Sky project and by describing my operational definition of scientific literacy. The third chapter will include the first research study - a largely quantitative analysis of pre- and post-test results with supporting interview data. The fourth chapter is mainly a qualitative analysis of online discourse in the Citizen Sky discussion forums.

The fifth chapter is a synthesis of the results from the two studies and a description of how they fit into the overall field. Finally, it concludes with a short summary of the dissertation and recommendations for further research.

CHAPTER TWO

RESEARCH CONTEXT: REVIEWS OF CITIZEN SCIENCE, SCIENTIFIC LITERACY AND THE CITIZEN SKY PROJECT

In this chapter I will describe the context of the study. It begins with a description of the overall field of citizen science, as told through the lens of three types of citizen science projects. Then it will discuss scientific literacy and how it is defined for this study. Finally, I will describe my project, Citizen Sky, in more detail. This includes the scientific aspects of the project, its background and how citizens participate.

Science Education through Citizen Science – Three Models

Citizen science projects, at their core, are about citizens assisting in scientific endeavors. This covers a broad continuum of projects from simple civic engagement in scientific projects in the background of their regular life (Ballard & Huntsinger, 2006) to citizens autonomously initiating and completing their own scientific research projects (Ferris, 2002). Different and overlapping labels have been used for various portions of the spectrum, with no universally accepted definitions or labels (Brandt, Shirk, Jordan, Ballard & Tomasek, 2010). The CAISE PPSR inquiry group studied many of the outstanding issues in the field

(Bonney, at al. 2009). One of their conclusions was the grouping of citizen science projects into three models based on the participation level of the volunteers. The models are idealized in that few citizen science projects neatly fit into a specific category, but they are useful as benchmarks illustrating the continuum of citizen science projects (Brandt, et al., 2010).

The Contributory Model

The first CAISE model is the *contributory model.* These are projects that use participants mainly as a distributed network of data collectors. These are the most common types of citizen science projects and also the stereotypical archetype of what "citizen science" means to a layperson. This dissertation introduces two further contributory sub-models, because the user experience is significantly different between passive and active citizen science projects.

- *Passive Contributory Sub-model:* After the initial recruitment phase, participant activity is passive as automated equipment collects the data and transmits it to a central repository. The Berkeley Open Infrastructure for Network Computing (BOINC) (Anderson, 2003) is the most successful of these projects. It applies unused computer processing power on participant computers to work on process-intensive tasks. Example tasks include SETI@Home (processing of radio astronomy data) and QuakeCatcher (monitoring earthquakes using laptop accelerometers). Over 300,000 volunteers at any given

time run a version of the BOINC software for one of its over 30 available tasks (Berkeley Open Infrastructure for Networked Computing, 2009).

- *Active Contributory Sub-model:* These projects actively engage participants in the process of data collection and/or data processing. They often require the participants to make decisions such as how often to collect data and how to make a decision regarding deviation from suggested protocol. The most popular projects in this category involve monitoring wildlife, including birds (Brossard, et al, 2005; Evans, Abrams, Reitsma, Rouxt, Salmonsen, et al., 2005; Wee & Subaraj, 2009), insects (Howard & Davis, 2004), turtles (Somers, Matthews & Carlone, 2009) and much more. In addition, similar projects exist to monitor weather (Cifelli, 2005) and various astronomical events (Percy, 1999).

The Collaborative Model

The second CAISE model is the *collaborative model*. In these projects, the public is involved in developing explanations and possibly analyzing data. The most popular example of this type of model is the Galaxy Zoo project. Galaxy Zoo is based on a web site where volunteers look at pictures of galaxies and categorize them into one of three categories. It's simplicity and ease-of-use have helped it achieve over 185,000 users who have submitted over 85,000,000 categorizations as of 2009 (Borne, et al., 2009). The volunteers have to analyze

(categorize) data (pictures) in a rudimentary manner, but in a way that actively engages them in a problem solving exercise with the results being analyzed by professional astronomers. In addition, volunteers are encouraged to come up with explanations for anomalous pictures. One volunteer's comments on a picture led to the famous discovery of a unique galaxy type (Lintott, Schawinski, Keel, van Arkel, Bennert, et al., 2009). This type of model can also be classified as a type of *crowdsourcing*, which is the process of using large number of volunteers to accomplish a task (Howe, 2006).

The Co-Created Model

The third CAISE model is the *co-created model* (sometimes referred to as "participatory action research" [Cornwall & Jewkes, 1995; Ballard, 2010]). In this model, volunteers do everything from defining research questions to publishing results. This is a relatively new category pioneered by the *Bossa* project (although in an indirect manner as they are focused on developing infrastructure for use by other projects) (Berkeley Open Infrastructure for Networked Computing, 2009). There are relatively few active projects in this field (Bonney, et al. 2009). *Citizen Sky* is conceptualized as one such project. There have been calls in the citizen science literature for more projects that involve citizens in more authentic research roles (Lakshminarayanan, 2007; Cooper, Dickinson, Phillips & Bonney, 2008).

These more demanding citizen science projects are often used as examples of *distributed thinking* (Hand, 2010). However, the volunteer is still usually

assigned a very narrow task to perform, such as the previously mentioned galaxy classification project, or projects to identify grains of sand encapsulated in gels flown in space craft (Stardust@Home) or to identify pieces of bone in pictures of surveyed ground (Hominids@Home). Citizen Sky differs because, in addition to this type of active data collection, participants are encouraged and trained to participate in other areas of the scientific method such as formulating their own unique research questions, testing hypothesis and reporting results.

Scientific Literacy

My research is conceptually oriented towards scientific literacy because of its importance in both education and civic responsibility. Both major collections of science educational standards in the United States establish scientific literacy as the fundamental goal of science education in this country (Eisenhart, Finkel & Marion, 1996). The first sentence of the National Research Council's National Science Education Standards (NSES) reads: "This nation has established as a goal that all participants should achieve scientific literacy," (National Research Council, 1996) (p. ix). Similarly, the first page of the influential American Association for the Advancement of Science's (AAAS) *Science for All Americans* report says that scientific literacy is needed to promote social justice, economic success and national security (American Association for the Advancement of Science, 1990) (p. xiii). Scientific literacy is also a fundamental goal in state level standards. The Massachusetts Science and Technology/Engineering Curriculum Framework says, "All participants need to

achieve a sufficient level of scientific literacy to enable them to succeed in post-secondary education, in careers, and as contributing members of a democratic society." (p. 19)

Despite being one of the most fundamental debates in science education (DeBoer, 2000), a common definition of scientific literacy has eluded interested parties (Roberts, 2007) since its introduction over a century ago (Huxley, 1880; Hurd, 1958). The amount of agreement regarding the importance of scientific literacy is rivaled only by the amount of disagreements over its definition. Hence, scientific literacy has evolved into a multifaceted term with definitions that reflect the interests of the parties writing the definitions (Laugksch, 2000). For example, scientists may see it related to inquiry and knowledge while policy experts may see it as the ability to make decisions in a scientific world. As a result, the science education literature points to a variety of meanings, most of which are necessarily broad, reflecting the fact that the definition changes over time (DeBoer, 2000). In a review of scientific literacy definitions used in 32 major publications, Norris & Phillips (2003) derived 11 separate conceptions of scientific literacy.

So, for this dissertation, I adopt a definition which is a hybrid of those described by those interested in scientific literacy from a civic perspective and those interested from an educational perspective. From the civic angle, let's begin with the three elements of scientific literacy as defined by Jon Miller (1983, 1998, 2004), a pioneer in the field of measuring public understanding of science:

1) Vocabulary of science: The vocabulary of basic scientific constructs needed to read and understand competing views from a popular science news source (ex: The New York Times Tuesday Science Section) (Miller, 1998).
2) Understanding of scientific inquiry: The process or nature of scientific inquiry (Miller, 1998).
3) Attitudes towards organized science and knowledge: The social impact of science on the individual and society (Miller, 1998).

A meta-analysis of the international scientific literacy studies shows that about 17% of the U.S. population is scientifically literate as described by this definition (Miller, 2004). Also, the analysis found that the use of informal science education resources was positively related to civic scientific literacy (0.30).

Now let's look at it from an educational perspective. This can be represented by the definition in the American Association for the Advancement of Science's *Project 2061 Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993), which is one of the most influential policy and curriculum documents in the United States. Its definition defines two broad elements of scientific literacy:

1) Knowledge: Knowledge and competencies associated with science.
2) Habits of mind: Decision making skills which people need in order to live a productive life in a culture of science. (Ch. 14; AAAS, 2010).

The main difference between the two definitions is that Miller breaks down knowledge into two categories: vocabulary and inquiry (AAAS' habits of mind is roughly equivalent to Miller's attitudes). In this study, I am assuming that participants already have a command of scientific vocabulary at the level of reading the science section of a newspaper critically. If they did not have this level of understanding then they likely would not understand what the project was about and would not go through the effort of joining it. Thus I am going to focus on the competencies element of scientific knowledge offered by the AAAS definition. I associate it with the presence of three elements of discourse: social knowledge, norms, and practices associated with science (Kelly, 2007). As a result, my working definition of scientific literacy consists of three broad elements:

1) Scientific habits and attitudes in everyday life (i.e. attitudes towards science)
2) Understanding of the nature of science (i.e. beliefs about the nature of science)
3) Competencies associated with science (i.e. social norms, practices)

This dissertation measures this definition of scientific literacy through two studies. The first study addresses elements one and two, scientific attitudes and

beliefs about science. The second study addresses the third element: scientific competencies in social settings.

Citizen Sky and ε Aurigae

Epsilon Aurigae is a bright star in the constellation of Aurigae, the Charioteer. Its brightness is nominally around magnitude 2.9 - easily viewable to the unaided ("naked") eye, even in urban skies. In 1824, German astronomer Johann Fritsch reported that he previously observed the star to drop below its normal brightness. Astronomers later recorded eclipses in 1848-49 and 1875-76, establishing a period of around 27 years between these eclipses. Nothing was formally published until 1903 when Ludendorff (1903, 1912; cited in Wood, 1985) wrote a series of papers summarizing everything known to date. In 1928, Harlow Shapley (then Director of Harvard College Observatory and a co-founder of the AAVSO) discovered a constant, but non-periodic variation of the star outside of the predicted periods of dimming.

The evolution of our knowledge of epsilon Aurigae mirrors the evolution of astronomical techniques through the twentieth century (Struve & Zebergs, 1962; Stencel, 1985). The spectrum was first analyzed in 1928 (Payne, 1928), providing the first hint that the system was somehow composed of multiple stars with unique characteristics. The first photometric campaign was organized in 1955, but most of that data went unpublished and has since been lost to the sands of time (Kloppenborg, 2009). The first version of the modern day accepted model of the system was proposed in the 1960's and 1970's (Huang 1965, 1974 and

Wilson, 1971). This model suggested that a disk of largely unknown properties, perhaps with one or more stars within the disk, orbits a F-class supergiant primary star (Figure 1). The eclipses are caused by the disk moving between the line of sight between the Earth and the primary star.

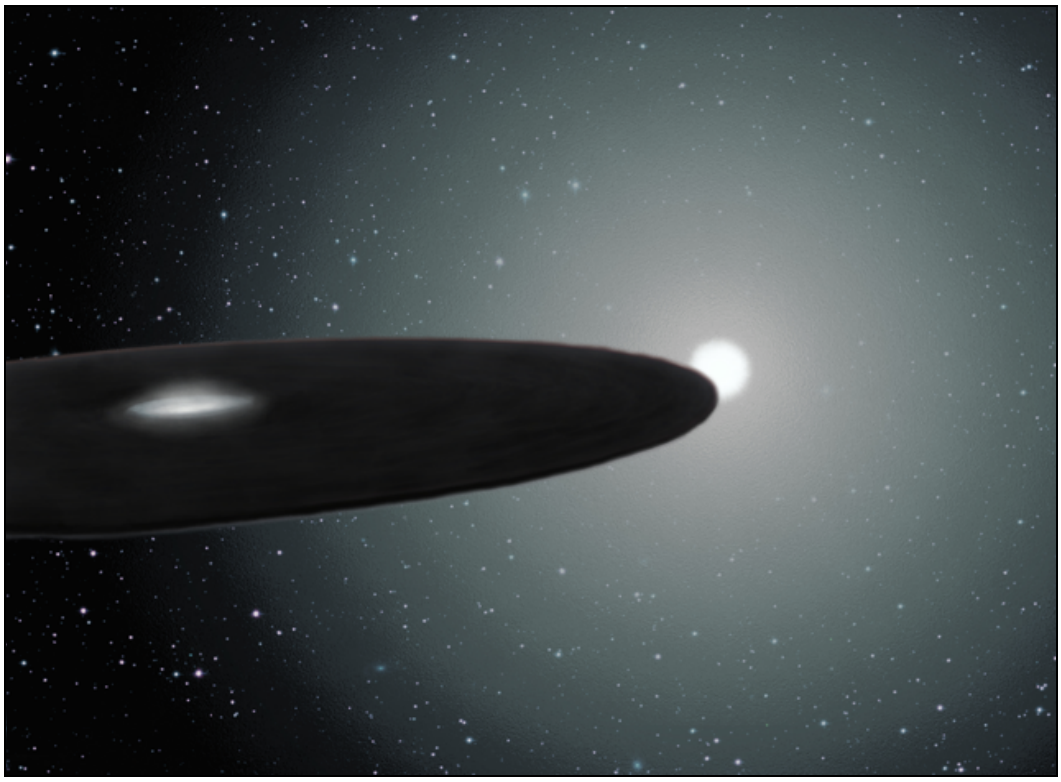


Figure 1. Artist interpretation of the most popular current model of the epsilon Aurigae system. (Art by Nico Comargo, courtesy of www.citizensky.org)

The 1982-1984 epsilon Aurigae eclipse was the first during the modern era of photometric detectors and computers. One of the new techniques employed during this eclipse was the organization of amateur astronomers to assist professional astronomers. Dr. Robert Stencel, Dr. Doug Hall and Russ Genet led

this new collaboration, which was organized through the International Amateur-Professional Photoelectric Photometry (IAPPP) organization (Hall and Genet, 1985). Twenty-nine photometrists had contributed data by the end of the campaign (Hopkins, 1985). A tremendous amount of data was acquired, but it did not make understanding of the system any easier (Stencel, 1985). Some theories (such as the existence of a black hole) were permanently discarded, still other theories would be discarded only to be resurrected decades later (existence of planets) and new theories were created (polar jets). But in the end, the original idea of a disk orbiting a supergiant star remained, albeit it slightly more constrained.

By the time of the 2009-2010 eclipse, amateur astronomy had undergone a technological revolution (Ferris, 2003). Amateurs had access to scientific grade equipment and software. And, thanks to the Internet, they could be easily coordinated and trained in the proper use of these new tools. The brightness of epsilon Aurigae continued to make it a challenging target for professionals. If anything, the increasing sensitivity of professional equipment may have actually diminished the resources available for professional monitoring of epsilon Aurigae in the optical wavelengths. This made the participation of amateurs even more important than before. In addition to using better equipment, amateurs have been doing their own research and analysis, including writing their own scientific papers and publishing them alongside professionals in peer-reviewed journals such as the Astronomical Journal, the Publications of the Astronomical Society of

the Pacific, the International Bulletin of Variable Stars, the Journal of the AAVSO and more.

The year 2009 was designated the *International Year of Astronomy (IYA)* by the International Astronomical Union (IAU), the United Nations (Cesarsky, 2007) and the United States Congress (To Honor the IYA, 2008). I was a member of the United States International Year of Astronomy program committee, and chair of the working group on Research Experiences for Participants, Teachers and Citizen Scientists. Dr. Rick Feinberg, then Editor In Chief of Sky & Telescope magazine, first brought the upcoming eclipse to the my attention. Intrigued, the working group adopted the eclipse as their central project and developed a proposal to the National Science Foundation's Informal Science Education (ISE) program. In mid-2009, the program was funded at a rate of $796,000 over three years. (The studies reported in this dissertation were included as part of the project evaluation plan.)

The main goal of the citizen science project is education of volunteer participants first. The scientific goal is secondary, which distinguishes it from most citizen science projects which are driven by the scientific goals. As a result, the project team had leeway to design a comprehensive project that enlists participation at many different levels (Table I). The project seeks to include participants in many stages of the scientific method including developing their own hypotheses, collecting data, analyzing data and publishing results. All of this will be organized in a collaborative nature, more closely mirroring real scientific enterprise (Cummings and Kiesler, 2005) than traditional, stand-alone, data-

driven citizen science projects. Also, two training workshops have been held for participants. The first workshop focused on data collection and was hosted at the Adler Planetarium and Astronomy Museum in Chicago, IL in August, 2009. The second focused on data analysis and was hosted at the California Academy of Sciences in San Francisco in September, 2010.

Table II.
Example Citizen Sky Activities and Their Relationship to Authentic Science

Elements of authentic science proposed by Rahm, Miller, Hartley & Moore (2003).	*Examples of Citizen Sky Activities*
Working hand in hand with scientists to collect data.	• Astronomers are writing blogs coordinating participant observations with their own • One astronomers is assigned as a liaisons to the participant teams, making the available for advice and direction • Astronomers participate in the online discussion groups, providing advice and feedback
Analyzing and presenting data.	• Participants will be trained in data analysis methods needed to test their own theories • Participants will receive training on writing both popular press and scientific journal articles
Co-constructing and challenging the authority of scientists.	• Participants are encouraged to offer their own ideas and suggestions as to what may be causing this mysterious eclipse. Professional astronomers respond constructively to the suggestions.

Becoming an active and consistent member of a research community.	• The project is designed to last for many years, so many of the technical features of the web site are designed with a large time frame in mind. For example:
	  o Discussion group posts do not expire
	  o A monthly e-mail reminder is sent to participants updating them on various project activities
	• participant teams are designed to build personal relationships. After they complete a goal, the teams are designed to remain together as they

turn to a new project.

The process of data collection in variable star astronomy is relatively straightforward. It involves looking at the variable star and comparing its brightness with other nearby, constant stars whose brightness has previously been measured. Through a process of interpolation, an observer can bracket the variable star with two other stars (referred to as “comparison” or “comp” stars) of brighter and fainter brightness, and use them to make an estimate of the variable star (Figure 2). This is the same basic process that has been used since the first recorded variable star observation by Frederick Argelander in 1649.

The star is too bright for telescopes, even small ones. However, modern digital single-lens reflex (DSLR) cameras have sensitive CCD chips that can make surprisingly accurate tools for measuring the brightness of stars. DSLR cameras are popular among both professional and casual photographers and can be purchased for a few hundred dollars at standard consumer electronics retail stores. To take advantage of this, Citizen Sky established a DSLR training initiative to teach DSLR owners how to use their cameras to observe epsilon Aurigae, using a process known as *photometry*. This initiative is one of the most popular among Citizen Sky participants.

In addition to data collection, teams of participants have been organized to work on data analysis projects. One team even developed an advanced statistical package in Java than can be used for basic time series analysis of periodic data.

This package, named *VStar*, is being used by still other teams to analyze data on epsilon Aurigae and other variable stars. The data they analyze comes from other members of the project and the historical AAVSO database of variable star estimates. Thus, a collaborative loop is closed - some participants collect data, which is analyzed by others using tools developed by yet other participants. It is hoped that many of these projects will result in publications submitted to peer-reviewed journals during the third year of the project. So far, poster papers have been presented at meetings of the American Astronomical Society (AAS), popular articles have appeared in mainstream scientific press such as Sky & Telescope magazine, Astronomy magazine and the web sites of Wired, National Geographic and Discover magazines. One of the first publications was a Central Bureau of Astronomical Telegrams report issued early in the project (CBET #1885).

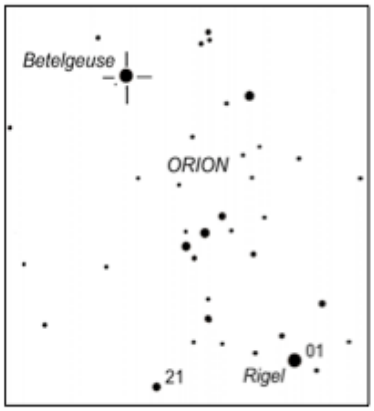
Citizen Sky's scientific advisor is Dr. Robert Stencel, one of the leaders of the 1982-84 campaign and the William Herschel Womble Professor of Astronomy at Denver University. One of the project staff members is Brian Kloppenborg, one of Dr. Stencel's graduate participants. In 2008 and 2009, they led a collaboration of researchers using the CHARA observatory to obtain near-infrared interferometric measurements of the star. The early results of the campaign include a spectacular direct detection of a disk of material passing in front of epsilon Aurigae (Figure 3). These results were announced in a paper accepted by the journal *Nature* (Kloppenborg, Stencel, Monnier, Schaefer, Zhao, et al., 2009) and resulted in considerable press coverage of the epsilon Aurigae eclipse in April, 2009 - including a substantial increase in interest in the Citizen Sky project.

The overall goal of the project is to increase public understanding of the scientific method by involving the public in active research involving an accessible, yet enigmatic astronomical phenomenon and then to apply this understanding to other scientific projects. It is funded from September 1, 2009 – September 2, 2012 by the National Science Foundation's Informal Science Education program. The original proposal was primarily designed and authored by myself. Included in the project design was a study about its impact on scientific literacy. This dissertation evolved out of that original design. I intend to present it as one of the first education research outcomes of the project. It will be the first of many studies.

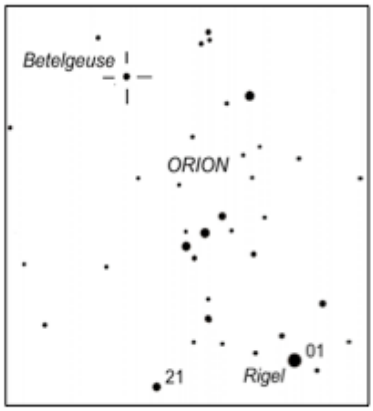
Measuring a Star's Brightness

a.k.a. making an "observation"

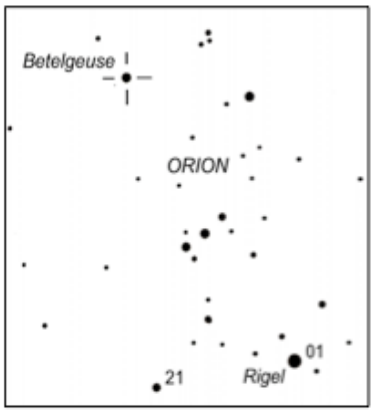
To measure a star's brightness, you simply compare it to other stars in the sky. Those other stars are called "comparison stars" because you use them to make the comparison. Astronomers have carefully measured the brightness of the stars and assigned them a number according to the brightness. **The smaller the number, the brighter the star.**



In this example, Betelgeuse will be close to the same brightness as Rigel, which has a 01 brightness. So one may estimate Betelgeuse at brightness 01.



In this example, Betelgeuse will be close to the same brightness as the star labeled 21. So one may estimate it at brightness 21.



In this example, Betelgeuse is somewhere in the middle between the 01 and the 21 comparison stars. So one may estimate it somewhere in between the two numbers, say, brightness 11.

Figure 2. A page from the "10 Star Training Tutorial", a Citizen Sky document used to teach brand new participants how to observe variable stars. This page describes the process of making a variable star estimate.

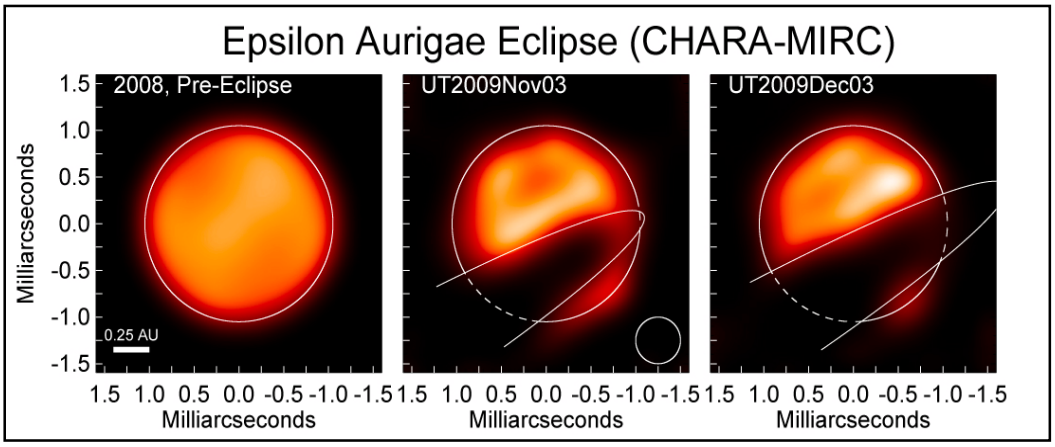


Figure 3. Images of the Epsilon Aurigae by John Monnier, University of Michigan. The first was taken pre-eclipse in 2008, the second two were taken in November and December 2009, respectively. All images were acquired using CHARA-MIRC, the Michigan Infrared Combiner (Kloppenborg, et al., 2009).

CHAPTER THREE

STUDY ONE: ATTITUDES TOWARDS SCIENCE AND BELIEFS IN THE NATURE OF SCIENCE

Introduction

This study is an attempt at measuring the impact the Citizen Sky citizen science project has on its participants' attitudes towards science and beliefs in the

nature of science. By “belief”, I mean the strength in which participants associate various concepts with the scientific method. The research question is: How do attitudes towards science and beliefs in the nature of science change through participation in a large-scale, online citizen science project?

I developed my own instrument to assess scientific attitudes and modified an established instrument to assess beliefs about science. Participants took both instruments twice, once when they join the project and again six months later. Data on additional demographic variables are also collected and post-test interviews are conducted to look for deeper understanding to the test responses.

One of the more unique aspects of this dissertation study is in the way that polytomous responses on a Likert scale are analyzed. Typically, Likert-scale data is treated as interval data and analyzed with parametric techniques. Limitations of this type of Likert analysis have been recognized for a long time (Knapp, 1990; Jamieson, 2004; Carifio & Perla, 2008), yet its ease of use makes it the “go to” method for those needing quick results. Through the application of Rasch analysis, I transform the Likert responses onto an interval scale that is more appropriate for traditional social science analysis methods (Bond & Fox, 2007).

This chapter begins with a brief literature review describing recent education research studies involving citizen science projects based on empirical evidence, building upon the literature review in the previous chapter. Then it describes our instruments and subjects. The analysis section describes the Rasch analysis applied to this research and how it feeds into traditional parametric statistical techniques to show changes in science attitudes and beliefs about

science between the pre- and post-tests. Next, I include interview selections that describe trends and deeper meaning behind some of the test responses.

Literature Review

This section is a review of the education research literature on empirical studies of the impact of various citizen science projects on the scientific literacy, or aspects related to scientific literacy, of their participants. Most citizen science projects are driven by the scientific goals of the project. As a result, there are a limited number of science education research studies for these projects.

Findings from Contributory Model Projects

An investigation of the literature found no education research studies about projects belonging to the contributory model of citizen science. I used Google Scholar to look for a variety of terms, beginning with specific terms and moving to more vague terms. Examples are "scientific literacy citizen science", "scientific literacy informal science education", "citizen science education research", "citizen science studies" and, finally, simply "citizen science" by itself. I also performed an investigation of the past five years of NSF Informal Science Education grants awarded to citizen science projects. I found no awards to contributory projects. In the literature, I did find many articles that describe citizen science projects. But most of them are in scientific journals or trade publications – not educational publications. And when I add "research" to the search phrase I found many articles that describe scientific results of citizen

science projects. However, I found very few that discuss science education results from an empirical study. The few I did find belong to other citizen science models (see below). Presumably this is because education is not a priority of these types of projects, which simply desire large human resources to accomplish scientific goal(s) that have been stymied by lack of scientific resources.

Findings from Collaborative Model Projects

Most of the empirical research literature that does exist addresses citizen science projects that belong to the collaborative model. In a study of The Birdhouse Network (TBN), researchers used a pre- and post-test survey postal mailed to participants at the beginning of their participation in the project and then again at the end of a single field season (Brossard, et al. 2005). The instruments were used to measure change in scientific attitudes, understanding of the scientific process and knowledge of birds. They used a mix of Likert and open-ended items, with a control group, but could not perform a paired-data analysis due to anonymity concerns of the participants. They found no change in attitudes or understanding of the scientific process. However, they did detect an increase in scientific knowledge of birds. Interestingly, they also looked at which participants actually contributed data to the project to see if data collection experience was related to any change. However, they found no such relationship. The authors of that study suggest that, because they mostly adopted previously used assessments designed for other projects, their instruments may not have been

sensitive enough to measure outcomes. Also, they conclude attitude is a complex continuum that needs more and different items than they prepared.

Researchers in the NestWatch project conducted a study to look for change in scientific literacy related to avian biology (Evans, Abrams, Reitsma, Rouxt, Salmonsen & Marra, 2005). They gave participants demographic surveys and then conducted interviews across various demographic categories. Then, they analyzed e-mail communication between participants and project staff. They found no evidence of gains in understanding elements of bird ecology in the e-mail communication. However, their interview data did show such evidence, suggesting that mixed methods studies may be needed to measure educational outcomes in citizen science projects.

In a study of another ornithology project involving bird seed preferences, researchers analyzed communication between participants and project organizers (Trumbull, et al., 2000). They investigated routine letters mailed to the project headquarters by 700 participants to look for evidence of scientific thinking. They performed content analysis on the letters by creating a coding framework based on the Biological Sciences Curriculum Study and the National Science Education Standards. They found evidence of scientific thinking in 80% of the correspondence, but could not attribute it to their project experience alone. They also looked for differences between those who had contributed data and those who had joined the project, but for whatever reason chose not to submit data. They found no difference in science thinking between the two groups.

Findings from Co-Created Model Projects

There are claims that the projects in the co-created model have been well studied (Fernandez-Gimenez, Ballard & Sturtevant, 2008). But I found a only a few studies about their scientific output. For example, one group of volunteers was trained to measure water quality in a river shed and made many discoveries over three years of monitoring (Wilderman, 2004). And in the Galaxy Zoo project one person discovered their own galaxy type (Lintott, et al. 2009). Cornwall and Jewkes (1995) discuss the important social relationships that form between volunteers and professional scientists when they work so closely together on these types of projects. They suggest that mutual respect is the key, as opposed to researchers treating volunteers as free labor and discounting their ideas and suggestions. But I could find no empirical studies about the impacts of these co-created projects on scientific literacy and no study at all of a co-created project in a refereed science education journal.

Method

Subjects

Participants were recruited through the Citizen Sky web site and e-mail. Registration for the project on the web site is required for active participation. During the registration process, participants are invited to take a pre-test and be entered into an annual drawing for a $50 Amazon.com gift card. Later, during the first time the participant logs into the web site after six months has passed since their first login, they are invited to take a post-test. In order to reduce the

selection effect caused by having post-test only from active participants, I also sent private e-mail invitations to participants who had registered for the web site six months prior but had not logged in during the previous three months.

As of August 1, 2010 the Citizen Sky web site had 3,302 registered users (participants). Of them, 1,385 had taken the pre-test. They self identify as 78% male, 19% female and 3% unreported. The mean age is 41 (SD = 16) years. That the gender ratio and age skew towards an older, male audience is typical for the amateur astronomy community. However, Citizen Sky participants are still somewhat younger and more gender equitable. Sky & Telescope magazine, the premier magazine in the market, reports 95% of their subscriber readership is male with a mean age of 51 (New Track Media, 2010). About a quarter of participants report no prior experience in amateur astronomy. About 61% of the participants have a bachelors or higher degree, which is below that of subscribers reported by Sky Telescope Magazine (77%). Participants represent 18 countries. The five countries with the most participants are the United States (58%), Canada (14%), France (4%), Denmark (2%) and Australia (2%). Five percent of the instrument responses do not report a country. The observational aspect of the project can only be performed by participants in the northern hemisphere, so there is a northern hemisphere bias in the registrations.

The post-test has been offered to 192 participants who took the pre-test at least six months prior and returned to the project web site. Of them, 125 opted to complete it. The demographics of this group differ somewhat from those who took the pre-test. Their mean age, experience and education are all slightly more

advanced than the subject population as a whole (Table IV). The pre-test mean age is 41 years (SD = 16, N = 1273) and the post-test mean age is 47 years (SD=16, N=109). The experience level of the post-test group is more advanced than the pre-test group (Figure 4), this is largely seen through an increase in the intermediate level of experience at the expense of those reporting no experience or a novice level of experience. Also, the education level of the post-test group has slightly more advanced degrees than the pre-test group (Figure 5).

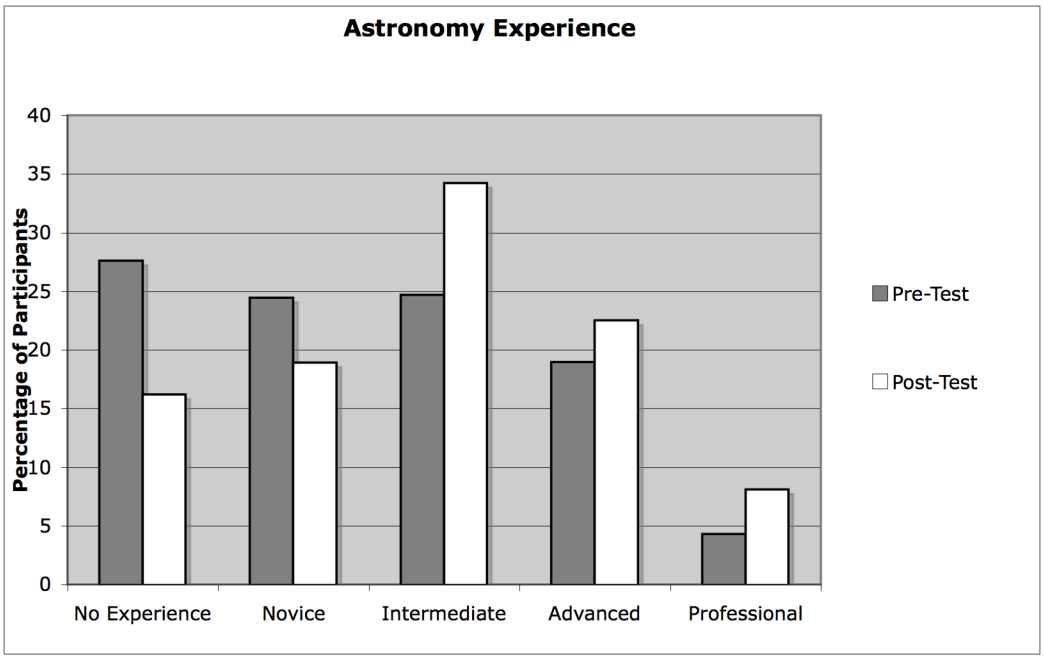


Figure 4. Astronomy experience level of pre-test and post-test participants.

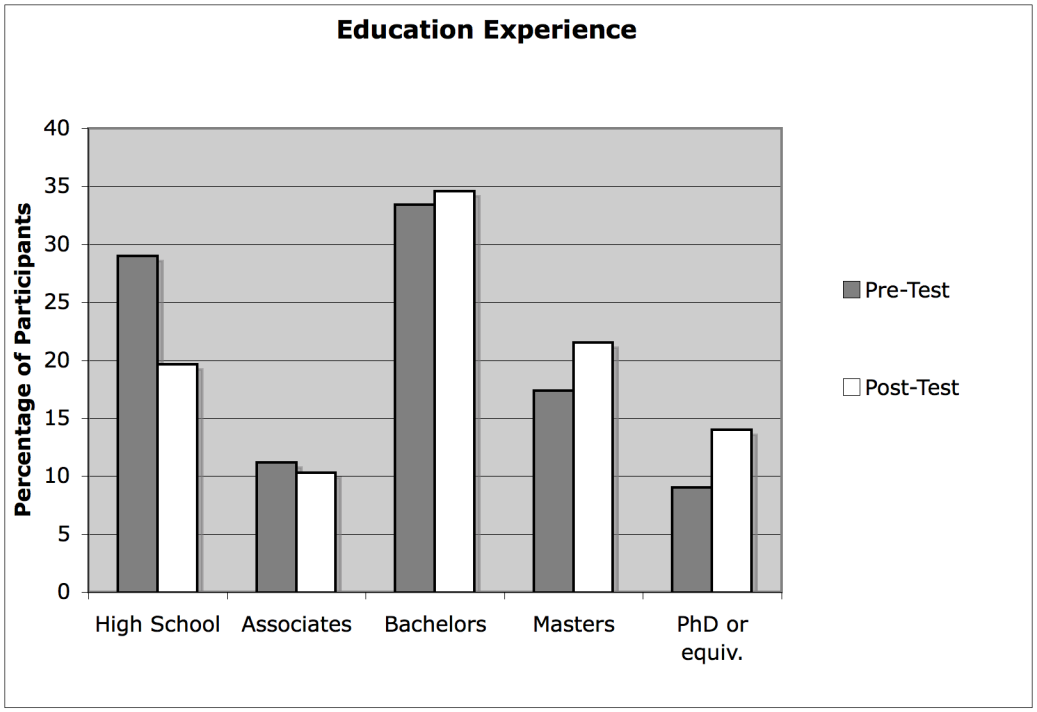


Figure 5. Education level of pre-test and post-test participants.

Additional variables were created based on responses to demographic questions on the pre-test and also on their activity in the project. *Age* was computed as the difference between the participant's supplied birth date and 2009 (the start of the project). A dichotomous version of the variable was created based on the split-mean measure of the computed age. Everyone below the mean (41 years of age) was assigned a "0" and everyone along and above the mean was assigned a "1". *Gender* was assigned as a 1 if the participant identified as a male and a 0 if the participant identified as a female. *Astronomy Experience* was assigned a "1" if the participant chose "none", "2" if the participant chose "novice", "3" if the participant chose "intermediate", "4" if the participant chose "advanced" and "5" if the participant chose "professional". *Chat Join* was

assigned a “0” if they never visited a live, online chat session, “1” if they have visited at least one live, online chat.

A number of variables associated with activity in the project were created as well. *Team participant* was assigned a “0” if the participant was not formally a part of an official Citizen Sky team (see Chapter Two) and was assigned a “1” if they were part of a team. *Post Count Di* was assigned a “0” if the participant had never posted to a Citizen Sky online asynchronous discussion forum and a “1” if they had posted to a forum. *Active Observer* was assigned a “0” if the participant had never submitted a variable star brightness estimate and a “1” if they had submitted an estimate.

Instruments

Pre- and post-tests were given to the participants about six months apart, followed by a selection of interviews. The test (Appendix A) consists of a series of demographic questions followed by two instruments. The first instrument is designed to measure attitudes towards science (hereafter referred to as the “scientific attitude test”). The next instrument is designed to measure beliefs in the nature of science. It is based on the Nature of Scientific Knowledge Scale (NSKS) by Rubba and Anderson (1978) (hereafter referred to as the “NSKS test”). An additional section consisted of four open-ended questions about variable stars - but is not being used in this study.

The scientific attitude test items were designed to assess participant intentions towards everyday scientific activities. They regard participant attitudes

and activity regarding their pursuit of scientific information (through reading news, attending talks, etc.) and some efficacy questions ("I am knowledgeable about science"). Finally, questions were also asked about how the participant applies science to daily life. There are a total of nine items answered with a 5-point Likert scale consisting of Strongly Disagree, Disagree, Neutral, Agree and Strongly Agree.

The original NSKS test is an established test largely accepted as valid by the scientific community (Bloom, 2008). It includes 48 items grouped into six categories: amoral, creative, developmental, parsimonious, testable and unified. Each group of items reflected a particular trait of the nature of science as defined by Rubba and Anderson (construct validity was examined through judgment and recommendations from a panel of experts and pilot testing with 165 undergraduate students grouped according to whether they were a in a science or non-science major). Each nature of science category was addressed by four positive items (ex: Certain pieces of scientific knowledge are good and others are bad.) and four negative items (ex: A piece of scientific knowledge should not be judged good or bad.). To constrain the length of the overall test, I omitted all negative items giving us four items per group for a total of 24 items (Appendix A). The NSKS uses a Likert scale with five options: Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree.

As shown in Table 3, the overall reliability for the NSKS test for this study was high, $\alpha = .94$, and is in general agreement with previous work (Rubba, 1997, Meichtry, 1993; Rubba and Anderson, 1978). One of the criticisms of the NSKS

is that its nature of having two versions of each question (a positive and a negative one) could artificially inflate its reliability (Lederman, Wade & Bell, 1998). However, since we omitted the negative items, the criticism does not apply to these results. Rubba and Anderson (1978) also broke down their reliabilities by the six item categories they deemed important to understanding the nature of science. We did the same in our analysis. Our item group reliabilities ranged from .68 to .87 and are similar to theirs, except slightly higher (likely due to our larger sample size).

Table III.
Coefficient Alpha Reliabilities and Means for the NSKS

	Cronbach Alpha		
Item group	10th grade participants*	Citizen Sky Participants	N
Amoral	0.76	0.82	1072
Creative	0.80	0.87	1072
Developmental	0.74	0.80	1072
Parsimonious	0.70	0.68	1072
Testable	0.77	0.89	1072
Unified	0.74	0.82	1072
Overall NSKS	0.84	0.94	1072

* Rubba and Anderson, 1978

Post-Test Interviews

Fourteen participants who took both the pre- and post-tests were randomly invited to participant in an interview session and nine accepted (Table IV). They range in age from 18-64. Their education experience ranges from graduates from high school to PhDs. Their astronomy experience ranges from novice to professional, however it is heavily clustered in the intermediate category.

Table IV.
Demographics and Test Scores of Interview Subjects

Gender	Age	Education	Astro. Experience	Attitude Test* (logits)		NSKS Test† (logits)	
				Pre	Post	Pre	Post
male	18	N/A	Novice	2.3	2.72	2.06	2.21
male	36	Bachelors	Intermediate	4.01	5.01	.18	1.37
male	44	Bachelors	Intermediate	4.01	6.33	2.29	2.21
male	46	Masters	Intermediate	4.85	5.01	.76	1.15
male	49	High School	Intermediate	4.85	4.04	1.86	2.75
male	51	PhD	Professional	6.15	3.38	-.15	.34
male	57	PhD	Intermediate	1.98	2.03	1.28	.72
female	64	Masters	Intermediate	6.15	5.01	1.07	2.60

*For all subjects, the attitude pre-test mean is 2.44 and post-test mean is 3.55.
†For all subjects, the NSKS pre-test mean is .96 and post-test mean is 1.30.

The interviews were conducted via the telephone or Internet communication software such as Skype, Google Voice and Yahoo Messenger. They were compensated with a $50 Amazon.com gift card each. The interview durations ranged from 25 minutes to 1 hour and 15 minutes with an average duration of forty minutes. The interview protocol (Table IV) included questions about their background in other astronomy citizen science projects, level of participation in the project, views on the various subcategories of the NSKS and questions tailored to their responses to the pre- and post-instrument.

Table V.
Interview Questions

Question	Follow Up Prompt(s)

Have you participated in any other astronomical project similar to Citizen Sky?	Please compare/contrast your experiences in Citizen Sky with what you have done in the past.
I would now like to as you about six questions regarding the nature of science. The first is about the amoral nature of science. That is…[read the amoral description from Rubba & Anderson, 1978]. Do you see this amoral aspect of the nature of science on display in the Citizen Sky project?	For these questions, the participants' responses to the pre- and post-test NSKS items were analyzed. The item that showed the greatest change (in either direction) of their response and the item that showed the greatest difference between their response and the mean response from other participants, were identified. Those two items were read back to the Participant, who was then asked to describe how they feel about them. These questions were asked after the corresponding question was asked. For example, if the item was "Scientific knowledge expresses the creativity of scientists" then that would be asked after the creative itm group question.
The next aspect I would like to ask you about is the creative nature of science. That is…[read the creative description from Rubba & Anderson, 1978]. Do you see this creative aspect of the nature of science on display in the Citizen Sky project?	
The next aspect I would like to ask you about is the developmental nature of science. That is…[read the developmental description from Rubba & Anderson, 1978]. Do you see this developmental aspect of the nature of science on display in the Citizen Sky project?	
The next aspect I would like to ask you about is the parsimonious nature of science. That is…[read the parsimonious description from Rubba & Anderson, 1978]. Do you see this parsimonious aspect of the nature of science on display in the Citizen Sky project?	
The next aspect I would like to ask you about is the testable nature of science. That is…[read the testable description from Rubba & Anderson, 1978]. Do you see this testable aspect of the nature of science on display in the Citizen Sky project?	
The next aspect I would like to ask you about is the unified nature of science. That is…[read the unified description from Rubba & Anderson, 1978]. Do you see this unified aspect of the nature of science on display in the Citizen Sky project?	
That is the end of the nature of science questions. I'd now like to ask you about attitudes about astronomy and science in daily life. [An item was chosen from the attitude questionnaire based on how different their response was to the overall	If the response was superficial, the interviewer responded with information on the person's test scores to

responses. It was read to them.] Have your feelings towards this changed during your participation in the Citizen Sky project?	prompt explanation. For example: "You showed the biggest change between the pre and post tests on this statement. Can you explain why?"
[A second item was chosen from the attitude questionnaire based on how different their response was to the overall responses. It was read to them.] Have your feelings towards this changed during your participation in the Citizen Sky project?	
What do you feel your role is in the Citizen Sky project?	No planned prompts.
Do you have any general comments or questions you'd like to ask about the Citizen Sky project?	No planned prompts.

Responses to the questions in the post-test interviews were transcribed into a spreadsheet so trends could be easily spotted among responses to the same question(s) (Appendix B). The trends were analyzed to look for deeper meaning behind some of the quantitative results. Some of the interview questions were common among all interviews. For these, I read all the responses one question at a time. For example, I read all responses to the question about the creative aspect of the nature of science before moving on to responses to other questions. This made it easier to identify common elements among the answers, which tended to be about a paragraph in length when transcribed. Recall that two questions asked were tailored for each subject based on their responses to the attitude tests. For these, I read the responses person-by-person so I could look for links between their responses to any of the other questions. Then, afterward, I read them again on a question-by-question basis to look for trends among interview subjects. Finally, I occasionally referred back to the interview questions after performing

further analysis on the test data, to see if there are any explanations to results I found in the test data.

Data Analysis

Scientific Attitudes and Beliefs in Science

For each item on the two Likert instruments, we created raw scores by assigning a "1" for those who selected "Strongly Disagree", "2" for "Disagree", "3" for "Neutral", "4" for "Agree" and "5" for "Strongly Agree". Unanswered questions were treated as missing data, which was ~5% of the responses to the pre-test and about ~8% of the responses to the post-test.

Likert scores, by their nature, are polytomous data (more than one category) originally in an ordinal, non-interval scale. This non-interval nature presents many complications (Knapp, 1990; Jamieson, 2004; Carifio & Perla, 2008). First, the data may not be normally distributed. Second, the data are ordinal in nature, while parametric tests assume equal intervals between scores. For example, "strongly agree" is often assigned to a numerical value of 5, but may not necessarily hold five times as much value as "strongly disagree", which is often assigned to a numerical value of 1. Third, there is a subjective nature to the definitions of the scores. That is, what "strongly agree" means to one respondent may mean something else to another respondent. Indeed, it could even mean something different between items on the same instrument. Consider an example of two items from the same creative group of items in the NSKS: For some people, to "strongly agree" that *science requires creativity* is different than to

"strongly agree" that *science is creative, like art*. Yet, if computed using traditional methods both would be assigned a raw score of "5", implying equivalence. Previous citizen science studies did not consider the problems associated with treating an ordinal scale as if it were interval, which may relate to the lack of sensitivity of the instruments used in other studies for measuring change.

To address these complications, the responses to the Likert scale were converted into an interval scale through the application of a Rasch analysis based on the Rating Scale Model (RSM) (Andrich, 1978; Wright & Masters, 1982; Muraki, 1990), which has been well explored by science education researchers (Boone & Scantlebury, 2005). The RSM establishes relative difficulty of each of the items and the tendencies of the participants to endorse the item. In addition, it creates a rating scale structure across all items as well as individual items by defining item thresholds between each of the Likert response choices within each item, relative to the overall rating scale.

The Rasch model (Rasch, 1960/1980) used in this study can be described by this equation (Wright, 1993):

$$\log(\text{Probability of Success}/\text{Probability of Failure}) = \text{Ability} - \text{Difficulty}$$

The RSM is a version of the Rasch model developed for use with polytomous data (multiple groups). It can be described through the following expression (Andrich, 1978; Linacre, 2002):

$$\log(P_{\text{nik}} / P_{ni(k-1)}) \bullet B_n - D_i - F_k$$

where P_{nik} is the probability that participant *n*, on encountering item *i* would be observed (or would respond) in category *k*. $P_{ni(k-1)}$ is the probability than the response would be in category *k*-1. B_n is the tendency to endorse of participant *n*. D_i is the difficulty of item *i*. And F_k is the difficulty of being observed in category *k* of the rating scale, relative to category *k*-1. Participant ability estimates ("ability") and item difficulty estimates are placed on the same scale with normalized values typically ranging from -4.0 to 4.0 logits (log-odds unit). The application of this model to Likert scale responses generates two sets of estimates: *item difficulty* and *person ability (*in this study, that refers to how likely someone is to agree with an item). Each set contains a measure, a standard error and a fit statistic. When an item's difficulty level and a respondent's ability are equal, then the respondent has a 50% chance of receiving the score assigned to that item. Higher estimate values reflect increased item difficulty or increased person ability. In this study, Rasch analysis was conducted using the *Winsteps* software program (Linacre, 2010).

Two overall scales were created on the attitude and the NSKS tests by applying the RSM to all of the pre-test responses. To compare pre- and post-test changes, I applied a technique known as "racking and stacking" (Wright, 1996). In this procedure, the items and participants common to both the pre- and post-tests of each were used to anchor the scales that were separately created using the

pre- and post-test data. To analyze change in person ability among those who completed both pre- and post-tests, the person ability estimates obtained from the post-test were calibrated on the overall scales developed with all pre-test respondents by anchoring the items in the both tests. Similarly, to analyze change in item difficulty, the 125 person ability estimates of participants who took both the pre- and post-tests were used as anchors to equate the pre- and post-tests. In Winsteps, RSM anchoring involves two sets of anchors: the person/item set of anchors and a set of scale anchors – all generated by the pre-test data.

One way to visualize the new scales is through the use of Wright maps (a.k.a. variable maps – see Figures 6-7). The horizontal axis in the center is the logit scale. The top of the scale indicates *increasing* person ability. The bottom of the scale indicates *decreasing* person ability. On the left side of the axis is a vertical histogram of the participant population. The vertical location of the participants reflects their ability. On the right side of the scale are the items in the tests. The vertical location of the items reflects their difficulty to be positively endorsed. When a participant and an item are at the same vertical level, then that participant would have a 50% chance of endorsing the item, as predicted by the Rasch model. If a participant is above an item, then the participant has a >50% of endorsing it and vice versa for participants who are below an item.

An important test of the Rasch model is to look at the chi-square statistics regarding the location of actual data compared with its location predicted by the model. These *fit statistics* are used to evaluate how well the data fits the Rasch model. There are two types of fit statistics. The *outfit* statistic is the mean square

of the standard deviation of all the measures of the item or person. The *infit* statistic is similar, but it involves the standard deviation from their position predicted by the Rasch model. This infit statistic is therefore weighted to the center of the scale. This is the main difference between the two statistics when it comes to their common usage: infit is weighted and outfit is not. Both are divided by their degrees of freedom. This creates a ratio scale centered on an expected value of 1. For this analysis, the outfit statistic is used since the data is clustered together and not subject to strong outlier influence. A proposed range for acceptable polytomous data fit statistics is 0.6 – 1.4 (Wright & Linacre, 1994). Items/people that fall outside acceptable range are referred to as *misfits.* Overfitting describes misfits that fit the model very well (fit statistics <0.6) and underfitting describes misfits that fit the model poorly (fit statistics >1.4). Bond & Fox (2007) go on to warn that:

> …fit statistics should be used to assist in the detection of problem item and person performances, not just to decide which items should be omitted from a test. Indeed, omitting the overfitting items… could rob a test of its best items. (p. 241)

In fact, investigation of underfitting persons found that most of the time this was due to participant mischievousness, such as selecting "neutral" for all answers – suggesting they were simply clicking on answers to get to the end of the test. Anecdotal checking of the web server log files found that most of these participants did indeed complete the test much quicker than usual. Overall, the fit statistics were used to identify possible problem entries for further investigation.

When the investigation was complete, I adopted the policy of omitting all participants with outfit statistics >=1.4 from the Rasch analysis (10 participants on the attitude test and seven participants on the NSKS test), but to retain all overfit participants (outfit <0.6).

For the item fit statistics, two were omitted from the NSKS test for having excessive outfit statistics >1.4 (The items were: "The various sciences contribute to a single organized body of knowledge" and "The applications of scientific knowledge can be judged good or bad; but the knowledge itself cannot."). No items were omitted from the attitude test.

Because all of the attitude items fit the Rasch analysis, I can say that they form a single dimension (if they did not, the Rasch analysis would have failed to successfully fit the majority of the items). With this in mind, I created an overall attitude score by averaging all nine item difficulties.

The same goes for the NSKS items. An overall NSKS total score was created by averaged the item difficulties on all remaining 22 NSKS items. The items were also divided into the six item categories defined by Rubba & Anderson (1978) – with 3-4 items in each group. A mean score of all item difficulties in each category was computed, with an assigned error computed as the quadrature of the Rasch standard error for each of the items in that group.

Thus, the results of the Rasch analysis consists of four data sets: the attitude pre-test, the attitude post-test, the NSKS pre-test and the NSKS post-test. As a result of the process described here, all scores have been converted from raw scores into estimates on the logit scale,. Thanks to the anchoring process,

scientific attitude pre- and post-tests are now in the same frame of reference despite the fact that different numbers of participants took the tests. And the NSKS pre- and post-tests are also in the same frame of reference. As a result, I can now analyze the data using more traditional parametric statistical techniques.

Results

Pre-Test Descriptive Statistics

The responses to the attitude pre-test indicate very positive attitudes toward scientific activities that occur in everyday settings. About 78% of all raw scores to both instruments on the pre-test lie between neutral and strongly agree. This is not surprising considering these were volunteers in a citizen science project who are naturally motivated to participate in scientific activities and have strong beliefs about science.

Attitudes toward Science

On the attitude pre-test (Table VI), the most difficult item was "I plan to participate in other citizen science projects in the future" (hereafter referred to as the OTHER item). The item "I am interested in science" (hereafter referred to as INTEREST) is by far the most endorsed. The pre-test was taken before active participation in the Citizen Sky project had begun for the Participant. Thus, it is unlikely many participants are planning their next project before their current project had even begun.

Table VI.
Attitude Pre-Test Item Parameters after Rasch Analysis (N=1,143)

Item (Abbreviation)	Rasch Item Difficulty (logits)	SE_{rasch}	Infit	Outfit
I plan to participate in other citizen science projects in the future. (OTHER)	.93	.05	1.27	1.27
I actively seek out stories about astronomy in the news. (SEEK)	.81	.05	1.01	1.00
I am likely to attend a science seminar, class or talk. (ATTEND)	.61	.05	1.26	1.25
I use knowledge of science in everyday life. (EVERYDAY)	.40	.06	1.01	1.00
I am knowledgeable about science. (KNOWLEDGE)	.03	.06	1.09	1.13
I use knowledge of science to evaluate claims made about science. (EVALUATE)	-.28	.06	.79	.75
I will pay attention if an astronomy news item crops up in a media source I am already following. (ALREADY)	-.54	.07	.90	.81
I am interested in news about astronomy. (NEWS)	-.69	.07	.85	.73
I am interested in science. (INTEREST)	-1.27	.08	.77	.56

NSKS

In general, the responses to the NSKS pre-test (Table VII) items were not as positive as responses to the attitude pre-test items. The item with the highest estimated difficulty (the most difficult to endorse) was “There is an effort in science to keep the number of laws, theories, and concepts at a minimum” (hereafter referred to as the MINIMUM item). The item with the lowest difficulty was “The laws, theories, and concepts of biology, chemistry, and physics are related” (hereafter referred to as the RELATED item). The most difficult category

of items was the testable category. The least difficult category of items was the creative category. The item categories themselves can be assembled into two clusters: most difficult (amoral, developmental, testable and unified) and least difficult (creative and parsimonious) (Table VII).

Table VII.
NSKS Item and Item Group Parameters after Rasch Analysis (N=1,313)

Item (Abbreviation)	NSKS Item Group	Rasch Item Difficulty (logits)	SE_{rasch}	Infit	Outfit
Scientific knowledge is stated as simply as possible. (SIMPLE)	P	.14	.04	.91	.98
The laws, theories, and concepts of biology, chemistry, and physics are related. (RELATED)	U	-1.00	.05	.68	.64
The applications of scientific knowledge can be judged good or bad; but the knowledge itself cannot. (JUDGE2)	A	-.29	.04	1.29	1.54
It is incorrect to judge a piece of scientific knowledge as being good or bad. (GOODBAD)	A	-.07	.04	1.13	.94
If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen. (OCCAM)	P	.36	.04	.93	.89
Even if the applications of a scientific theory are judged to be good, we should not judge the theory itself. (APPLICATION)	A	.57	.03	.87	.72
A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions. (VERIFY)	T	-.40	.05	.97	1.04
We accept scientific knowledge even though it may contain error. (ERROR)	D	.66	.04	1.10	1.07
Scientific knowledge expresses the creativity of scientists. (CREATIVE)	C	.46	.04	.99	.94
Scientific laws, theories, and	C	.44	.04	.96	.90

concepts express creativity. (EXPRESS)					
The evidence for scientific knowledge must be repeatable. (REPEAT)	T	-.77	.05	.80	.77
Today's scientific laws, theories, and concepts may have to be changed in the face of new evidence. (CHANGE)	D	-.69	.05	.88	.99
A scientific theory is similar to a work of art in that they both express creativity. (ART)	C	.43	.04	.97	1.01
There is an effort in science to keep the number of laws, theories, and concepts to a minimum. (MINIMUM)	P	.92	.04	.90	.91
The various sciences contribute to a single organized body of knowledge. (SINGLE)	U	.04	.04	1.00	1.87
Scientific knowledge is a product of human imagination. (IMAGINATION)	C	.83	.03	1.08	1.17
Biology, chemistry, and physics are similar kinds of knowledge. (SIMILAR)	U	-.05	.04	.97	1.07
Scientific knowledge is subject to review and change. (REVIEW)	D	-.94	.06	.91	.88
Scientific laws, theories, and concepts are tested against reliable observations. (TESTED)	T	-.51	.05	.67	.65
Those scientific beliefs which were accepted in the past and since have been discarded should be judged in their historical context. (HISTORY)	D	-.02	.04	1.14	1.18
Consistency among test results is a requirement for the acceptance of scientific knowledge. (CONSISTENT)	T	-.40	.05	.88	1.07
Scientific knowledge is comprehensive as opposed to specific. (COMPREHENSIVE)	P	.66	.04	1.08	1.16
The laws, theories, and concepts of biology, chemistry, and physics are interwoven. (INTERWOVEN)	U	-.26	.05	.71	.78
A piece of scientific knowledge should not be judged good or bad.	A	-.11	.04	.92	.81

(JUDGE1)

NSKS Item Groupings			
Amoral Items	A	-.16	.04
Creative Items	C	.54	.04
Developmental Items	D	-.25	.05
Parsimonious Items	P	.52	.04
Testable Items	T	-.52	.05
Unified Items	U	-.43	.04
Creative Items	C	.54	.04

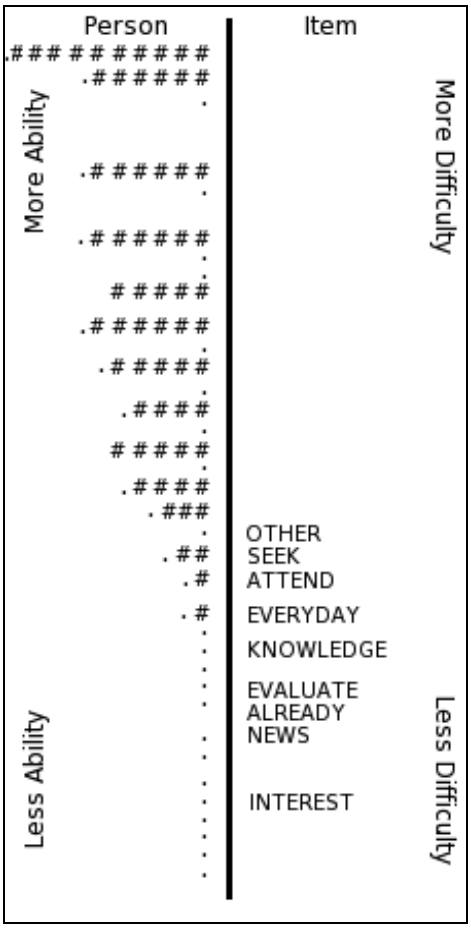
Comparison of Pre- and Post-Tests

Comparison of the pre- and post-tests were based on the results of the Rasch analysis. Thus, units are in logits and comparison was only between participants who took both tests. However, the logit scale itself was developed with all of the participant data from the pre-tests. Remember, lower estimate values mean the item difficulty is more likely to be positive.

Wright Maps: Scientific Attitudes Item Analysis

An easy way to visualize any change between pre- and post-test responses is to look at person ability and item difficulty distributions on Wright Maps. Comparison of the attitude pre- and post-test Wright Maps show little change in the distribution of item difficulty and person ability. Comparing the pre-test map with the person-anchored post-test map (Figure 6) shows that the range of item difficulty is about the same (i.e. items are distributed along the y-axis for roughly the same amount on both tests). The only major positional change was with the ALREADY and the NEWS items, which became easier to endorse. Also, the KNOWLEDGE item became more difficult to endorse, changing positions with the EVERYDAY item. It is not surprising that the two would be bunched

together, since they both involve perceived knowledge of science. The pretest scale shows the distributions of all participants (N=1,143) while the post scale shows only participants who took the post-test (N=117) (both scales omit participants who exceeded our fit criteria). It is still clustered together at the top, reflective of a persistent ceiling effect. This shows that the items on the scientific attitude test are not well matched with the respondents' ability distribution, making using this test difficult to differentiate among participants on the scientific attitude scale.



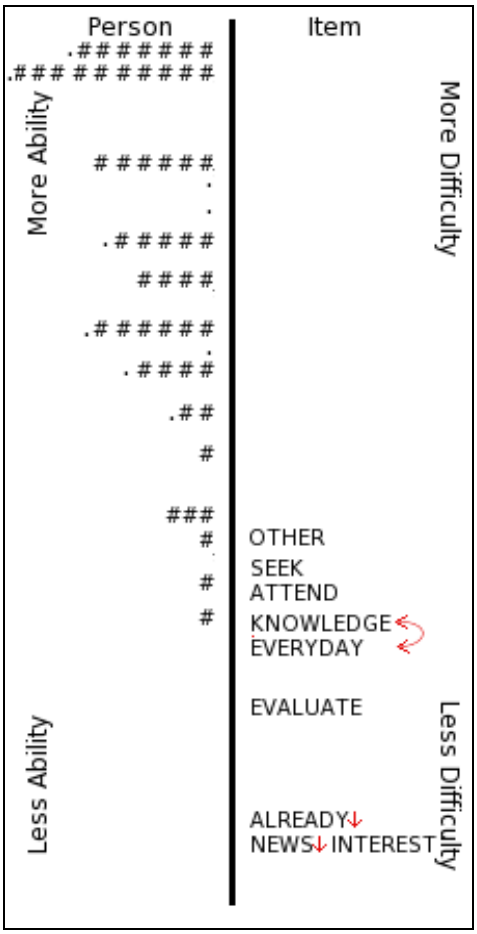


Figure 6. Wright maps for the attitude pre-test (left) and the *person*-anchored attitude post-test (right). On the pre-test, each pound (#) equals 15 participants and each period (.) equals 14 or fewer participants. On the post-test, each pound (#) equals 2 participants and each period (.) equals 2 or fewer participants. Major items position changes are noted with arrows.

For the NSKS tests, comparison of the pre- and post-test Wright Maps show a slight change in the distribution of item difficulty. Comparison of the pre-test map with the person-anchored post-test map (Figure 7) shows that item difficulty is spread out more on the post-test. This increase in range is mainly reflected in items becoming easier (vertical extension of items towards the bottom of the Wright map, but not at the top). The items with the biggest change are OCCAM, GOODBAD and ERROR. The only item to become more difficult is the SIMPLE item. Taken together, these changes suggest that certain items became easier, but the relative person ability did not.

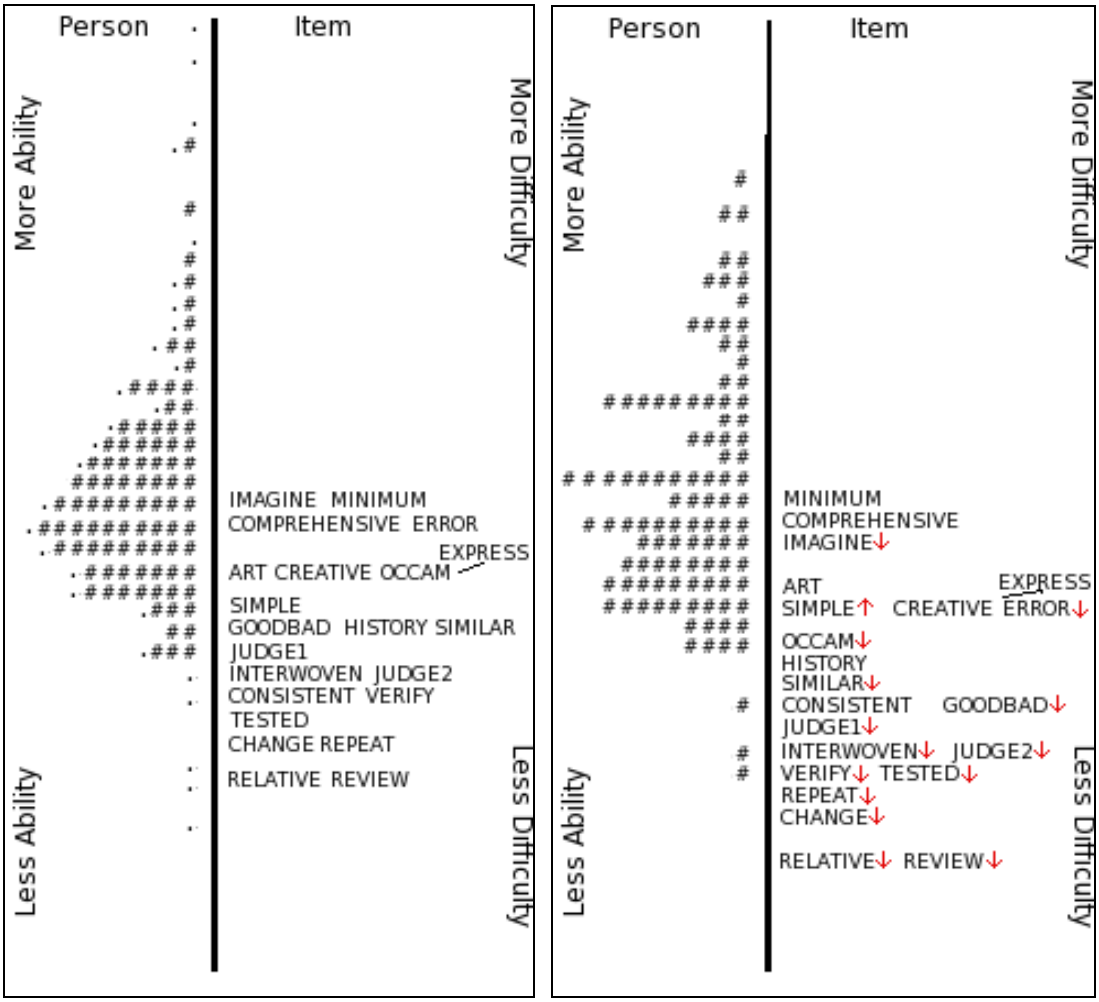


Figure 7. Wright maps for the NSKS pre-test (left) and the *person*-anchored NSKS post-test (right). On the pre-test, each pound (#) equals 9 participants and each period (.) equals 8 or fewer participants. On the post-test, each pound (#) equals 1 participant. Arrows denote major movement of items.

Attitude towards Science

A paired-samples *t*-test between the overall attitude ability estimates of those who took both pre- and post-test show no significant change between the two time points, $t(101) = -1.221$, $p = .225$. The pre-test mean is 3.34 (SD = 1.7)

and the post-test mean is 3.53 (SD = 1.6). Figure 8 shows the pre- and post-test scores on the nine attitude items. Next, I wanted to see if the repositioning of the NEWS, ALREADY and KNOWLEDGE items on the Wright Map was statistically significant if evaluated separately. First, I calculated the difference between the difficulty of each of the three attitude items and the participant's tendency to endorse the item (hereafter referred to as a *differential*). The smaller the differential, the more likely the participant was to endorse the item. I then calculated a paired-samples *t*-test between these differentials. All three items showed a statistically significant change: NEWS, $t(106) = -4.374$, $p < .001$; ALREADY, $t(106) = -4.691$, $p < .001$; and KNOWLEDGE, $t(106) = 2.281$, $p < .05$. On the NEWS and ALREADY items, participants showed significant increases in their level of positive endorsement while on the KNOWLEDGE item they showed a significant decrease in their level of positive endorsement. This means that participants on the post-test increased their level of agreement that they are interested about astronomy news and will pay attention if they see it in a news source they are already viewing. It also means that participants were less likely to agree that they were knowledgeable about science on the post-test than they were on the pre-test. There were no significant changes on the rest of the items between the pre- and post-tests.

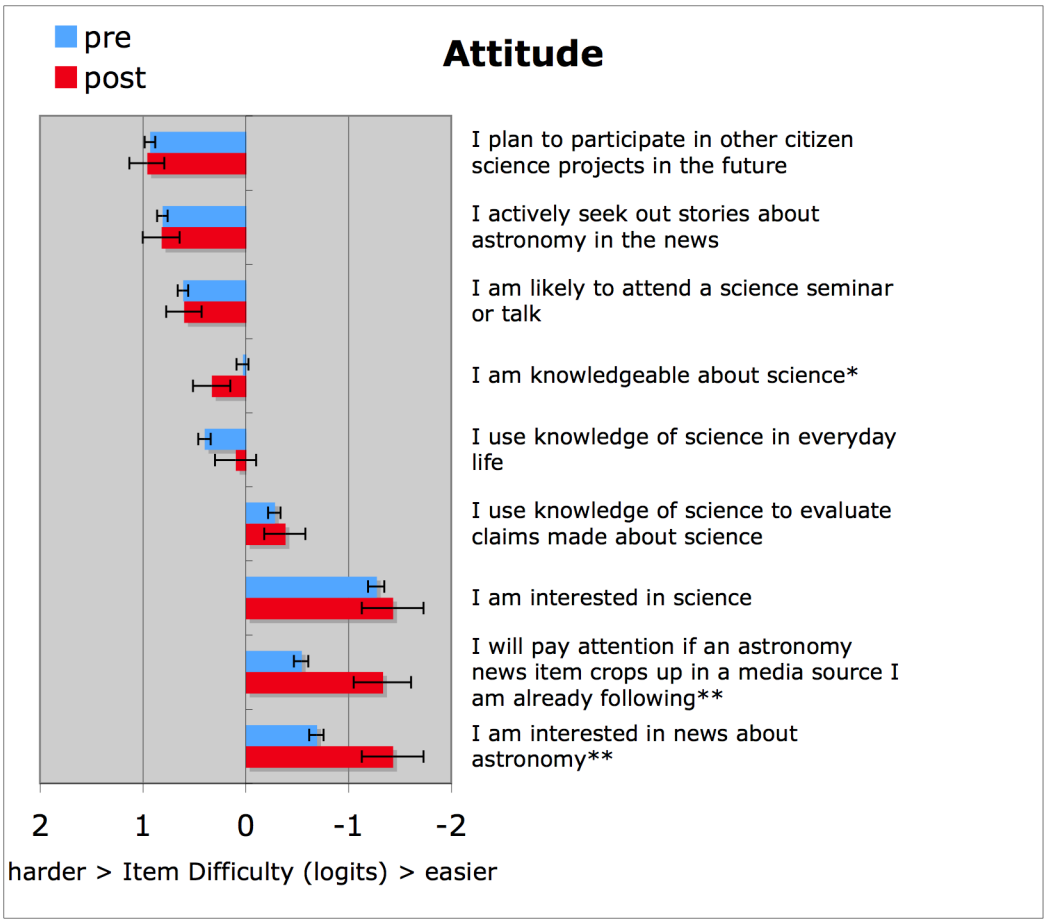


Figure 8. Comparison of attitude items on the pre- and post-tests. Bars represent item difficulty on the attitude pre- and post-test. Error bars reflect the standard error calculated from the Rasch model.

I created a latent variable called *Participant Communication* to reflect how active participants were in communicating with other participants. This variable has three categories: low, medium and high. The low category consists of participants who had never joined a chat or posted a message in a forum. The medium category consists of participants who have either joined a chat or posted at least one message to a forum. The high category consists of participants who

have joined a chat and also posted to a forum. The correlation for the items making up this variable is positive and strong, q=.497, $p < .001$.

A two-way repeated measures ANCOVA was used to look for differences in the attitude scores between various groups of participants. The dependent variable was the overall person ability estimates on scientific attitudes which was repeatedly measured on the pre- and post-tests. The independent variables were the Participant Communication, Team and Active Observer variables. Covariates were the Astronomy Experience, Gender and the dichotomous Age variable. The independent variables were chosen because they reflect areas where the Citizen Sky project differ from most other citizen science projects, thus will provide a valuable contrast with the existing literature. The covariates were chosen as demographic variables that could not be randomly assigned since this is a self-selecting, volunteer project. As a result, I wanted to control for their effect.

Two main, fixed effects were detected (Table VIII). For the independent variables, only participant Communication was significant, $F(2,70) = 3.236$, $p = .045$. Active Observer was not significant, $F(1,70) = 0.491$, p =.486., and neither was the Team variable, $F(1,70) = 2.711$, $p = .104$. There were no significant interaction effects. Of the covariates, only Astronomy Experience was significant, $F(1,70) = 10.629$, $p = .002$. The dichotomous age variable ($F[1,70] = 0.033$, p =.857) and Gender (($F[1,70] = 2.311$, $\rho = .133$) were not significant. The degrees of freedom are lower than the total number of participants who filled out both surveys due to missing data on some of the variables (participants were not required to answer all items).

Table VIII.
Analysis of Variance for Attitude DIFFERENTIAL Scores

Source	*df*	*F*	Partial eta Squared	*ρ*
	Fixed effects			
Participant Communication (P)	2	3.236	.085	.045*
Active Observer (AO)	1	.491	.007	.486
Team (T)	1	2.711	.037	.104
P x AO	2	.304	.009	.739
P x T	2	.599	.017	.552
AO x T	1	.628	.009	.431
	Covariates			
Age Dichotomous	1	.033	.000	.857
Astronomy Experience	1	10.629	.132	.002**
Gender	1	2.311	.032	.133

*$p < .05$, **$p < .01$

The significance of Participant Communication means that there are significant differences in scientific attitudes among the three groups of participants as defined by the participant communication variable (low, medium and high). There are no interaction effects between this variable and the factor of time, meaning the significance is not related to the six months spent in the project between the pre- and post-tests. Inspection of the mean overall attitude estimates on the pre- and post-tests for each of the three groups sheds light onto the differences (Figure 9). An LSD pair-wise comparison of the three groups found a significant difference between the medium and high group, $p = .02$, and between the low and high group, $p = .03$. This means that, coming into the project, those who had higher Participant Communication measures (i.e. became most active in the chat room and online discussion forum)s had more positive attitude scores on

our pre-test. A Tukey HSD post-hoc analysis of the astronomy experience variable found differences between the low and medium groups, $p = .02$, and between the low and high groups, $p = <.01$. There was no difference between the medium and high groups, $p = .76$.

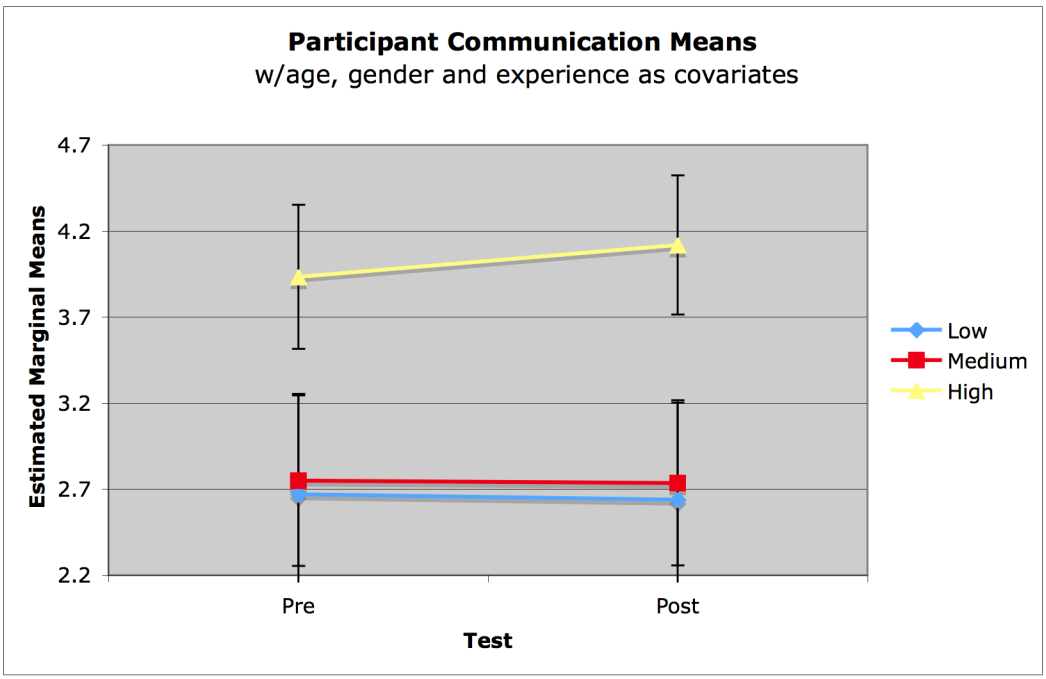


Figure 9**.** The pre- and post-test mean pair-wise comparison for participants in each of the three Participant Communication variable groups.

Belief in Nature of Science

The overall ability estimates on the NSKS scale increased between the pre- and post-test scores and is significant according to a paired samples *t*-test, $t(109)=-2.135$, $p = .04$. The pre-test mean is 0.96 (SD = 1.1) and the post-test mean is 1.29 (SD = .08). Figure 10 shows item difficulty changes when anchored by the persons. Three of the six subcategories showed significant changes in item

difficulty and ability differential: the amoral group of items, $t(109) = -3.410$, $p = .001$; the developmental group of items, $t(109) = -3.158$, $p = .002$; and the unified group of items., $t(109) = -2.480$, $p = .015$. All of the change in these subcategories was negative, meaning easier endorsement on the post-test. The mean score of the testable items approached significance but was not significant[1], $t(109) = -1.852$, $p = .067$. The creative and parsimonious item scores did not come close to showing significant change. The mean scores on those two were also much lower than the other item groups.

As with the attitude test, two-way repeated measures ANCOVA was used to look for differences in various groups of participants. The dependent variable was the overall pre- and post-test NSKS ability estimates. The independent variables were the Participant Communication, Team and Active Observer variables. Covariates were the Astronomy Experience, Gender and the dichotomous Age variable. No significant effects were detected (Table IX). Participant Communication was not significant, $F(2,70) = 0.442$, $p = .644$. Active Observer was also not significant, $F(1,70) = 0.007$, $p = .933$, and neither was the Team variable, $F(1,70) = 0.261$, $p = .611$. Of the covariates, Astronomy Experience was not significant, $F(1,70) = 0.456$, $p = .502$, and neither was dichotomous Age variable ($F[1,70] = 3.079$, $p = .084$) or Gender (($F[1,70] = 0.030$, $p = .864$). There were no significant interaction effects.

---

[1] The Rasch model also computes a standard error for each item difficulty. If I take a mean of the item difficulties for all the items in the testable category, and add their Rasch standard errors in quadrature, the pre- and post-test means fall outside of the standard error margins. I interpret that as meaning the testable category pre- and post-test difference is on the borderline between being statistically significant and not. More data should resolve that issue.

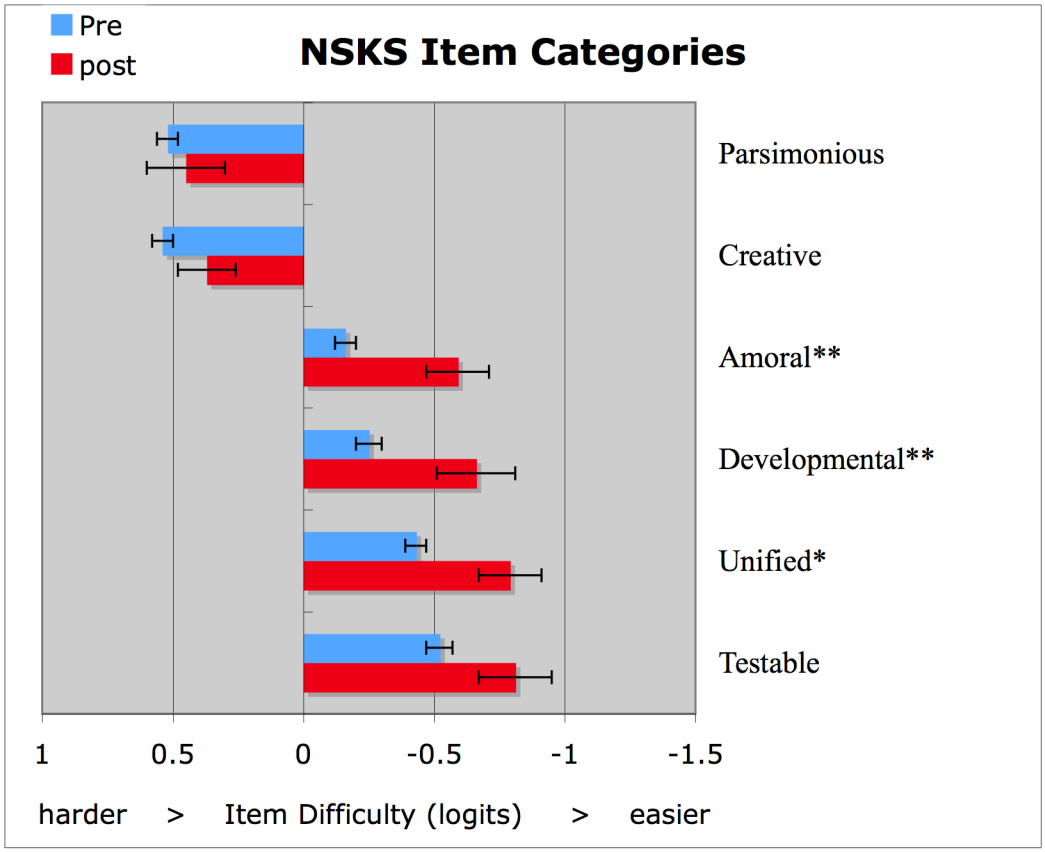


Figure 10. NSKS item category scores. Each bar represents mean item difficulties. The means are based on items within that group. Error bars reflect the standard error from the Rasch model for each item in the group, added in quadrature.

Table IX.
Analysis of Variance for NSKS Differential Scores

Source	*df*	*F*	Partial eta Squared	*p*
	Fixed effects			
Participant Communication (P)	2	.442	.012	.644
Active Observer (AO)	1	.007	.000	.933
Team (T)	1	.261	.004	.611
P x AO	2	.211	.006	.811
P x T	2	2.340	.063	.104
AO x T	1	.649	.009	.423
	Covariates			
Age Dichotomous	1	3.079	.042	.084
Astronomy Experience	1	.456	.006	.502
Gender	1	.030	.000	.864

*$p < .05$, **$p < .01$

Post-Test Interviews

Participant Communication

The first trend I found in the interviews related to the importance of social contact for participants. I found references to social interaction in six of the nine interviews (interviews 1, 2, 4, 5, 8, 9). Recall that scores on the attitude test were significantly different between participants separated into the Participant Communication groups, which was a latent variable built on three other variables, including participation in the asynchronous online discussion forums and the synchronous online chats. These are the main tools participants use to

communicate with each other in the project and they are the only public communication mechanisms (e-mail is the other, private method) supported by the project software. This relationship between participant communication and attitudes towards science and astronomy is also reflected in many of the interview responses. For example, when asked about changes in their news reading activities, three participants referred to posts to our discussion forums as new sources of news:

> Participant 4: I tend to read specific sources that allow me to gain as much info as quickly as possible, e.g. while I'm eating my lunch at work I read general news headlines… I will tend to read Citizen Sky posts at night when things are a bit quieter.

> Participant 5: I've always eagerly read any of those [forum] posts from citizen sky.

> Participant 9: To some degree CS has led me more into the blogosphere and the web with regard to news. At the same time I've had to enhance my way of critically reading such news and be able to try to deal with the sources it is coming from… the forums have had discussions with regard to the validity of sources and methods. You don't usually get that just reading blogs or the web and those discussions have been interesting along those lines.

In addition to the items related to news reading, the interviews suggest that working with others makes the project more interesting and also allows them to look at things from new perspectives. Regarding the increased interest, three participants commented on the collaborative nature of the Citizen Sky project:

> Interviewer: What are some differences between Citizen Sky and other astronomical research projects you have worked on?
>
> Participant 1: [Citizen Sky has] more people involved than in planetary work [which I also participate in]...
>
> Participant 8 (responding to same question): [other citizen science projects] feel less personable.
>
> Participant 2 (responding to same question):: When I'm viewing potential projects to take on I see a greater capacity for the involvement of people outside of the lab and the university and the astronomy club.
>
> Interviewer: How has participation in the Citizen Sky project affected your interest in science?

> Participant 5: Yeah, its made it even greater. Because its become a pretty important part of my life (laugh). These people - its partly the people too its not just the science, it's the combination of the two.

Regarding the new perspectives collaboration can contribute, two participants said:

> Participant 2: Just in participating in it I've learned things about interacting with other people and assumptions about sort of the knowledge and the interpretation skills of other people.

> Participant 5: One thing I've really learned is that when you are doing science it is really helpful to have a team. It is really helpful to be able to throw ideas out there and bounce them around each other and have people with different expertise's that can clarify things that you might now have understood completely or to see something in a different way than someone else did. I was a teacher so I've been on teams, but this one was different. It was much more satisfying. We have people from all over the world and working towards this common goal that it’s just been so much fun.

Astronomy in the News

There are three items on the Attitude test that related to habits of engagement with astronomy in the news. In addition to the NEWS and ALREADY items, there is an item that says "I actively seek out stories about astronomy in the news" (hereafter referred to as the SEEK item). The difference between the SEEK item and the other two news-related items is that the seek item emphasizes active participation, rather than passive news gathering. The SEEK item does not show a statistically significant change in endorsement, while the other two items do. Interview data from four of the interviewees suggests that this is not an artifact of participation in the Citizen Sky project, but rather a reflection of busy everyday lives. When asked about the SEEK item, three participants said:

> Participant 1: I haven't had a lot of time to put into the hobby, so its only been this month over the last year that I've had time to spend on it. I haven't had as much time as I like…
>
> Participant 4: I have less time to seek out material at the moment… I am increasingly choosy about what sources I read due to a lack of time…
>
> Participant 7: I wish I had more time to spend on [the project].

One participant commented on the lack of time when responding to the final question asking for general comments on the project:

Participant 9: I think our most challenging aspect will be to keep people engaged through the project's life. A three year project, for people who have other primary focuses in life, is large..

Self Efficacy Regarding Scientific Knowledge

An important difference between the NEWS/ALREADY items and the KNOWLEDGE item is the direction of the pre- and post-test change. The former items showed an increase in endorsement while the latter item showed a decrease in endorsement. However, six of the nine interviewees stated that their knowledge increased or was otherwise unaffected through participation in the project.

Participant 1: I'm learning more about variable stars as a whole.

Participant 3: I definitely have more knowledge.

Participant 4: I have a better appreciation of the different kinds of variable stars and some of the characteristics of their light curves. I'm learning more about data analysis in this context as a result of asking questions and experimenting with data.

Participant 5: I do see a lot of learning taking place.

> Participant 7: I always felt before that variable star observing was too advanced for me. That along with the thought that [it] sounds boring. It's not so boring now.

> Participant 9: I don't think my knowledge of astronomy has been affected, no. But there has been a big effect on my knowledge of *how to do* astronomy. (emphasis theirs)

There was no statement in any interview where a participant suggested they were not learning. An explanation for the discrepancy between what they said and what the test results show could be in how the item was worded ("I am knowledgeable about science."). That could be interpreted as a question about *efficacy* as opposed to *knowledge.* That is, participants are gaining more knowledge but this is also opening their eyes to how much more they have to learn ("the more you know, the more you don't know"). This was suggested by one of the participants who identifies as a professional astronomer who voluntarily participates in the project. This participant is neither affiliated with nor funded by the project and does not have access to any special resources. They comment on their own perception and also what they see in other participants, through participation in the chat room or in the discussion forums:

> Participant 2: There have been many instances where I think people's awareness of limitations of past knowledge has been

> increased. One of the overwhelming feelings I get is how much we don't know. So, many times it's more like in what direction to move your boundaries of ignorance, as opposed to your boundaries of knowledge.

Creativity in Science

As for the NSKS data, the higher scoring subcategories tended to show the most change while the lower scoring subcategories showed no significant change at all. The two unchanging, lowest scoring subcategories are the creative and parsimonious subcategories. Regarding the creative group of items, the interview responses were consistent in that the participants felt like the project does involve creativity. This is consistent with the test results. Even though it was among the lowest scoring groups, the creativity group still received an overall positive score. However, all nine participants interviewed gave different examples of creativity in the project. And only one of the participants cited their own work in the project as an example of creativity (participant #5, who described their problem solving skills as creative). Most of the examples of creativity involved other people:

> Participant 3: In the part I participated in, I was just gathering data so other people could do the creative part of explaining the data. So I didn't do much of the creative stuff but there are definitely other people who did.

> Participant 4: In general, discussions in the CS forums in which people are coming up with alternative explanations for aspects of eps aur.

Participants 7, 8 and 9 also listed various examples of creativity displayed by other participants. The interviewer noted in their field notes that when asked about the creative items, participants often had to pause and think more so than in the other subcategories. Also, early in the project a particularly heated discussion occurred in the Citizen Sky forums over the topic of creativity in science, with two participants flat out rejecting the notion completely. Investigation of the four items that make up the creative items showed that one item was more responsible for the relatively low score than the others. That item was "Scientific knowledge is a product of human imagination" (hereafter referred to as IMAGINATION). Its mean score was about twice as low as the means of the other three items. It was also the only item not to have the word "creative" in it. For a reason that escapes this analysis, and may simply be an illustration of our culture, participants were more skeptical of applying the word "imagination" to the nature of science than they were of the word "creativity". In general, the mean score on the creative items could be due to the fact that creativity is not emphasized very much in typical discussions about science and the participants were just unfamiliar with how it fits in. This is reflected in the randomness of their examples and how the use of a stronger word, imagination, got even less support.

Parsimony in Science

The other NSKS item group with a low relative score was the parsimonious group. The reason behind this is clear through the interviews – participants did not completely understand the word's definition and, when defined for them, did not understand how to apply it to science:

> Participant 1: …this is more difficult question than I thought...(laugh)
>
> Participant 5: What does that mean? (laugh)
>
> Participant 7: That's a bit harder to wrap my head around.

This is also seen in our item group reliabilities, where the parsimonious group had a lower reliability (α=.60) than the other subcategories (mean α=.84). Four participants referred to Occam's Razor (summarized as "when confronted with two explanations of equal accuracy, choose the simpler."), which is a common quotation in popular astronomy literature. Thus, the interviewer began using "Occam's Razor" as an example in three subsequent interviews and found that it resolved much of the confusion. After it was cleared up, everyone interviewed exhibited support for the parsimonious nature of science. Most often they quote the evolving theory of epsilon Aurigae and also the ongoing development of a "Theory of Everything" in the physics community.

The Amoral Nature of Science

On the NSKS, the amoral group of items showed a significant increase in belief. However, six of the eight interviews show evidence where the participant felt there was no major moral issue with the Citizen Sky project.

> Participant 2: I do not think I can think of a single instance where this has been issue in citizen sky.

> Participant 3: There isn't much malicious use for why a star dims

> Participant 4: The investigation into the nature of epsilon Aurigae is, from my perspective, amoral.

> Participant 5: I don’t see anything I haven’t seen anything that really struck me as being you know amoral (laugh) or that had any moral issue to it that I can think of.

> Participant 6: I don’t recall seeing anything on there that would seem to imply any specific moral judgment one way or the other about the endeavor of making the observations, recording them and feeding them in an aggregate database.

> Participant 8: I would think that the entire Citizen Sky project is amoral (that sounds bad in a layman's context, but...). The point of the Citizen Sky project is to find out facts, or create a fact-based thesis about what is eclipsing this particular star. There is no morality in that. It is neither good nor bad.

Only one interview responded in the affirmative that there was a moral aspect to the Citizen Sky project. However, that person then added that they were referring to the choice of attitude pre- and post-test questions. Thus, it did not reflect the actual project itself. I think the change in amoral scores could be caused by simply thinking about the issue more, not necessarily because the Citizen Sky project is directly involved in issues of (a)morality. For example, we have debates in our forums about global warming and government funding of science – two issues with definite moral stances in today's political climate, but not directly related to the project itself.

Summary

This study found that attitudes towards science and beliefs in the nature of science increased slightly for project participants. The increase in attitude is mostly a result of increased interest in science and astronomy news. And this is due to participants sharing news and stories with other. It is also related to the level of communication participants have with each other, although the level itself did not change over time. The increase in belief is mostly the result of participants

solidifying previously held beliefs. None of the changes detected were related to other activity measures of the project, except prior astronomical experience. Some of these changes were confirmed by subsequent interviews with project participants.

CHAPTER FOUR

STUDY TWO: SCIENTIFIC COMPETENCIES AND LEARNING IN ONLINE DISCOURSE

Introduction

Online discussion forums have been a staple of Internet based science education projects for decades (De Wever, Schellens, Valcke & Van Keer, 2006). With their ancestry in the bulletin-board systems of 1980's computer networks, they provide a place for users to "post" a message to a forum and also to reply to other posts. In some ways, this back and forth can mimic discourse in a classroom. However, there are also differences too, mainly related to their asynchronous nature, allowing the author time to carefully phrase a message.

Citizen science projects are using online discussion forums largely as a method of social interaction for their participants with the goal of providing a an

incentive to return to the web site. Some of these have been vastly successful, with tens of thousands of users (Raddick, Bracey, Gay, Lintott, Murray, et al. 2010). Very little research has been done on the educational impact these discussion forums may have on their participants. In fact, I could find no systemic research on citizen science online discussion forums. I searched Google Scholar and also visited the presentations and publications listed on the websites of citizen science projects that I know use online forums.

The Citizen Sky online discussion forums are a little different from a typical forum in that they serve both a social *and* an educational (instructional & learning) purpose. First, it is a way for participants to share ideas and start collaboration – the corner stone of the Citizen Sky project. The role of online our discussion forums is to foster small communities and networks of participants who will coalesce around a topic and formally incorporate themselves into a "team" to solve a problem or answer a question. Second, the forums act as a training mechanism where Citizen Sky staff and other participants can give advice on various issues in the project.

The ultimate educational goal of the Citizen Sky project is to increase the scientific literacy of its participants. The prior study on attitudes and beliefs measured two aspects of scientific literacy: attitudes towards science and beliefs in the nature of science. This study will add to those results by looking for evidence of science competencies in discourse within these online discussion forums. To that end, I looked at three levels of data: the author level (messages grouped by author), the forum level (messages grouped by the different forum

topics) and the project level (all messages analyzed en masse). The research question for this study is "How can competencies associated with science be observed in the discourse of an online citizen science project? And how do the competencies differ according to the structure of the forums? How do they change over time? And are there differences among groups posting to the forums?" Competency is a multifaceted term describing many elements needed to consistently reach a level of accomplishment. It is difficult to measure competency with multiple choice or Likert scale instruments. Since the Citizen Sky project has access to a database of online forum messages, I thought it would be a natural place to look for evidence of competence. The messages cover many topics over the entire lifespan of the project and all participants are welcome to post to the forums. What better way to assess scientific competency than to look at how people are discussion scientific topics in a real world forum? That is, the message topics are not influenced by this study and reflect real world issues related to citizen science.

Of course, in order to look for competency we need to be able to define and identify it. I've chosen a framework based on the Community of Inquiry theory of three types of "presence" in an online discussion environment: cognitive, social and teaching (Rourke, Anderson, Garrison & Archer, 1999). Those three elements are roughly aligned with three elements of successful scientific discourse (Kelley, 2007). When all three types of presence exist at once, then learning may occur. A sampling of messages in the forums were coded according to this framework with the results analyzed using descriptive statistics

and correlations to look for trends and relationships that may shed light on the level of scientific competencies on display in the discourse.

This chapter begins with a brief literature review of online discourse analysis, building upon the literature reviews in the previous chapters. Then it describes its subjects and instruments. This is followed by an analysis section that describes the coding and statistical procedures. Finally, the chapter ends with a discussion of the results.

Literature Review

Online Discourse Analysis

Computer-mediated communication (CMC) refers to communication that takes place through two or more computers (Naidu & Järvelä, 2006). Most online educational programs involve CMC as a way to emulate discussion that would otherwise take place in a classroom. While CMC technologies have been used for decades, there are few theories and limited empirical research regarding the learning process present in such groups (Jeong, 2003) and there are no widely accepted methods for assessing participant involvement (Dringus & Ellis, 2005). However, most of the CMC research studies have in common two requirements: the establishment of a unit of meaning and a theoretical framework used for coding (De Wever, Schellens, Valcke & Van Keer, 2006).

Thus, my first step in online discourse analysis is to determine a consistent unit of meaning (Henri, 1992). For asynchronous CMC, reliability and validity of the analysis can be increased by using an entire message itself as a unit of meaning (Garrison, Anderson & Archer, 2001), as opposed to the use of individual phrases or sentences. This is mainly due to the control the author has over the unit characteristics. Since the author decides what goes into a post and when to end it, it removes arbitrary decisions by coders regarding boundaries of the unit. Sometimes, thread-based approaches have often been used for analysis of synchronous chat discourse (Cakir, Xhana,, Zhou & Stahl, 2005). These approaches separate threads of topics from each other and analyze them as independent units of meaning. However, in asynchronous environments the advantage of thread analysis diminishes as threads become unwieldy and often change directions midcourse.

The next step in designing my analysis is to define a theoretical framework. Most CMC theoretical frameworks are based on two assumptions: that participants are required to participate (and have been told what is expected of them) and an instructor is leading the discussion. In the Citizen Sky project, neither assumption is valid. The participants are volunteers, thus are engaged in the project for reasons of personal interest and satisfaction. Also, there are no instructors posing formal problems to be solved or questions to be answered, with graded results. There are staff members who occasionally help steer discussion, give answers and post new discussion topics. But the vast majority of the discussion is initiated, driven and concluded by the volunteers. And discussions

end only when the participants decide not to post any more messages to the thread. Indeed, the project's longest thread has been active for about a year and continues to get new posts (Appendix C). As a result, the analysis of the discourse has to be more flexible than most CMC theoretical frameworks.

In 1999, Garrison, Anderson and Archer proposed a versatile framework for analyzing CMC discourse in science education settings (Figure 11). The framework is based on Rourke, et al.'s (1999) definition of a Community of Inquiry, consisting of instructor and participant interaction through three elements: *cognitive presence*, *social presence* and *teaching presence*. Together, these three elements can lead to learning. Cognitive presence is most closely related to critical thinking. In the form of online discourse, it begins with a triggering event, is followed by progressively more involved deliberation (exploration and integration) and ends with decision making and discussion of implications (resolution). Social presence is most closely related to social expression. In online discourse, it is related to the use of emotional adjectives, humor, and open communication with others. Its role in this framework is to allow and sustain the cognitive presence by promoting collaboration and interactivity. The main role of the teaching presence is to focus the cognitive and social presence on the act of learning. It is process-oriented, intending to build understanding within the educational context. Many subsequent studies have used this framework for transcript analysis. A Google Scholar query on September 1, 2010 reveals 857 citations to the originating paper (Google, 2010).

Figure 11. The Community of Inquiry framework. Figure from Garrison, Cleveland-Innes & Fung (2004) and reproduced with permission from the author.

Another reason I adopted this framework is that it is aligned with the three elements of competencies in community scientific discourse described by Kelley (2007): social, norms, and practices. The social element from Kelly is aligned with the social presence of the COI, the normative element is aligned with cognitive presence and the practice element is aligned with teaching presence.

This study will also investigate gender differences, which are common in online discourse (Rodino, 1997; Blum, 1999; Wang, Sierra & Folger, 2003). Women have been found to be more collaborative (Blum, 1999) and display more social interdependence (Rodino, 1997) while men were more competitive (Arbaugh, 2000). However, one study reported that online discourse contributions by men were more of a social nature than those of female participants, who

tended to be more interactive (responding to previous messages) (Barret & Lally, 1999). A study by Thomson and Murachver (2001) found that readers of text messages could predict the gender of the author with 91% accuracy. Finally, female participants of online discussion are more likely to post anonymously than men, when that feature is available (Hsi & Hoadley, 1997).

A study like this involves a substantial amount of data from many different sources. Dringus & Ellis (2005) offer strategies for applying data mining techniques to discourse analysis. These techniques allow the researcher to analyze larger amounts of data and to look for more complex interactions that form in online forums that remain active over large periods of time, including time scales greater than those typically associated with single semester educational course work. These strategies will be useful in the analysis of large server and database files containing activity logs of participants.

Method

Subjects

As of August 1 2010, 124 out of 3,302 registered participants in the Citizen Sky project had posted 1,269 messages to one of the seven online, asynchronous discussion forums (hereafter referred to as "forums). They self reported as 82% male, 17% female and 1% unreported (vs. 78% male, 19% female and 3% unreported for the overall population of participants who have taken the pre- and post-tests). The average age of a message poster was 43 (SD=14) years old (vs. 41 [16] for the greater project population). About 19%

report no prior experience in amateur astronomy and about 15% self identify as "novice" level amateur astronomers. About 66% of the participants have a bachelors or higher degree.

This analysis will be based on two levels of data: messages and forums. First, I analyze the coded messages to look for trends between the various online forums. Secondly, I analyze the coded messages to look for changes over time in message content. Lastly, I will analyze all messages to look for changes in message topics and message length.

Data Collection

The forums on the Citizen Sky web site allow participants to asynchronously post messages and replies to one another (Figure 12). The public can read them but only participants can post messages. Seven forum topics have been setup to guide discussion (Table X). The first forum is titled *Citizen Sky in General*. It is a place for participants to discuss general topics that do not clearly fit into another forum. The second forum is titled *Ad Infinitum* and is open to discussion of any topic. While non-astronomy topics are allowed, almost all have something to do with science in general and astronomy in particular. The third forum is *Visual Observing*, which is dedicated to discussion of how to make a visual estimate of a star's brightness. The fourth is *Photometry*, which is about using digital CCD and DSLR cameras to make more precise estimates of stellar brightness. The fifth is *Spectroscopy*, which is focused on discussing about how to measure the spectra of stars. The sixth is *Data Analysis*, dedicated to discussion

about analysis of variable star data. The seventh and final forum is *Education and Public Outreach*, which covers a broad range of topics such as education, promotion of the project and scientific visualizations. There are two additional forums that only Citizen Sky staff can post to and only cover administrative content. Those two forums were excluded from this study.

A collection of posts consisting of the original message and all subsequent replies to it are referred to as a *thread*. As of August 1 2010, a total of 1,269 posts had been made by 124 people. Of those posts, 242 were original (thus, we have 242 threads) and 1,027 were comments on one of those threads. And 172 of those messages were by participants who took the pre- and post- tests. These are the messages that were coded.

Table X.
List of online asynchronous forums and number of posts as of August 15, 2010.

Forum Title	*Forum description, as written on the Citizen Sky web site.*	*Number of Messages (coded)*
Citizen Sky in General	If it is about Citizen Sky and doesn't really fit into the other specific categories - here's the spot!	149 (22)
Ad Infinitum	For discussion of any (non-Citizen Sky) thing under the Sun - or above it for that matter!	111 (31)
Visual Observing	About using your eyeballs to do real science	257 (41)
Photometry	More than meets the eye - the ins and outs of digital observing	307 (37)
Spectroscopy	Reading between the lines	34 (7)
Data Analysis	Theories, techniques, discuss your results	272 (10)
Education and Public Outreach	Citizen Sky in the classroom, at star parties, etc.	147 (20)

Forums / The Science / Visual Observing / How do you get an accurate magnitude estimate visually?

How do you get an accurate magnitude estimate visually?

View | Edit | Outline | Track

Offline

Joined:
Posts: 12
Teams: None

Posted: November 18, 2009 - 3:11pm

I have made a few observations of Ep. Au. and made my data entries, but I often wonder if my visual estimates are correct. I live in a rural part of Maine and am fortunate enough to have very dark and clear skies. I've observed Ep. Au. and even with binoculars, it is rather difficult to guess a magnitude using the comparison stars. Is there a trick to doing it better? Lately, I've been entering anywhere from 3.4 to 3.6 for it, but I have doubts. Even when viewing Ep. Au. through binoculars at the same time as the two comparison stars, it is difficult to guess where the magnitude falls.

Reply report to Mollom Unsubscribe from: This post Subscribe to: Posts of type Forum topic Subscribe to: Posts by tonyome

Suggestions on Visual Estimates

Offline

Joined:
Posts: 130
Teams: The 20/20 Vision Team

Posted: November 18, 2009 - 6:59pm

I'm glad you are observing Eps Aur. I love Maine. I spent a week on Hog Island at an Audubon Educators Camp 2 summers ago.

First of all, from your dark skies you shouldn't even need binoculars to observe Eps Aur or its comparison stars. However, if you are using binoculars, I find it very useful to defocus the star images a bit when you make your magnitude estimate. I do this all the time with variable star observing. It gets rid of star color, which can play games on your eyes, especially red stars. I don't think any of the stars we are talking about are red, but they are bright, especially in binoculars. Just throw them all out of focus a bit, but not to much, when you make your observation, but not when finding the field of view.

Sounds to me like you are right in the ball park as far as your observations go. Sometimes as a new observer, one can doubt if his/her observations are very accurate. But your's sound right on. So, have at it, you are doing a fine job.

delete edit reply report to Mollom

Figure 12. A sample post in a forum (top) and a subsequently posted reply (bottom).

Analysis

This analysis was designed to look for evidence of science competencies through evidence of science learning in online forum discussion. Using the Community of Inquiry framework, elements of cognitive, social and teaching presence were recorded. Together all three elements support learning, even though they may not be direct evidence of learning by themselves. So by measuring them separately we can get more details about the learning environment that was created by the participants.

The unit of meaning is defined as an entire forum message – whether it be the first post in a thread or a reply to another. By choosing this unit of meaning, I allow the author to establish the boundaries of what they wish to say and thus minimize a subjective element of analysis that would exist if I used a more detailed or broader unit of meaning.

The author and one other coder – an education researcher with extensive experience with transcript analysis – first practiced by using messages from a similar online discussion forum hosted by the same organization that runs the Citizen Sky project - the AAVSO. This training was used to adjust the coding elements to our context and to become familiar with the process of negotiation. We adopted the coding practice of *negotiated transcript analysis*, suggested by Garrison, Cleveland-Innes, Kool and Kappelman (2006) as a useful process for exploratory transcript analysis – due to its more flexible nature. This procedure first calls for separate analysts to code the messages. Then their codes are compared. Where they disagree, the two parties discuss and come to an agreement

(negotiate) when possible. Thus, in the end each message received only three codes: one each for the cognitive, social and teaching categories – upon which both coders must agree.

The coding scheme has a different category for each of the three elements of the Community of Inquiry (Table XI). We made some adjustments to better reflect the audience for the project (informal vs. formal education program participants). The coding categories for the cognitive presence element were mostly left unchanged. They include, in ascending order of hierarchy, *triggering events*, *exploration*, *integration/fragmentation* and *resolution/dissolution*. The only change made to these elements was to add "fragmentation" to "integration" and "dissolution" to "resolution", in order to make the categories more neutral. The coding categories for the social presence element changed the most. Because the unit of analysis was the message, it was difficult to use the social categories proposed by Garrison, et al. since the entire message is, by its nature, authored by a single person. The changes involved renaming "Affective" to "Reference to Others", "Open Communication" to "Open Invitations" and "Group Cohesion" to "Specific Requests for Collaboration". Finally, the coding categories for the teaching presence elements were largely kept the same, but renamed to reflect the fact that most of the instruction was coming from fellow participants and not formal instructors. Therefore, the categories needed to be a little broader in order to allow for the more varied tones and goals of posts made by participants. As a result, the "Design and Organization" category became "Instructional

Management", "Facilitating Discourse" became "Building Understanding" and "Direct Instruction" remained the same.

The coding categories in each element were assigned a number. I chose a rough ordinal form that assigns the simpler categories a lower number and the more sophisticated categories a higher number. If there was no evidence of any presence for that particular category, it was assigned a 0. Thus, for the cognitive category, the codes ranged from 0-4. For the social category, the range was 0-3. For the teaching category, the range was also 0-3. We consider the categories ordinal because they tend to be hierarchical. As an example, let's look at the cognitive categories. First, a triggering event is needed to begin a discussion. The next category is exploration. One cannot explore a discussion that has not yet begun. The next category is integration/fragmentation, which requires making judgments. One cannot do that without having information to judge, which comes from the exploration phase. The final category is resolution/dissolution based on evidence. One cannot resolve a discussion without having brought new information to the original triggering event and then judging how that information fits into the discussion. With that said, I feel it is not *strictly* hierarchical, and none of the subsequent statistical analysis assumes that it is. However, my interpretation of the analysis *is* based on the assumption that the category codes are ordinal in nature.

Next, we coded Citizen Sky messages posted by a select group of Citizen Sky participants – chosen because they took the pre- and post-instrument tests. (I had intended to compare coding results with pre- and post-test data, but the data

did not support such an analysis). Then we compared our results, which consisted of a total of 555 codes (three codes each for 172 messages). We had 75% inter-coder reliability at this stage. After negotiation, we came to an agreement on a total of 97% of the categories (N=516). The categories we continued to disagree on were coded as "Other" and excluded from further analysis. Most of the message disagreement had to do with messages on the borderline. We considered adopting a policy of always choosing the more conservative code when this occurred, but after a few instances decided that it would skew the results too much. Often, the disagreement came down to a message where the intent was clear but it was not specifically mentioned in the message content. These are grey areas where we had to decide whether the attempt was obvious enough to warrant a code adjustment or not. Sometimes we could not agree and the message's code was omitted from the analysis.

These raw codes were entered into a spreadsheet and PASW Statistics 18 database for analysis. Each message author was assigned a user ID consistent across messages. The forum each message was posted into was also recorded as an integer between one and seven, corresponding to the order of the forums as they appear on the Citizen Sky web site. Additional data was mined from the message database software (MySQL) and web server log files to create variables for message length and date posted.

Table XI.
Coding schema (modified version of the Community of Inquiry scheme by Garrison, Anderson and Archer [2000]).

Elements	Categories	Examples
Cognitive Presence	Triggering Event (1)	Puzzlement, Questions
	Exploration (2)	Information Exchange
	Integration/Fragmentation (3)	Linking concepts (differentiation, unification), comparison
	Resolution/Dissolution (4) based on evidence	Accept/dismiss ideas
Social Presence	Reference to others (1)	Acknowledgement
	Open invitations (2)	Broad, generalized requests, humor, emotion
	Requests for collaboration (3)	Specific requests
Teaching Presence	Instructional management (1)	Introduction of new topic
	Building understanding (2)	Extending discussion
	Direct instruction (3)	Statement of action, manage/focus discussion, instructions

As an example of coding technique, the following are two messages posted to the forums. I describe how and why we assigned it a code in each of the three categories. The first is a longer message with more content and the second is a shorter message with more focused content. This first message was a reply to a question posted by another participant.

> It's great to have someone observing from India. I am the administrator of the 20/20 Vision Team (click on Teams link on the web site). This would be a great team for you to sign up and join. We deal with visual observing, making observations of naked

> eye, binocular, and telescopic variable stars. We even do some teaching on picking out and using telescopes. We also include all kinds of different celestial objects, like, the Moon, planets, deep sky objects, etc.
>
> I have been a variable star observer with AAVSO since 1973, and have made about 34,000 variable star estimates. I am also a middle school science teacher in Florida, USA.
>
> I will email Rebecca, our Citizen Sky manager, about your question on the certificate. Until then, please go on the Citizen Sky web site and join the 20/20 Vision Team. Good Observing. (User 81 – Posted February 20, 2010 to the Visual Discussion forum)

For the cognitive element, this message was assigned a code of 2 because it is providing additional information to a previous request for help. It was not given a 3 because it did not resolve the question (the question was forwarded to a project staff member). For the social element, it was assigned a 3 because this was a specific request for collaboration in that the original poster was invited to join a team. For the teaching element, it was assigned a 3 as well due to the fact that the author gave specific instructions to the original poster (go to the web site and join his team).

Below is a message posted in reply to a discussion about the possible existence of a secondary eclipse (which happens when the primary star eclipses a secondary star – basically the opposite of a regular eclipse):

> I would have thought that the diameter of the F star would be even more important for this? (User 591 – Posted February 9, 2010 to the Citizen Sky in General forum)

For the cognitive element, this message was assigned a code of 1 because it shows a sense of puzzlement. For the social element it was assigned a 0 because it did not directly reference any other person or message. For the teaching element, the two coders originally disagreed. One thought it was a 2 because it was extending a discussion and building knowledge. The other thought it was a 0 because it did not actually add any real content to the discussion – just asked a question with no context. In negotiation, the mutual agreement was to code it as a 0.

Results

Forum statistics

For the first stage in this analysis, I wanted to look at differences between messages posted in each forum. First, I computed the frequency and percentages of messages assigned a certain code in each forum (Table XII). For example, in the Citizen Sky in General forum 5% of messages were coded with a 0, 27% received a 1, 36% received a 2, 23% received a 3 and 9% received a 4. Due to

rounding, not all totals add up to exactly 100%. Next, I created histograms of this data with the results clustered around the codes in each category. Thus, there are seven cases in each cluster (one for each forum) and one cluster for each code (five for the cognitive element and four each for the social and teaching elements). The ordering of the forums in the clusters is based on the order they appear on the Citizen Sky web site (i.e. there is no special meaning to the order).

Table XII.
Distribution of COI codes across forums from a total of 172 coded messages.

Forum Title	Community of Inquiry Types of Presence (Percentage of posts to each forum)												
	Cognitive					Social				Teaching			
	0	1	2	3	4	0	1	2	3	0	1	2	3
Citizen Sky in General	5	27	36	23	9	20	50	25	5	16	16	32	37
Ad Infinitum	19	6	39	32	3	23	61	10	6	16	17	48	19
Visual Observing	18	8	34	19	29	29	46	22	2	8	20	50	23
Photometry	27	19	11	35	32	8	49	30	14	3	14	46	38
Spectroscopy	14	14	29	29	14	0	71	29	0	0	43	43	14
Data Analysis	0	10	20	50	20	10	30	60	0	0	0	90	10
Education and Public Outreach	0	25	50	15	10	5	30	50	15	10	10	80	0

Online Forum Discourse Patterns

Cognitive Elements across Forums

The top two forums with the most category 4 codes are the Visual Observing and Photometry forums (Table XII). As seen in Figure 14, these two

forums (forums 3 and 4, respectively) stand out the most. An example of a category 4 message in one of these forums is:

> This will work well just if the used terrestrial target is pretty far away (say at least a mile or better more). If its too close one will introduce a parallactic displacement that will require a fine adjustment on a star. For this Polaris is the best target as it doesn't move much. (User 1437, posted on October 12, 2009)

Notice the message uses evidence to answer an original problem.

The forums which are not technical in nature but dedicated to more social topics had the lowest cognitive codes. For example, the forum with the lowest number of resolution/dissolution (4) codes was Ad Infinitum, a forum open to the discussion of any topic – including topics not related to the project. The Citizen Sky in General and Education and Public Outreach forums were the next two lowest scoring forums in this element. Also, the Citizen Sky in General forum had the highest number of triggering events and queries (1). Finally, the forums that tended to have the highest percentage of resolution/dissolution codes in the cognitive element also are the ones that tended to have the lowest percentage of direct instruction (4) category codes for the teaching element, and vice versa.

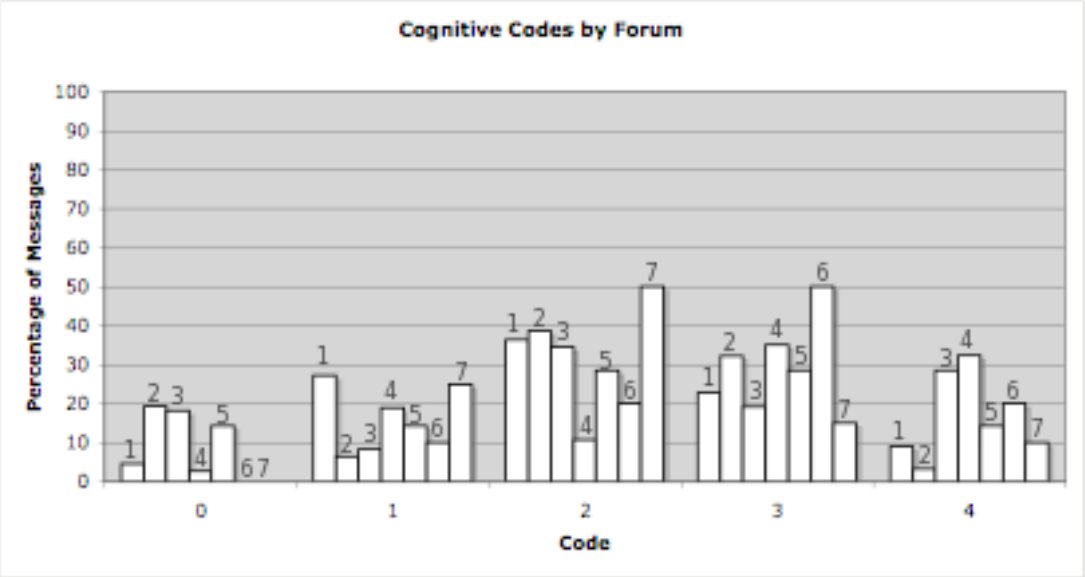


Figure 13. A histogram of the cognitive COI category clustered by the percentage of assigned codes for each of the seven forums. Missing bars represent forums with no assigned codes for that value. Forum 1 is "Citizen Sky in General". Forum 2 is "Ad Infinitum". Forum 3 is "Visual Observing". Forum 4 is "Photometry". Forum 5 is "Spectroscopy". Forum 6 is "Data Analysis". Forum 7 is "Education & Public Outreach". (N=168)

Social Elements across Forums

The social element codes display some of the strongest trends in the forums (Table XII; Figure 15). First, across all forums most of messages containing social elements were classified as references to others (1) and open invitations (2). Also, there is a reverse symmetry between the forums with a high percentage of category 1 codes and forums with a high percentage of category 2 codes. That is, forums 1-5 had high percentages of category 1 codes and forums 6-7 had high percentages of category 2 codes. Rarely did any forums have

category codes of 0 (no social presence at all) or 3 (specific invitation to collaboration). An example of a social element category 1 message is:

> [REDACTED],
>
> Your observatory sounds wonderful and your telescope's superb!
>
> :-) (posted by user 127 on June 20, 2010)

And an example of a social element category 2 message is:

> Hello Observers,
>
> I want to inform you of a great event that is absolutely lovely to observe. This is the Geminid Meteor Shower. The Geminids are one of the 2 best showers of the year, rivaling the summer Perseids. This shower produces 50-100 meteors per hour, and this years maximum date is just a few days before the New Moon, so there will be little to no moonlight to interfere. The maximum is scheduled for December 13/14, 2009, but is still strong the day before and after the maximum.
>
> Observers can submit good data for science. The American Meteor Society www.amsmeteors.org , of which I am a member, is eager to receive data and study it. Please use the AMS Recording Form attached, and when you have completed it mail it to:
>
> [REDACTED]

You can check the AMS web site for tips on how to observe. Good Observing. (posted by user 81 on November 24, 2009)

This pattern is largely the result of the codes in the Data Analysis and Education and Public Outreach forums. They have a relatively low number of references to others (1) and a relatively high amount of open invitations (2). Also, a number of forums have a high percentage of messages with messages assigned codes of 0, meaning no social content was detected in the message. Those are forums with lower levels of collaboration in the messages.

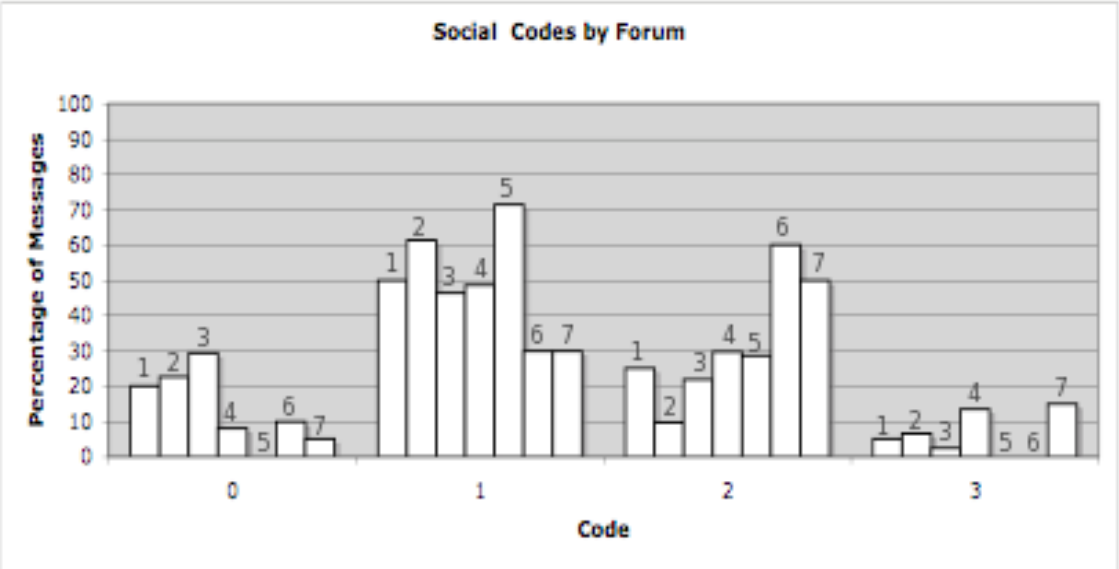


Figure 14. A histogram of the social COI category clustered by the percentage of assigned codes for each of the seven forums. Missing bars represent forums with no assigned codes for that value. Forum 1 is “Citizen Sky in General”. Forum 2 is “Ad Infinitum”. Forum 3 is “Visual Observing”. Forum 4 is “Photometry”.

Forum 5 is “Spectroscopy”. Forum 6 is “Data Analysis”. Forum 7 is “Education & Public Outreach”. (N=168)

Teaching Elements across Forums

Two forums dominate the teaching element: Data Analysis and Education and Public Outreach (Table XII; Figure 16). For these two forums, 90% or more of their messages were classified as building understanding (2) or direct instruction (3), with the vast majority being assigned a category code of 3. An example of a message classified as building understanding is is:

> The basic idea goes back to the times of Herschel and Norman Pogson, the father of the "modern" logarithmic magnitude scale.
>
> http://adsabs.harvard.edu/full/1968ASPL...10..145J
>
> I don't think I'll try this, I'm more into DSLR photometry. Still I think it might have some use.
>
> [REDACTED] (posted by user 591 on November 18, 2009)

That received a category 2 code because it was extending discussion (adding information – the URL is to a paper on the topic) but not ending discussion. An example of a classification as direct instruction (3) is:

> Hmm....
>
> Hi [REDACTED]
>
> This will work well just if the used terrestrial target is pretty far away (say at least a mile or better more). If its too close one will introduce a parallactic displacement that will require a fine adjustment on a star. For this Polaris is the best target as it doesn't move much.
>
> CS
>
> [REDACTED] (posted by user 369 on October 15, 2009)

That received a category 3 code because it gave specific instructions to solve a problem. Another dominant forum is Photometry, which has a high level of category 2 and 3 codes, but evenly distributed between the two codes (as opposed to having more 3 codes as the Data Analysis and Education and Public Outreach forums do). Here is an example of a category 2 message in the Photometry forum:

> I was using the V magnitudes for the companion stars and I did check off the "Transformed" checkbox when I submitted the data. I was originally going to select the filter as "Johnson V" since I did calculate and apply a TC. After thinking about it for a couple of minutes, I changed my mind

> and selected Tricolor Green, since that is more accurate.
>
> If it is considered valid to mark a measurement made with a DSLR and the Transformation Coefficient as equivalent to "Johnson V", then I"ll go back and edit the filter on my submission.
>
> -[REDACTED] (Posted by user 797 on March 11, 2010)

That message received a category 2 code because it added information to a discussion and suggested some alternatives, but did not specifically give instructions to others. Here is an example of a category 3 message:

> I think if you are using V magnitudes(sic) for the comparison star(s) and correct your measurements with a Transformation Coefficient, the better way to submit data would be to choose "Johnson V" as a filter (because the TC is calibrating the results to match V magnitudes) , but additionally tick the "Transfomed?"(sic) checkbox in the submission dialog to indicate that the measurement was taken thru a different filter.
> (posted by user 591 on March 11, 2010)

That received a category 3 code because it gave specific instructions (which was a reply to the thread that also included the category 2 message sampled above).

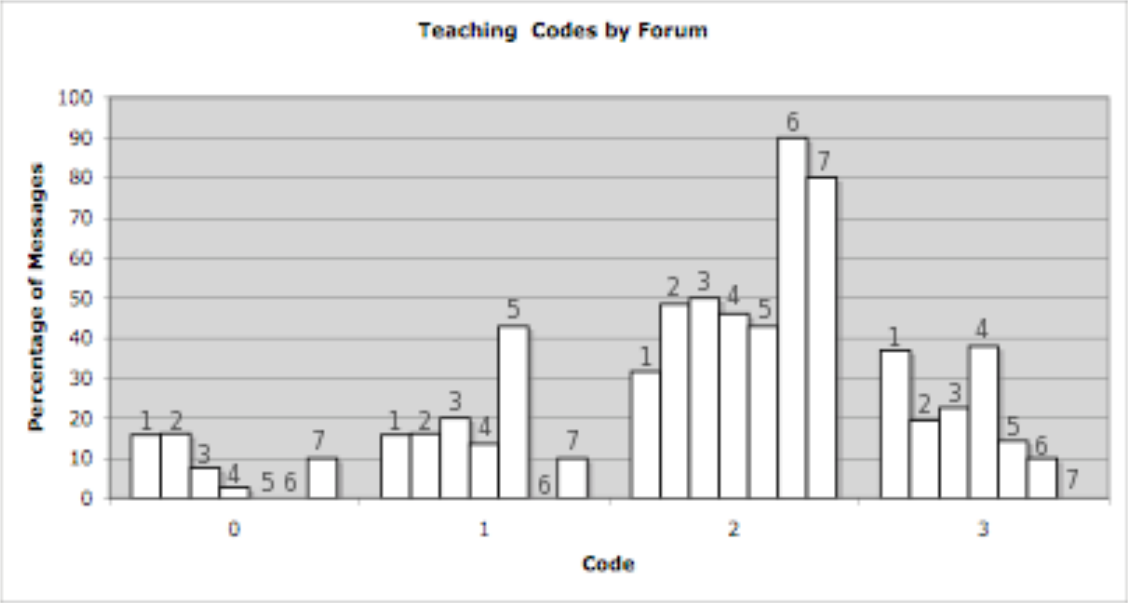


Figure 15. A histogram of the teaching COI element clustered by the percentage of assigned codes for each of the seven forums. Missing bars represent forums with no assigned codes for that value. Forum 1 is "Citizen Sky in General". Forum 2 is "Ad Infinitum". Forum 3 is "Visual Observing". Forum 4 is "Photometry". Forum 5 is "Spectroscopy". Forum 6 is "Data Analysis". Forum 7 is "Education & Public Outreach". (N=168)

Changes in Message Content over Time

I wanted to look for any changes in message content during the time period authors of the messages participated in online forums. Time was measured relative to each individual's participation in the project rather than to the project time line. I took the coded messages and calculated the difference between the day the message was posted and the day the author joined the project. The result is the number of days that the author was in the project when they wrote the message, hereafter referred to as a participant's "project experience". I calculated

the mean of all the project experiences and then divided them into two groups, before and after the mean. I ran chi-square analysis comparing the category code distribution of the less experienced group of the messages with the codes of the more experienced group of the messages. The chi-square test found no significant difference between the two experience groups for the cognitive or teaching elements, $\chi^2(4,108) = 1.611$, $p = .807$ and $\chi^2(3,108) = 1.938$, $p = .585$ respectively. However, it did detect a significant difference between the two groups for the social element, $\chi^2(3,109) = 11.07$, $p = .011$. Visual comparison of the distributions (Figure 16) clearly shows the change responsible for the difference. The percentage of messages with no social content (0) substantially increased in the more experienced group. This means that participants who have been in the project longer tended to post a greater share of their messages with little or no social content compared to those who were relatively new to the project. Recall that the social variable measures the amount of collaboration and referencing to others a message has in it (among other things). Thus, this difference could be because those who are experienced have already formed social bonds and do not need to specifically look for new friends or collaborators. While earlier in the project, participants are more likely to post messages asking for help, advice or otherwise being more open towards forming relationships with others.

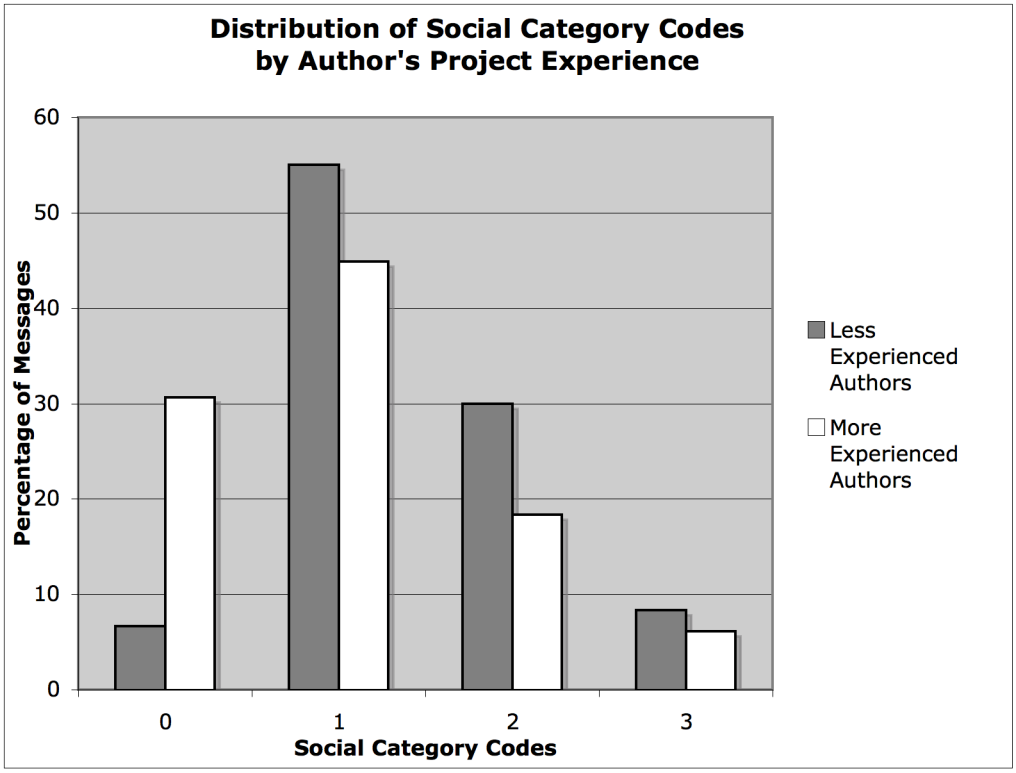


Figure 16. Comparison of social codes of messages divided into two groups using the split-mean method of the author's experience in the Citizen Sky project. (N=168)

I also wanted to see if there was a change in which forums participants posted to as they gained experience in the project. So I performed a similar analysis, but this time replacing the category codes with forum identity (Figure 17). Also, I used all messages in all forums (N=1,269) to increase statistical power since I was not restricted to messages that had been coded. First, I computed the project experience for the author of each message using the same split-mean procedure I used when comparing distribution of category codes over time. Then, I calculated the mean of all the project experiences and divided them

into two categories, before and after the mean. I ran chi-square analysis comparing the distribution of messages posted across the forums of the less experienced group with the distribution of the more experienced group. The chi-square test found a significant difference between the groups, $\chi^2(8, 1372) = 82.17$, $p = <.001$. More experienced authors tend to make a greater percentage of their posts in the Citizen Sky in General and Ad Infinitum forums than less experienced authors. Less experienced authors tended to post to the Photometry and Data Analysis forums, our two most technically advanced forums.

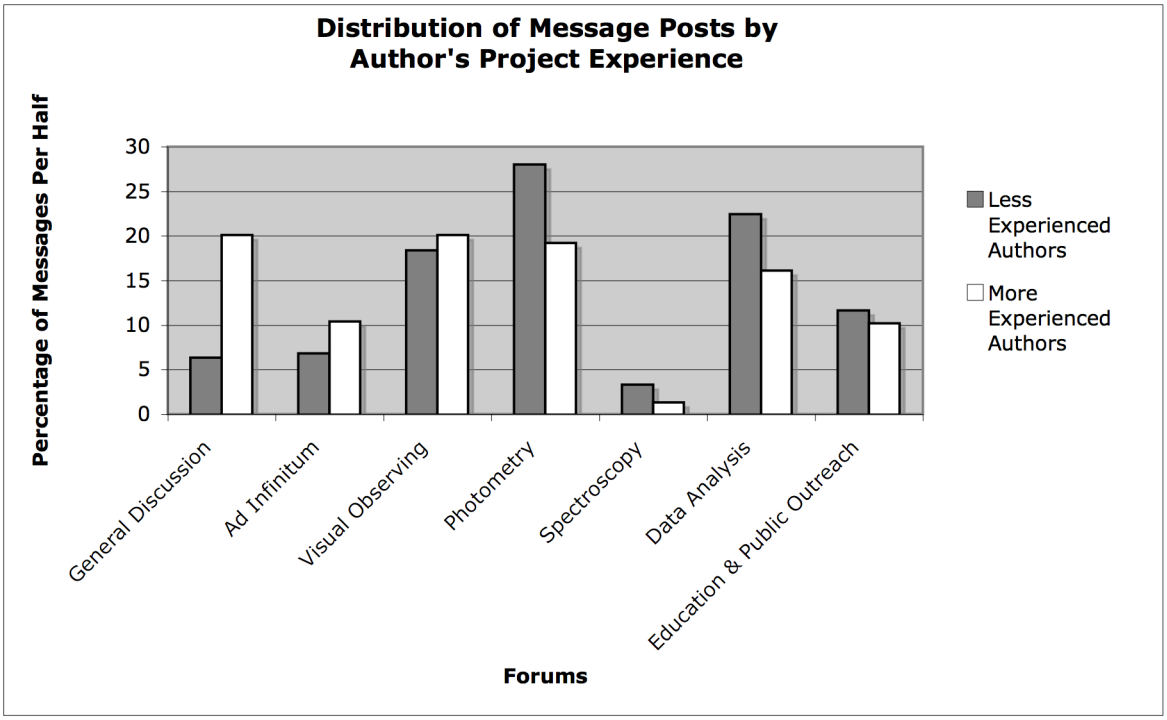


Figure 17. Distribution of messages posted to the seven forums divided into two groups using the split-mean method of the message author's experience in the Citizen Sky project (N=1,269).

I ran a chi-square analysis between gender and the three Community of Inquiry elements to look for differences in message content. No significant relationship was found with the cognitive or social element, χ^2 (171,4) = 4.304 , p = .366 and χ^2 (3,169) = .377, p = .945 respectively. However, the distributions of codes between men and women in the teaching element still came close to significance, χ^2 (3,167) = .433, p = .059. These results are likely affected by a skewed gender ratio as only 22 of the 171 coded posts were authored by females.

Message length across forums

Message length can also be used as a measure of complexity (Schrire, 2006), so I looked for a relationship between message length and project experience. First, I established a message length for each message in the forums by counting the total number of characters in each message, omitting spaces. As before, I computed the participant age for each message's author when the message was posted. I ran a Pearson correlation between the project experience of the author posting the message and the length of the message. No significant relationship was found, r = -.009, p = .778. I also found no significant relationships between message length and other demographic variables such as age (r = .077, p = .17) education (r = .035, p = .54), and gender (r = .103, p = .07). Only astronomy experience had a significant relationship. It was a positive, small correlation by Cohen's guidelines, r = .124, p = .03. This means that those who report higher levels of astronomical experience tended to post longer

messages which makes sense since they are likely providing answers to questions by others.

Summary

Online discussion forums are popular tools for science education, both of the formal and informal variety. The challenge of this study was to characterize whether learning may be taking place in forums which are part of a citizen science project. This required a flexible, exploratory analysis method. The use of the Community of Inquiry model has shown to be an effective framework for this study. It uncovered both expected results (the Photometry and Data Analysis forum messages have the highest cognitive presence) and unexpected results (more experienced authors tended to post more message in the less technical forums and those messages tended to less socially complex). In general, it shows that scientific competencies, as measured through the Community of Inquiry framework, can be detected in online discourse but, across the board, that they did not measurably change over time through experience in our project. Instead, the forums are used mainly as a support mechanism for other activities as opposed to a place where scientific knowledge is built on its own.

CHAPTER 5. DISCUSSION

The combined results from studies 1 and 2 provide a picture for the scientific literacy of participants in the Citizen Sky project in three aspects consisting of attitudes, beliefs and competencies. The first study describes the

attitudes towards science and beliefs in the nature of science of project participants, based on written surveys administered online and interview data. The second study describes evidence of scientific competencies occurring in online discourse. Together, they point to moderate increases in scientific literacy by participants. But the increases are limited to specific aspects of scientific literacy. In this chapter, I will summarize the findings of the two studies that make up the research portion of the dissertation.

Study One Findings

There are three interesting overall results from the first study. The first main result is that the project did not have an impact on the *overall* attitudes of project participants when you consider the attitude test as a whole. However, it did have some item-level impacts. First, it had positive impact on two measures of how participants follow science in the news. Second, it had a negative impact on their self efficacy concerning their knowledge of science and astronomy. However, our attitude test was not well aligned with our participants' response levels in that it shows a ceiling effect (see Limitations in Chapter 5). The second main result is that the project did have a significant, positive effect on participants' beliefs in the nature of science, mainly through more positive beliefs in the amoral, development and unified aspects of the nature of science. Finally, while I did find a relationship between Participant Communication and a change in overall attitude, the last important finding was the lack of significant

relationships with other project participation variables such as history of data collection, web site visits and participation in a research team.

Attitude towards Science

Interest in astronomy and science was very high on all of our attitude measures, as expected for a volunteer science project. Still, participant endorsement of the NEWS and ALREADY items increased significantly during their first six months in the project as evidenced by significant declines in their item difficulties. Interview data suggests that this change is likely due to participants sharing news items and news sources with each other via the project web site and online forums. Participant endorsement of the KNOWLEDGE item decreased significantly. Interview data suggests that this is not due to participants' losing (forgetting) knowledge but rather that they are becoming aware of how much they do not know. This is an important effect since it speaks towards the fundamental relationship one has with science. One of our interview subjects coined the term "boundaries of ignorance". I think that is an apt description of the process.

The increases in attitude are not significantly related to a variety of factors regarding participation in the project. These factors include the number of observations of the star the participant has made, whether they are part of a team and how much they communicate with other participants. Nor is it related to demographic factors such as age or gender. The lack of an age effects is not surprising as there is no real literature suggesting that in today's world age has a

relationship with informal science learning (although this could be more due to lack of studies on the subject). The lack of gender effect is not surprising giving 1. the strong overall attitudes of participants who are predisposed to support science likely overshadows any underlying gender differences and 2. this project has a relatively unequal distribution of gender roles (18% female, 82% male), meaning that gender effects based on groups with unequal sample sizes may not be well estimated.

However, I was surprised that the Participant Communication variable was not more significantly related to change in attitudes. Modern conventional wisdom is that collaboration and social factors are key to learning about science (Vygotsky, 1964), including science learning done online (Linn, Davis & Bell, 2004). Also, anecdotally, I find a strong relationship between the most successful participants and how active they are in online discourse (even though there are always a few loners who work quietly yet turn out fantastic results). However, perhaps this should not have been a surprise after all. A recent study of motivations of participants in another online citizen science project found that only 6% of them joined for reasons related to "community" or working with others (Raddick, et al. 2010). This could also be a result of limited sample size. Developing an instrument to measure scientific attitude is a big challenge. Psychologically, changing participant attitudes is more difficult to measure than changing cognitive level outcomes. While there is no significant interaction effect between time and any of these tested variables, the interaction between time and team was approaching significance (p = .181) and it comes even closer when you

add Participant Communication to the interaction ($F[2,70]=2.293$, $p = 108$). Looking at the differences between the three Participant Communication groups (Figure 9), it appears that the low participation group is the group closest to showing a significant change. This may be because they are lower in scientific attitudes to begin with and have more room to change.

Even though I detected change in specific types of attitudes toward science, I cannot say that I found an overall change in attitudes. This is consistent with earlier literature that also did not find a change in attitudes by participants of a citizen science project (Brossard, et al. 2005). Their conclusions were that their instrument was not sensitive enough. Their instrument had only four items and allowed for undecided responses – which received high scores. I increased the items, and chose a more sensitive analysis procedure, but I did not include an option for undecided (although they did have the option to not answer, which a few exercised). It also had a large ceiling effect since it was designed mainly for the general public and not amateur astronomers. I believe the proper response is to work more diligently to create a better instrument to assess attitudes. It needs to go through rigorous content and construct validation and probably would need to be a stand-alone assessment due to its length. I also need more items that match the project's participants' level of attitudes and to make an effort to improve content validity by covering more attitudes.

There are a few possible implications for this and other citizen science projects interested in increasing scientific attitudes of their participants. One is to build self-efficacy goals into the project. It seems "the more they know, the more

they don't know" applies to this project. This is a good thing because participants learn about boundaries to their knowledge. This should be explicitly recognized so that they can be open to learning more. But participants should not be overwhelmed by what they don't know and scared away from the project. Providing adequate scaffolding can be critical here, especially for projects with complicated arrangements and significant barriers to entry, such as ours. Second, the projects can be tied closer to other formal and informal education opportunities. In this data, I do not see a significant change in people's reported attendance at lectures or their likelihood to participate in other citizen science projects. Yet there are plenty of opportunities for overlap between this project and others (especially in astronomy). With the release of our planetarium show, I hope to build more ties with museums and science centers. But the project has little to offer teachers, professors, lab managers and others associated with formal education. More cross-disciplinary ties may go a long way in increasing attitudes, especially with regard to use of science in everyday life and habits. Finally, the relationship with intra-participant communication and news gathering is clear in the data. While it is not clear that the relationship exists in the time domain (or whether it is simply something brought into the project at the beginning), this is a strong hint that differences do exist somewhere between people who communicate at different levels. This is especially evident in the interview data. Future citizen science projects may want to build in lessons about how to critically read science news articles. Further research into this aspect may uncover interesting relationships between the social nature of citizen science projects and

their ability to influence change in attitudes. Future citizen science projects would be wise to build such research into their program design.

Belief in the Nature of Science

Beliefs in the nature of science by participants, as measured by the NSKS, increased slightly over the first six months of participation in this project. This increase is unrelated to any of our project participation variables or demographic variables. Investigation of change in the six subcategories reveals the change was mostly associated with the four subcategories of which participants already had a high endorsement. The two subcategories with the weakest endorsement (creative, parsimonious) are the two that showed no clear significant change. This suggests that project participation is serving to reinforce previous beliefs, rather than restructure them. Interviews showed that interpretations of scientific creativity vary widely and that lack of understanding of the parsimonious items may have contributed to those lower scores. More precise definitions and wording of items in both categories may raise their overall endorsement levels, but it is unclear whether it would have affected any rates of change in the subcategories.

The amoral group of items showed the greatest positive change. This was somewhat surprising since issues of morality or value judgment are peripheral to the Citizen Sky project, if there at all. Most of the interview responses on this subject agreed that this was an inconsequential part of the project. My only possible explanation for this change could be the fact that modern culture is emphasizing the amoral aspect of science more and more with ongoing debates

over such political issues as evolution, human cloning and global warming. And these issues are being discussed in our online forums. In fact, a thread on global warming topic appeared on our discussion forums and turned into one of our most hotly debated topic. The discussion mostly focused on the scientific aspects of the debate (for example, the responsibility of scientists to release data to the public) but, nevertheless, political views were shared and opinions were strong.

Much of the potential behind citizen science projects rest in the assumption that they will increase how people understand science as a process (Cohen, 1997). Our data shows that largely to be true, but through reinforcing existing beliefs rather than changing them. Another study of a citizen science project also found overall high beliefs in the scientific process by participants, but it was not a pre/post-test design so it is unclear whether the participants brought that belief into the project with them (Trumbull, et al. 2000). Their questionnaire was also Likert-based, but with the neutral option removed. They also asked only a handful of questions that covered items related to the NSKS developmental and testable categories. They found more disagreement in their responses than we did, however this could be due to more extreme wording in their questions. For example, one item on their test was "The results of an experiment will be the same each time it is conducted" which is an extreme version of the NSKS item that said "Consistency among test results is a requirement for the acceptance of scientific knowledge." Both items are trying to get to the same fundamental aspect of the scientific method: repeatability. But disagreeing with the former item does not have to necessarily be incongruent with belief in consistency as an

important factor in the scientific process (different results could mean minor differences that don't affect overall theory, such as new tests coming up with more precise measurements, but not different enough to challenge accepted theory).

My results differ somewhat from a more recent citizen science study about monitoring bird houses. Brossard, et al. (2005) gave out pre-tests to those just entering their program and post-tests at the end of the program (a separation of 4-10 months). But they could not do a paired-analysis due to anonymity requirements. Their tests included four Likert-formatted items related to the process of science and one open-ended item asking the participant to explain what it meant to study something scientifically. They found no significant difference between the two tests, nor between the post-test and a test-effect control group who participated in the program but did not take the pre-test. They suggested that the baseline between tests was not long enough to detect real change and/or that since the primary motivation to join the project was an interest in birds, participants did not view the project in a scientific light but rather as a knowledge-building exercise (i.e. a hobby). This is backed by Raddick, et. al's motivation study that shows only 12% of their participants joined the Galaxy Zoo project due to an interest in "science" or "discovery". On the other hand, this project specifically refers to the scientific process throughout its training methods and marketing materials. In fact, Citizen Sky recruits by focusing on the scientific aspect and telling participants that they can work with and even become real

scientists as part of the project. So this level of meta-cognition may explain why this study finds more of an increase in beliefs.

Project Participation Level

Another third (non)result is the lack of a relationship between various project participation measures and change in attitudes towards astronomy and science and belief in the nature of science. The Citizen Sky project is designed to give participants a chance to participate in every stage of the scientific process with the belief that this greater engagement will increase their scientific literacy. Anecdotally, Citizen Sky staff hear all the time (and I see in some of the interviews) that this is a new experience for participants and they are doing things they did not think possible and seeing things from new perspectives. However, measures to support these anecdotes have been elusive. For example, one may expect to find a relationship between the number of variable star observations submitted to the database (the "active observer" variable) and belief in the testable aspect of the NSKS since the very nature of variable star observing is to combine lots of data from independent sources. However, I find no such statistical relationship in our data. Other research on citizen science projects have also found that contributing data did not increase participants beliefs in science (Trumbull, Bonney, Bascom & Cabral, 2000).

One possible culprit could be it takes much more than participation in data collection for participants to gain new insight into science. Initially funded as a 3-year effort by the NSF, the first year of the Citizen Sky project was always

planned to be based on building infrastructure and collecting data (although many participants have gone much further on their own). The second and third years of the project will be focused on other aspects of the scientific method such as developing research questions, data analysis, writing research papers, etc. with far more emphasis placed on the team aspect – which our data here shows may be among the most important aspects of the project, in terms of its effect on scientific literacy. Finally, as the project continues the sample size of the post-test participants will increase. Correlations with the pre-test data (N=~1300) alone reveal additional project activity variables with small but significant relationships with the test data. This data was not included in this study because it does not represent change, however it is possible that the same variable relationships will be seen as significant in future pre- and post-test comparisons, as the sample size increases.

Study Two Findings

Forum Content

A few things stand out when looking at the cognitive element. First, the Photometry and Visual Observing forums had messages with the highest level of messages that integrated new information into a discussion and/or then resolved it. These are forums where participants are trained (largely by each other, with some staff input when needed) in how to collect data for the project. So there are lots of threads that can get quite technical and lengthy (Appendix B). Second, the less technical forums had the most messages categorized as triggering a

discussion and/or adding information to it. For example, the forum with the lowest number of assigned category 4 (resolution) codes was Ad Infinitum, a forum open to the discussion of any topic – including topics not related to the project. The Citizen Sky in General and Education and Public Outreach forums were the next two lowest scoring forums in this element. Finally, the Citizen Sky in General had the highest number of messages categorized as triggering events and queries. This makes sense considering it is the forum that new participants usually post into first when they join the project.

The teaching element codes show some of the strongest trends between the forums. There is a reverse symmetry between the forums with a high percentage of category 1 codes, involving instructional management, and forums with a high percentage of category 2 codes, which reflects building of understanding. That is, forums that were higher on one were lower on the other. This is related to the distribution of codes in the Data Analysis and Education and Public Outreach forums. This could be because those forums are more focused on team activities than the others. That is, team building usually takes place in those forums and the majority of teams that currently exist are either analysis or outreach teams. Thus, there is a higher number of posts related to collaboration, which are assigned higher codes in our framework. Though, interestingly, the Data Analysis posts did not have any *specific* requests for collaboration. This is likely because the data analysis training of the project did not begin until after data collection for this study concluded, thus the conversation was more related to

throwing out general ideas and discussing feasibility rather than starting specific analysis projects.

Another interesting trend is in the number of forums with a high percentage of messages with no social presence detected. In the Spectroscopy forum, for example, almost a third of the posts had no reference to other people or collaboration. Spectroscopy is a cutting edge technology for amateur astronomers and only a handful of amateurs in the entire world know how to acquire and process scientific grade spectra. Thus, this forum is far less active than the others and consists mostly of messages with factual information and references to other web pages in them. There are very few threads that actually involve in depth discussion.

Two forums dominate the teaching element: Data Analysis and Education and Public Outreach (Figure X). As mentioned previously, the Data Analysis forum is really used to float ideas and learn more about analysis and the science behind the project. So it makes sense that most posts would be about building understanding and less about management or direct instruction. Teachers and outreach specialists dominate the Education and Public Outreach forum. The vast majority of the discussion that occurs there is about experiences participants have had in performing outreach on behalf of the project. Another forum with high teaching codes is Spectroscopy. This is a brand new topic for most people and is dominated by people posting questions (which would receive a category 2 code – building understanding) and others answering with references to web pages and other resources (which would receive a category 3 code – providing direct

instruction). There is very little discussion (usually assigned 2 codes) because there is little participant knowledge in this area.

Change over Time

When analyzing all the messages in all the forms, only one of the COI elements showed any change over time – the social element. This was surprising because I expected that messages posted by participants would become more cognitively advanced (because they would know more about the project and have more sophisticated issues to discuss) and/or more instructionally advanced (because more experienced participants would be helping out the newer participants). Not only is it a surprise that the social presence is what changed, the direction of change was also unexpected. The content of the messages did not become *more* social. Instead, they became *less* social. As seen in Figure 4, the distribution of the social element codes between the more and less experienced groups is almost the same except for the number of messages assigned a category 0 code. The difference is substantial, reaching almost a third of posts by more experienced participants. To look for meaning behind this, I scanned all the messages that were assigned a social code of 0. Of the 18 messages, nine of them were reports about an observing session. Three typical examples follow:

> Sample Forum Post 1: I saw the Orion nebula and the bee cluster I looked at EA and it looked even less brighter than the 38 Comparison Star….

> Sample Forum Post 2: I have gotten two morning data points in H and J on eps Aur, both of them last week. I stayed up all night and waited for it to rise high enough (about 15 degrees) to get good measurements. This was at 4 AM EDT, by 5 AM, the sky was beginning to lighten. No issues with early morning fog. I did get some data on a few other stars during the overnight, as well.
>
> I remember when I was young I thought that it was great to stay up all night-- its a whole lot tougher now:-) I think that from here on out, I will just get up early instead of staying up all night.
>
> Sample Forum Post 3: I suppose it was the reflection from a satellite.

The explanation for the lower social codes by experienced observers could be that they are simply observing more and thus posting more anecdotes and stories about their observing sessions. It takes some training to learn how to observe a variable star, and the first few sessions tend to take a long time (mainly due to the challenge of finding the star field). But after you have done it a few times, you can make an observation very quickly. Typically the first observation may take half an hour, but the 5th or 6th may take a few minutes. So more experienced observers tend to make observations more efficiently and frequently.

In addition to the change in social presence, there is also a change in the forums where the messages were posted. More experienced participants tended to post a greater percentage of their messages to the Citizen Sky in General, Ad Infinitum and (to a lesser degree) the Visual Observing forums. This could also be a result of participants posting observing anecdotes, since they could be logically placed into any of those three forums but would not fit in well in the other forums. But there may be another reason as well. The biggest jump is in the Citizen Sky in General forum. In the last six months of the project there has been considerable press coverage and discoveries announced regarding epsilon Aurigae, including the Nature article published in April, 2010. A look at the recent thread topics in the forum finds a number of them are about various news articles. So the increase in posts may be partially attributed to a reflection of news coverage of the project. Since the frequencies are based on author experience, and not overall date of posting, I doubt this explains all the difference. However, the project did have more participants join the project in the first half than the second half (though not by much) of the year, so this could be partially responsible for the change in message content – along with the tendency to report observing activities.

Also, I investigated change in message length as a measure of content complexity. I found no significant change in the length of messages posted by less or more experienced participants. We did find a relationship between message length and astronomical experience, suggesting more complex messages posted by those with a more advanced astronomical background. This is not a surprise

result by itself, but does provide support for using message length as a measure of complexity (Schrire, 2006).

I did not find a gender difference in the content of the messages posted. Previous studies of online discourse found women to be more collaborative (Blum, 1999) and men more social (Barret & Lally, 1999), which would appear as differences between messages coded as 2 or 3 in our social category codes. Yet we find no such difference.

Altogether, these results point to the usefulness of discussion forums in a citizen science project. Also, they illustrate the usefulness of data mining to look for trends in posting statistics, as suggested by Dringus & Ellis (2005). The online discourse in this project seems to be aligned most closely with the social aspects of scientific education. This is in line with modern science education constructivist principles (Vygotskzy, 1980; NAP, 2006) that suggest the social element is critical to science education. We did not find many non-null results for the cognitive and teaching COI categories. This may point to some limitations of using online discourse as an educational tool. Finally, the minor modifications we made to Garrison, Anderson & Archer's (2000) COI framework were useful in coding messages in our forums and I feel they would be useful to others interested in applying the COI framework to online discussion forums used in informal science education.

In summary, this study showed that scientific competencies, as measured through the COI framework, did not change much through participation in this project. What little change that was detected was largely related to the social

aspect of the framework and the result of more experienced participants asking fewer questions in the technical forums and discussion anecdotes and notes in the general forums. Also, the topic of individual forums can have a major impact on the competencies found within the forums. Thus, it is important to carefully design a forum structure that is aligned with the educational goals of the project.

Summary

The results are somewhat limited by sample size, a result of the relative young age of the Citizen Sky project. However, significant effects have been shown relating to an increase in attitudes (specifically, how people learn about science news), beliefs in the nature of science (participants original beliefs become stronger) and a nuanced increase in the social presence in online discourse over time. Surprisingly, none of these effects are found to be related to project participation variables (ex: observational activity, visits to the web site, etc.).

CHAPTER 6. CONCLUSIONS

There are many ways to measure the impact of citizen science projects on scientific literacy (Bonney, et al. 2009). In this study, I chose to measure change in scientific literacy by looking at attitudes towards science, beliefs in the nature of science and scientific competencies as seen through online discourse.

Recommendations to Citizen Science Practitioners – Scientists & Educators

Future citizen science projects that want to influence attitudes toward science may want to emphasize social aspects of the project. This data show that participant attitudes were affected by their direct communication with others in the project. Participants interviewed also found that aspect to be one of the most rewarding and unique to this project. With modern technology, setting up mechanisms for online social interaction is easy and does not require a great deal of oversight. Modern content management systems such as Drupal or Joomla are free and have built-in support for features such as personal blogs, wikis, discussion forums, chat rooms (text, audio and video), and much more.

Future citizen science projects can be expected to have a modest impact on the beliefs of the nature of science of their participants. According to the results of this study, this effect will be mainly reinforcement of current beliefs. Future data may shed more light onto what specific participant actions have the most impact on this change. Since this result is not found in the literature, I can surmise that it is the result of something unique to our study. I suspect it is either due to the use of a more detailed instrument that has been well validated in the literature (NSKS) and/or the fact that our project makes a conscious and clear attempt to engage participants in the entire scientific process, therefore encouraging participants to think about the process itself, instead of just focusing on the scientific context of the project. Thus, applying some meta-cognitive aspects to future citizen science projects may prime participants to think more about the scientific method.

There are a few possible implications for citizen science projects interested in increasing beliefs in the nature of science. First, participants need to

be challenged on their beliefs (as opposed to the tendency to "preach to the choir") so as to create Piaget style disequilibrium, opening the way to learning. These types of eye opening events may help address the trend we noticed that beliefs tended to be reinforced by this study rather than changed. Secondly, emphasis can be placed on scientific content that expresses creativity and parsimony since these are aspects least understood by participants (at seen in this project). In addition to careful definition of scientific terms (to avoid jargon-based confusion), it would make sense to discuss creative and parsimonious processes. For example, every citizen science project begins with a scientific research question. Other citizen science projects have found that participants sometimes have trouble understanding their role in the entire project (Evans, et al., 2005) I suggest project designers also include a clear and comprehensive description of the back story to the project in terms of 1. Strategically, how the scientific field evolved over time to come to this question and 2. Tactically, how the scientists leading the project came to the idea to involve citizen scientists to help them answer the question. Discussing those issues in depth, and focusing on the decisions made by various key players, may help participants understand the important of creativity in scientific endeavor. In some ways it comes down to lifting the veil of science and increasing transparency.

Recommendations to Researchers

Rigorous, empirical research into the effects of citizen science projects on their participants is a field poised for rapid growth, but realistic levels of funding

is needed to support it. The biggest challenge to collecting data on citizen science projects stems from the fact that they are volunteer projects, thus there is little incentive for participation (and those who do participate in the research will likely generate a selection effect in favor of more active participants – something we attempted to address in this project by inviting inactive participants to take our post-tests). In this project, we built in a substantial budget for compensating study participants. This worked well as finding participants was not difficult. By offering a chance to win gift cards we received over a thousand survey responses. And by promising gift cards to those interviewed, almost everyone who was asked to participate agreed. Another citizen science project found that offering books autographed by scientists was enough to entice participants to volunteer to be interviewed for research purposes (Raddick, et. al, 2010). Thus, my first recommendation is to set aside a portion of a project's budget for research stipends.

A second recommendation involves analysis methods. Both future and past education research studies in citizen science may want to look into applying the Rasch model to their instrument data. Since citizen science is, by its very nature, a volunteer effort it is very important to design measurement instruments, which are as non-invasive as possible. Indeed, we received many complaints from participants regarding the length of our instruments and other citizen science studies have found low response rates to surveys (Brossard, et al., 2005). Thus, instruments with Likert scales are likely to continue to be popular since they are quick to administer and easy for participants to understand. However, when Likert

raw scores are included in analysis they are, at best, a coarse measure. This study has shown one example of how the Rasch model can be applied to Likert data to make it fit the needs of traditional social science quantitative analysis methods. The literature is full of many others (Linacre, 2002; Bond & Fox, 2007). Rasch analysis allows the data to be thought of in terms of developmental and not just descriptive aspects (Callingham and Bond, 2006). This will require more advanced preparation as Rasch requires some assumptions basic GLM models are less sensitive to, such as unidimensionality of the instrument. However, with some basic pilot testing a Rasch-supported instrument could be easily developed and will help with a more sensitive analysis. It is possible that the lack of impacts reported in the citizen science education research literature could be due to the limitations caused by analysis of raw Likert scores. Applying the Rasch model may unmask some positive results hidden in previously studied data.

Also, a cross-disciplinary citizen science research journal is needed. Performing the literature review for this study was particularly challenging since every scientific discipline has its own ecosystem of journals. Since citizen-science has one foot in the natural sciences and one foot in the social sciences, it can be difficult to design a well-balanced research project that fits in a single field of research. For example, research on education outcomes will likely be published in educational research journals – meaning that scientific content will often be ignored. The same will go for papers published in scientific journals, which will be forced to marginalize the learning aspect of the project. In the best citizen science projects, the line between the citizen and the scientist can be blurred to

such a degree as to be indistinguishable (Indeed, from my anecdotal experience, if you ask participants what they prefer to be called you'll get responses ranging from "volunteer" to "amateur" to "scientist" to "professional" and, if you make the mistake of asking in a public setting, a passionate debate will likely erupt.). The same goes for the best research projects. Drawing an artificial line where one does not naturally exist will limit the research results (Brossard, et al., 2005). A research project that measures both components at the same time will give a multidimensional analysis of the project's impact. Luckily, there is a movement afoot to try to create such a journal (Raddick, 2010b). However, the journal will have to guard against the trap many new journals face of wanting to support its field of research so much that it has relaxed standards and a selection bias towards self-reported and anecdotal studies with positive results.

Finally, astronomical citizen science projects need to be studied more. As a "gateway science" (Duestua, Noel-Storr & Foster, 2009), astronomy provides a context for interdisciplinary teaching that the public generally finds fascinating (Fraknoi, 2005). Yet, the NSF-sponsored CAISE inquiry group did not include an astronomer on its panel and astronomy citizen science projects received a single sentence of attention in its 58-page report. This is despite the fact that astronomy citizen science projects are among the most highest profile projects in the media and have the most participants (GalaxyZoo alone has hundreds of thousands of participants). This could be because astronomy, historically, has been a "gentleman's pursuit" with little to distinguish the professional from the amateur. A coherent and sustainable professional community of astronomers did not

emerge until the middle of the 19th century. Thus astronomy may be seen by others as a different beast altogether from stereotypical citizen science projects where professionals lead the citizens. That is not always the case in astronomy. Yet it is precisely this reason why it needs to be studied. The astronomical citizen science projects in astronomy have among the most active "citizens", who sometimes act mostly on their own, with very little professional guidance yet delivering professional results. I hope that this study has opened eyes towards the scale and complexity of some astronomical citizen science projects.

Finally, instruments need to be adapted for adult audiences that are already interested and knowledgeable about science. Most instruments in the literature are developed for children in formal educational settings and were validated accordingly. In order to advance research in informal settings, new and targeted instruments need to be developed.

Limitations

There are many limitations to this study, the biggest being the limited sample size. We have a large number of pre-surveys (N=1,385) but a small number of post-surveys (N=125). And while we have a large number of messages to analyze (N=1,269), we have a small sample of corresponding authors (N=124) meaning most messages were posted by a smaller group of people. As the Citizen Sky project continues into its second and third year, that situation should improve as data collection will continue through the end of the third year. Many of the relationship tests that were not significant were actually quite close.

It is possible a larger sample size will detect more relationships (see: Future Research). Also, the overall project evaluation is planned to take three years. This study only involved the first six months of the project. There may be more change detected after participants have been working for three years and entering the more advanced stages of the project.

Another limitation relates to the Rasch analysis. Since the vast majority of items and persons on each of the two tests fit a Rasch model, I can assume that there is a single underlying construct being measured. However, I cannot assume that there are not other factors at play as well. Factor analysis, once I have a larger sample, would be a prudent test.

The Rasch analysis also clearly displayed another major limitation of the study. My attitude test was too easy to agree with. It was more aligned with attitudes of the general public than attitudes of those who are already self selected to be interested in science. I should add more difficult items, such as "Children should be able to pass a basic astronomy test before graduating high school.", "I am a scientist." or "I apply what I know about astronomy to daily life activities.".

There are some limitations brought on by technical difficulties in the project. First, due to problems with the web server configuration, some items on the tests were not required to be filled out, meaning that some items had lower N, which affected the ANOVAs. For example, I wanted to analyze the difference between participation in the synchronous chat rooms and the asynchronous discussion forums. But an error in the surveys prevented synchronous chat room

activity from being recorded for the first few months of the project. This left me with a very small sample that could not be studied.

Finally, my biggest regret is that I do not have a measure for change in scientific knowledge. I originally designed such a measure, but due to time limitations I did not pilot it properly. Therefore, the final data was not consistent enough to be analyzed. This is one of the only measurements suggested by the CAISE group that is missing from this study. This ties into an overall difficulty I had with conceptualizing project participation constructs. I haven't seen that measured in the literature before, so this is a first attempt. Finally, scientific literacy is a beast to measure. It can mean anything to almost anyone, so I had to establish my own definition. Yet it is the dominant outcome that leaders in the field want to see measured.

Future Research

The most obvious avenue for further research is to simply continue collecting data for the next two years. This study included pre- and post-test data separated by six months and discourse data for the first year of the project. The project is funded for three years, with the possibility of further funding. Current plans are for participants to take the same tests two years after they joined the project and to include discourse data from years two and three, to perform a longitudinal study of longer-term effects on scientific literacy. I would like a measure of scientific content learning as well. So I will likely design an instrument to measure knowledge about astronomy and variable stars.

A look at some of the close, but non-significant, effects may provide some hints as to new research directions. First, there was almost a significant interaction effect between Participant Communication and time on the attitude test scores ($p = .108$). The possible effect was largest with the Low group in the Participant Communication variable, meaning it is possible that with further study focused on this (less-communicative) group more effects could be detected. Secondly, gender was almost significant on the attitude ($p = .133$) test, so more focused research on gender could be useful. This may be especially true in the online discourse analysis, which included few messages authored by women. Finally, and perhaps most tantalizing for me, is that the Team variable is an almost significant fixed effect in the attitude scores ($p = .104$) and as an interaction effect with the Participant Communication variable on the NSKS scores ($p = .104$). We had relatively few team members in this study since that phase of the project doesn't begin, in earnest, until the second year of the project. Yet that was one of the focuses of our project design, based on the hypothesis that collaborative teamwork will affect scientific literacy more than solo work. I greatly look forward to researching the effects of team participation on scientific literacy once the project is done and we have a maximized data set.

Outside of Citizen Sky, there are a number of research avenues suggested by these results. The first, obvious, route is to attempt to replicate this study using other online citizen science projects. Since the field is new, there is little empirical data out there. I would especially like to see more Rasch analysis of survey data and the development of an attitude instrument for online projects. Secondly,

online discourse analysis holds great potential. But most of the protocols and frameworks are based on formal education settings and are based on assumptions that are not valid in informal settings. My study is a first stab at taking a formal framework and adjusting it for an informal setting. However, we need a much larger study of discourse analysis in order to find a common framework to analyze online discourse.

Appendix A: Pre-Test Instrument

About Us | Get Started With... | Communicate | Data | Teams | Search

Citizen Sky

Home | Contact Us | FAQ | Blog | Forums | Teams

View the Survey

View the Survey

Thank you for taking a minute to fill out our survey.

Gender
- Male
- Female

Birth year:
2005

The country that you live in:
Please Choose One

Enter your zip code:

Your highest level of completed education
- High School
- Associates Degree
- Bachelor's degree
- Master's degree
- PhD or equivalent

If associates degree or higher, enter your major:

Level of astronomy experience
- Have never participated in an astronomy program before.
- Novice with very basic astronomy program experience.
- Intermediate Level
- Advanced level experience in astronomy, but not in a professional capacity.
- Professional astronomer, astrophysicist, etc.

Your profession:

Please choose the one item that best represents your current feelings about the statement:

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I am interested in news about astronomy.	○	○	○	○	○
I will pay attention if an astronomy news item crops up in a media source I am already following.	○	○	○	○	○
I actively seek out stories about astronomy in the news.	○	○	○	○	○
I am likely to attend a science seminar, class or talk.	○	○	○	○	○
I use knowledge of science to evaluate claims made about science.	○	○	○	○	○
I use knowledge of science in everyday life.	○	○	○	○	○
I plan to participate in other citizen science projects in the future.	○	○	○	○	○
I am interested in science.	○	○	○	○	○
I am knowledgeable about science.	○	○	○	○	○

Please Complete the following sentences:

I am interested in the Citizen Sky project because...

aaron_testing_survey's Menu
- Teams
- Blog
- Forums
- Recent posts
- My profile
- Log out

Please Complete the following sentences:

I am interested in the Citizen Sky project because...

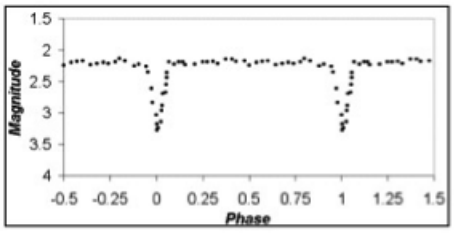
My biggest reservation concerning participation in this project is...

Please choose the column that most closely describes your feeling of the statement.

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Scientific knowledge is stated as simply as possible.	O	O	O	O	O
The laws, theories, and concepts of biology, chemistry, and physics are related.	O	O	O	O	O
The applications of scientific knowledge can be judged good or bad; but the knowledge itself cannot.	O	O	O	O	O
It is incorrect to judge a piece of scientific knowledge as being good or bad.	O	O	O	O	O
If two scientific theories explain a scientist's observations equally well, the simpler theory is chosen.	O	O	O	O	O
Even if the applications of a scientific theory are judged to be good, we should not judge the theory itself.	O	O	O	O	O
A piece of scientific knowledge will be accepted if the evidence can be obtained by other investigators working under similar conditions.	O	O	O	O	O
We accept scientific knowledge even though it may contain error.	O	O	O	O	O
Scientific knowledge expresses the creativity of scientists.	O	O	O	O	O
Scientific laws, theories, and concepts express creativity.	O	O	O	O	O
The evidence for scientific knowledge must be repeatable.	O	O	O	O	O
Today's scientific laws, theories, and concepts may have to be changed in the face of new evidence.	O	O	O	O	O
A scientific theory is similar to a work of art in that they both express creativity.	O	O	O	O	O
There is an effort in science to keep the number of laws, theories, and concepts at a minimum.	O	O	O	O	O
The various sciences contribute to a single organized body of knowledge.	O	O	O	O	O
Scientific knowledge is a product of human imagination.	O	O	O	O	O
Biology, chemistry, and physics are similar kinds of knowledge.	O	O	O	O	O
Scientific knowledge is subject to review and change.	O	O	O	O	O
Scientific laws, theories, and concepts are tested against reliable observations.	O	O	O	O	O
Those scientific beliefs which were accepted in the past and since have been discarded, should be judged in their historical context.	O	O	O	O	O
Consistency among test results is a requirement for the acceptance of scientific knowledge.	O	O	O	O	O
Scientific knowledge is comprehensive as opposed to specific.	O	O	O	O	O
The laws, theories, and concepts of biology, chemistry, and physics are interwoven.	O	O	O	O	O
A piece of scientific knowledge should not be judged good or bad.	O	O	O	O	O

How do you know if a star is a regular star or a variable star?

In what way(s) does epsilon Aurigae differ from our Sun?
Please use scientific evidence to support your answer:



This is a light curve of a variable star. Is it an intrinsic or extrinsic variable star? (Choose One)

- ○ Intrinsic
- ○ Extrinsic

Explain why you chose that answer:

How can you tell if a 'star' in the night sky is really a star or is really a planet?

Submit Form

*Sky & Telescope Illustration by Casey Reed

Privacy Policy | Contact Us | Affiliates | About Us | Participant Sites
International Year of Astronomy | American Association of Variable Star Observers (AAVSO)

Appendix B

Interview Transcripts. See chapter 3 for description.

Interview #1

Question	
Prior Astronomy & Difference w/CS	more people involved than in planetary work... i would say easier because there are more facets that you could follow along. There are more things to be interested in.
Amoral	I think that scientific research should be an end in itself...
Creative	Some of the groups that have started, like the 20/20, i'm a visual astronomer. To have a group say lets get the visual astronomer working with the photometer astronomer was an idea I wouldn't have thought of. So the creative aspect was pretty important there I think... i've never tried doing light curves before, but I've done the 10 star tutorial tutorial and did some light curves with that so it's pretty cool that after 10years in the hobby I'm still finding new things to do.
Developmental	its the literature that is being presented or historical purposes, and its being compared with what we know... i think i am getting a lot more out of it because of that reason.
Parsimonious	when i read science literature, it is trying to explain things in a holistic fashion but to really understand it holistically you have to understand the parts... what i've been reading on the web site I think is a good combination of both. what i read in the literature is saying that historical perspective adn they are trying to tlk about which stars - this is more difficult questiont han I thought...(laugh) I think my interpretation is that I'm learning more about variable stars as a whole than about epsilon aurigae. in some ways it maybe very specific, but i'm trying to generalize it... i enjoy reading both types of posts.
Testable	some of the articles that have been presented, or sites checks, have talked about the past but also some of the current research being done...
Unified	more or less... im looking at one aspect of variable stars and then i'm looking at another aspect in the posts or on the web site. maybe its my interpretation of what i'm reading but its getting me more interested in other aspects of astronomy that I may not have been... i think you can enjoy the pieces of the puzzle more if you can see the whole picture at the end. i like seeing how everyone's thoughts take them to seeing different aspects of this particular star.
Attitude 1	Seek: i havent had a lot of time to put into the hobby, so its only been this month over the last year that I've had time to spend on it. I havent had as much time as I like to spend on the hobby.
Attitude 2	Interest: I've started following the variable stars more than I have befor. I used to look at them just to see the brightness change. But now I'm following them to ee their cycle and i've done more with variable stars because of citizne sky.
Attitude Misc.	Other: i'm enjoying it more than i thought i would, so i would definitely get involed in more projects like this.
Role	Trying to bring visual photometry into the fold. I'm strictly a visual astronomer...
General Comments	My daughter and I are doing the project together...

Interview #2

Question	
Prior Astronomy & Difference w/CS	I've participated in many amateur astronomy group projects but nothing that was target to people from the outside who would otherwise come to an astronomy group or conventions... there has been a lot more preparation of the people involved with background information and planning and ways to engage the project whereas those projects among amateur astronomers there tends to be an assumed level of knowledge - even if it isnt there (laugh)
Amoral	i believe it is possible to measure what people consider to be amoral or moral and one can apple, one can judge whether an action based on scientific information is closely aligned with the prevailing morality over time. I read that science doesn't provide any independent standard of morality... scientific knowledge, when we speak fo scientific results or scientific understanding that is something that is a condensation from experience and if you try to take that condensation back into the worked that is another process and that is no longer a result of the scientific method... it is an application so i do think there is a distinction between applications of scientific knowledge and scientific knowledge itself. i do not think i can think of a single instance where this has been issue in citizen sky.
Creative	the creative element has been somehow interfered with.. there is a natural initial suppression of the creative element by the communication of what people knew about this objects coming into the citizen sky project. So i think there is a tendency for people to worry that they may disagree with experts or published results. especially if you aren't a full-time astronomer who makes their living and reputation by interpreting observation... so there is a tension of course between bringing somebody into an interesting project which needs background, techniques and all that and to a certain degree disagreements of interpretation or suspicions of what might be happening or what might not be happening. So to that extent I think it would be unnatural to think that you could create astronomy out of whole cloth for people who have not done it before without fulfilling a naturally potential suppressing the initial creative urge... some of he understanding before citizen sky started was that there was over interpretation of the data, which I think was eye opening for the people at the time (laughing) that astronomers and scientists just do the best job they can at the time.
Developmental	I do see it on display [in the citizen sky project] i have seen certainly even at the very first meeting we were being treated to results that were right off the press, that were opening people's eyes to why you can come back to a question and give it more attention and make progress. you have new techniques , more precise data, you have the awareness of people that epsilon aurigae gets pretty close to the horizon at long periods of time therefore the data may not be so good at those times... there have been many instances where i think people's awareness of limitations of past knowledge has been increased. one of the overwhelming feelings i get is how much we don't know. so many times

it's more like in what direction to move your boundaries of ignorance, as opposed to your boundaries of knowledge. we tend to take on problems we have the opportunity to make progress on.

definitely, i think the whole business of describing the occulting object and the system itself in the fewest number of accurate parameters is one of the goals of citizen sky - to have both improvements in the data and improvements in the interpretation to produce something that is more accurate but more light weight.

Parsimonious

I do see it in terms of the ability to take the experiences from this particular eclipse and decide what - based on this particular eclipse's data lone - what is the most probable model of epsilon aurigae. and then be able to take that back and be able to compare it with (garble) and account for the differences you may be able to project or predict to the past eclipses and what people concluded with the same data before.

Testable

Only in terms of the unity of the effort for precise results and for improved understanding. i think it is fair to say there are some systems the most difficult to figure out tend to be exception in some way. and they tend not to be representative of every system. they can be information but not necessarily representative. and so i do think that while figuring out epsilon aurigae is an interesting and useful endeavor and will perhaps help us understand the extreme of binary star evolution or dusty discs or something like that, it doesn't project all the way to figuring out dark energy cosmology. and so it isn't infinitely connected in my mind. there is a degree of, whats the word i want to say, there is even a horizon beyond which it just doesn't influence n any measurable way our understanding of other things. follow up Question: I think every person I know who wants to be a professional scientists wants to be the one that increases that number [of laws, etc.]. the forces aren't coming along as much as they used to, so there is certainly more of a skepticism to ideas being introduced. there is more of an appreciation than an "effort".

Unified

News: it isn't greater or lower than before simply due to the nature of my ongoing interest in astronomy.. but just in participating in it i've learned things about interacting with other people and assumptions about sort of the knowledge and the interpretation skills of other people.

Attitude 1

Other: I see much - when I'm viewing potential projects to take on I see a greater capacity for the involvement of people outside of the lab and the university and the astronomy club.

Attitude 2

Attitude Misc.

Conveying the underlying meaning of statements people make and the degree to which certain claims and can be trusted or not. I think that I'm able to convey to people uncertainties that are too easy not to see if you take everything at face value.

Role

General Comments

Interview #3

Question	
Prior Astronomy & Difference w/CS	Nothing on CitSky level that I can remember, though I have gone to many astronomy events. My Dad introduced me to it, and the whole 'mysterious dimming star' thing really interested me.
Amoral	There isn't much malicious use for why a star dims
Creative	In the part I participated in, it was just gathering data so other people could do the creative part of explaining the data. So I didn't do much of the creative stuff but there are definitely other people who did.
Developmental	Definitely. The whole thing was about figuring out a new explanation for why the star dimmed even if there wasn't any explanation before.
Parsimonious	Yes. Hundreds, maybe thousands of people were making observations so that the people organizing the project could come up with one concept to explain all of them. Granted, they are all similar observations, but still.
Testable	The project was about 'testing' -- gathering data on the star -- to find which theories could be true. There were a bunch of different theories on how and why the star dimmed. AP: Have you seen those theories change during the course of the project? User: Yes. There were a bunch of different theories initially- star itself varies in brightness, star has planet blocking light, star has dust cloud blocking light, etc, etc, etc. But at the end, a bunch of theories had been cut out by the data.
Unified	This project was mostly limited to astronomy. So no. Not much to unify it with.
Attitude 1	News: I have become more interested in astronomy stories since starting out. Before, I was not so interested in astronomy. There just weren't many big questions there. This project kind of gave me the heads up of that, that astronomy still existed and that there was a lot more waiting. It felt good to be back to figuring out life, the universe, etc. Well, at least the universe.
Attitude 2	Knowledge: I definitely have more knowledge. I do feel more confident about it now, probably. It's been updated from before, and I haven't come across anything telling me that this factoid that everyone thinks is incredibly cool after I tell them and which I have related to everone is actually not true after all. That's actually happened a lot before. AP: okay.. your experience is showing that you trust what you are learning? User: Yes, I do trust what I am learning here, having gathered a bunch of data myself.
Attitude Misc.	Mostly gathering data. I go out at night, when it is freezing cold even for Edmonton... Try to find and focus on the star with binoculars ... Find the comparison stars and compare brightness ... then come back inside and enter the data into my excel chart and onto the site. Its actually not that bad, i'm just very good at complaining, as my dad and sister will attest.
Role	
General Comments	

Question

No.
This is a first for me. I have submitted data...
e.g. for Jovian satelliet timings but not this kind of project. AP: What is it about the CS project that makes it unique for you? What are the elements that you have never done before? User: For me, the unique elements are:
1. The opportunity to contribute directly to the software toolset of a scientific community.
2. Related to 1., the chance to apply my software development skills to that.
3. More broadly, the blend of amateur/citizen astronomers and professionals.
4. Also, for me, I'm learning an enormous amount about variable stars that I never knew much about before.
International collaboration is great too, but I have done that before in other contexts.

Prior Astronomy & Difference w/CS

Yes, certainly.
The investigation into the nature of epsilon aurigae is, from my perspective, amoral.
We're not trying to understand Eps Aur in order to create some new technology, but because we want to understand the true nature of the system.
That in turn will help us to understand other similar systems, protoplanetary disks etc. In general, contribute to the store of knowledge.
Perhaps the only sense in which we attach goodness values in this context is when we ask questions like "Is this data likely to be in error?" or "Does that hypothesis have a good fit with the observations?" But those are different questions from ones like "Is the data we are collecting somehoe harmful or beneficial to people?"

Amoral

Yes.
For example, when I read Brian K's literature reviews and other commentaries, there's definitely creativity on display. It's not just a restatement of facts or 2nd hand information.
The development of tools like VStar involves some creativity.
The recent planetarium trailer video obviously involves artistic creativity and communication skill.
In general, discussions in the CS forums in which people are coming up with alternative explanations for aspects of eps aur.
It's not just about deduction or induction...

Creative

Yes. The obvious manifestation of that is in the progression of ideas that can be seen in the literature. BK's lit review shows the progression of models over time. This also became clear to me when I was preparing my talk for ASSA in Feb this year.
(sorry for the speed; I'm typing, stopping, thinking, deleting...)
When the Spitzer data came in, it added weight to a particular line of thinking about the nature of the system.
So, I think the key thing in CS here is that it involves the use of data (basic, from observers and more exotic, like that from Spitzer) in

Developmental

conjunction with theoretical models/hypotheses in order to inch closer to the "real model" of the eps aur system.
AP: Have you seen any progression with your own knowledge?
User: Sure.
In at least a couple of areas.
1. I have a better appreciation of the different kinds of variable stars and some of the characteristics of their light curves.
2. I'm learning more about data analysis in this context as a result of asking questions and experimenting with data.
3. I'm getting back to having a go at visual observations again. So that's a more practical skill I'm re-learning.
4. I knew essentially nothing about eps aur before CS. I've learned a lot about that.
Probably nothing too generic about Science that I didn't have some exposure to before.

When I think of "minimum number of concepts..." I think of Ockham's Razor.
(hang on, my son is calling out; be right back) AP: In the survey, you disagreed with the following statement more than any other statement: "There is an effort in science to keep the number of laws, theories, and concepts at a minimum." Can you describe to me how you feel about that statement? User: I suspect I may have been thinking about the ideal state toward which Science in general wants to tend vs the likelihood of achieving that ideal state in practice. So, I feel that as per my allusion to Ockham's Razor earlier, this is a goal of Science. An extreme example from Physics is something like a Theory of Everything in which a goal is to unify all the forces so that they could be stated in a small number of equations from which could be derived everything else in principle. Or the explanatory power of Natural Selection vs the lack of explanatory power of ID. So, I actually feel that, in Science in general, this idea is a good one. If I could come back to the unfinished but related CS question...I think we see this principle at work, again, in discussions like "what components could account for the composition of the disk?", or "what effects could account for the mid-eclipse brightening?" In those cases, the idea of finding the simplest set of things that could account for the observations seems to recurr.

Parsimonious

There's a couple of things here... In the first workshop, it was clear that different professional astronomers held different views of the relative merits of the hypotheses under consideration (e.g. the "party line"). But alongside that was often repeated statements like "when the data comes in..." and "...this s why your data is so important..." and "we're not sure which one of these explanations is right yet..." So, a key thing I took away was that the theoretical explanations are barren with the empirical data with which to test them against.Re: the last part of that statement: "Consistency among test results is a necessary, but not a sufficient condition for the validity of scientific knowledge."... Different tests using different sets of empirical data may point to a theory as being the right one. But there may come along some other piece of data that is inconsistent with 99% of the tests and calls into question the validity of the favoured model/theory. I'm trying to think of a CS example.
AP: How do you feel about this statement: "Scientific knowledge is comprehensive as opposed to specific."?
User: Mid-eclipse brightening comes to mind wrt the possibility of it being explicable by effects external to the system. (that was the tail end of the

Testable

	last question; a bit half baked) Regarding, Scientific knowledge is comprehensive as opposed to specific... Well, I think that much scientific knowledge is very specific.But there's both breadth and depth.A biologist knows infinite detail about the creatures or plants specific to his domain of research. Ditto for the astronomer, as witnessed by the detailed discussion of details about eps aur and many other var stars.But scientific principles can also be very broad, e.g. those of physics and chemistry which apply to all other areas.Then there are the mathematical techniques and models that underpin all of this. It would be nice to say that the Enterprise of Science was a single consistent whole, but of course there are in practice "silos" and different approaches. But the Scientific Method is common to all disciplines. I think I've strayed into that with my last response. In the context of CS... One example from CS is something I mentioned before, and that is the idea that a better understanding of the structure and origin of the eps aur disk could contribute to our understanding of how planetary systems formed. AP: yeah, there usually are not neat boundaries between these aspects User: yep In CS we have a pile of different techniques that are all trying to help us "get there", e.g. the photometric data reduction techniques and subsequent data analysis.But those are more like the practical techniques used within the current discipline. I do strongly support the sentiment expressed by the statement above. The unique importance of science is the explanatory power derived from testable hypotheses and the use of empirical data. It's clear that borders between disciplines are often artificial and there is movement across the borders. It's the best hope we have of understanding the world. And I do see Citizen Sky as embodying the core principles espoused here.
Unified	
	News: I may have said that because I have less time to seek out material at the moment. I tend to read specific sources that allow me to gain as much info as quickly as possible, e.g. while I'm eating my lunch at work I read general news headlines, Sky & Telescope, xkcd/Dilbert :), Slashdot, and programming language related blogs and sources. I will tend to read Citizen Sky posts at night when things are a bit quieter. So, I think what I'm saying is that my focus is very much on things astronomical these days, and learning more about var stars and related matters, but that I am increasingly choosy about what sources I read due to a lack of time (too much coding to do).
Attitude 1	
	Everyday: Yeah, I think, if anything, apart from a daily (or a couple of times per week in some cases) dose of Sky & Telescope News, I tend to be focussing on more specific aspects of astronomy. Mostly because of VStar I suspect. Apart from the whole general "lack of time" thing.
Attitude 2	
Attitude Misc.	
Role	
General Comments	

Interview #5

Question	
	In astronomers without borders. It isnt just the science thing but its connecting people together. Getting people from across the world and connecting them together to share astronomy stuff. The team I have here, southern gems, half the people on the team are from astronomers without borders but the other half is from citizen sky who joined us. My thing that i've been doing mostly is trying to get these, you know, organizing the team and getting them - keeping them going, and encouraging them and things like that. and, um, i don't know it just has the same kind of feeling i have when i do things with astronomers without borders, which is also connecting people to do astronomy projects. AP: Do you notice any difference between those two groups of people? User: Maybe a little bit, with a couple of them. Yeah, um, I think there - but as we've gotten going i really feel like people on the team care about each other - some are more talkative than others and, of course, some are more active than others because they're - they have more expertise. I think it is quite a bit the same now. At the beginning there was a bigger difference, because some of those people actually maybe knew each other a little bit. Working together on a project you get to know each other. You star to, you know, um, I don't know its just a kind of bond that is created when you are working on a project together.
Prior Astronomy & Difference w/CS	
	No, not really because i thoroughly believe is what you get is what you get (laughs). So,um, and i dont see anything i havent seen anything that really struck me as being you know amoral (laugh) or that had any moral issue to it that I can think of.
Amoral	
	Certainly this thing we are doing with the southern gems feels like a very creative project. Even though what we're coming up with is actual you know, stuff that people can use, it was still having to use creativity in how we're going about finding things and how we go about working together. yeah i think there is a lot of creativity needed. AP: Do you feel like the southern gems project is a science project? User: Oh, yeah. Definitely. AP: In the science questions you have to answer in order to do your project, do you use creativity to answer those questions? User: Coming up with those ten stars, to come up with those ten stars that we were going to use which had several different parameters we had to consider. We had to look at more than one thing. we couldn't say take the ten brightest stars. No. There were things to consider like how they spread out across the sky, do we have a variety of types of variables here, what is the range of brightness, can these be seen by people not having to use binoculars through most of the light curve. All these things we had to consider and we had to really kind of ask lots of questions about different ones to try to clarify which ones were going to work best and we come to an agreement. So i think... Imagination: I think you do need imagination, actually, in order to think up some of these possibilities. but then once you've done that of course you have to be very like coming up with different possibilities, you need to throw out all kinds of ideas. But to test them you have to be objective and use kind of like the analytical side of your mind.
Creative	
	My gut feeling says yes but I'm trying to think of examples (laugh). Certainly ti think the growth of probably a lot of people in our southern gems group - quite a few of were quite beginners. And not that we aren't still beginners but I know that I've learned some things from other members in the group who were already at a higher level. You know,
Developmental	

about different types of stars but also about the kinds of things you need to look at to decide about the star - such as here is a star that you might have some problems observing with it and why, and how what you could do to make this more accurate and stuff like that. These were things that I had no idea. And Sebastian was really, help this group a lot, to understand a lot more about how to observe these stars. I think you are asking about how we discovered this theory and it led to that, but i don't think I can give an example of that. It's too.. i don't have an an example for that. But i do see a lot of learning taking place. We do have a fair number of real beginners in this group who have not been able to do quite as much towards the project yet, but really want to. And maybe they will be able to help this project by trying out the tutorial after it is finished. And some of them are going to do translations. One thing I've really learned is that when you are doing science it si really helpful to have a team. It is really helpful to be able to throw ideas out there and bounce them around each other and have people with different expertise's that can clarify things that you might now have understood completely. or to see something in a different way than someone else did. I was a teacher so I've been on teams, but this one was different. It was much more satisfying. We have people from all over the world and working towards this common goal that -its just been so much fun.

I think they were probably trying to do that with the epsilon aurigae theory. The people who are actually doing the photometry or whatever on it, like, I would assume that's something that we would be striving for with the theory about what's causing this eclipse and the mideclipse and all that. AP: Since the beginning of your participation in the project until now, do you feel like your understanding of the current theories of the epsilon aurigae eclipse have become simpler to understand or simpler to explain to other people? User: I dont know if they' become simpler but I feel like more research has actually been done... so its looking like they're getting closer to what might actually be happening so I feel a little more confident telling people about what they think is happening.

Parsimonious

We're having to come up with data and see if it is consistsent with the theory. Yeah, I certainly think that is true. AP: Have you been involved in any astronomy project that had the same type of theory that had to be tested - the same type of experience you are having in the Citizen Sky project? AP: No, I really haven't but I'm liking it (laugh) - alot. I've always wanted to do something with science but I havent had the opportunities... so this is like a real um you know, an opportunity that I wouldn't have gotten otherwise and I think it is great. And I want other people to have this opportunity that is one of the reasons I wanted to um do things with citizen sky and astronomers without borders - to make it available to people all over the world. I think it is really important for more people to experience science beacause if that happens then there will be more people willingt to fund things and the general public a lot of them just have no clue and if they're involved in more things like this then I think they'll be more apt to say yeah we need to fund more things like NASA and stuff like that. They're so removed from everything but if they can be invovle din a program like this then I think its really good for science itself.

Testable

Well I certainly see it in astronomy in general because there all kinds of things - chemistry is really necessary if you want to understand stuff having to do with astronomy, geology is important, yeah i think they are

Unified

interrelated and you might find out something in one field of science that

can certainly affect a theory you have - even in biology. I can't really think of any examples [in citizen sky].

Attitude 1

Minimalism: I know they are trying to come up with a theory of everything and all that. But I guess just thought that if you aren't willing to throw out a bunch more of ideas you may miss something. And one of these people who like to brainstorm in this crazy way and have these wild ideas out there because sometimes they become really good ones. (laugh)

Attitude 2

News: I was doing that even before citizen sky. i read about astronomy and physics and other science stuff all the time. Its my favorite thing to read. I'm fascinated by all the aspects of astronomy. AP: Have you seen any integration of recent news in the citizen sky project? User: The epsilon aurigae stuff [the chara announcements] i've seen stuff in sky and tel about the epsilon aurigae thing. I've seen it in a lot of places. I don't think I've seen a lot of things about citizen sky in general, just mostly about epsilon aurigae. BUt I'm putting the world out there to everybody - worldwide. Seek: Of course I've always eagerly read any of those subscription posts from citizen sky. I put my thing in there so everyone of them that comes out comes from me. I would say that I don't know that its changed any of the publications that I go to. But I'm still very actively seeking stuff that has to do with astronomy and cosmology or even things having to do with geology that might affect aspects of astronomy. All of the sciences really, not just astronomy. Attend: Definitely. I've always have liked to, but now I feel more confident. Having the opportunity to go to the one in chicago gave me confidence and being able to go to the next one I'm sure is goign to give me even more confidence. and its encouraging me to do some things I wouldnt have done before. For example, I've always had this fear of math. (laugh) Math fears are probably the reason why I didnt go into astronomy or science in the first place. Not that I was horrible at math, but I really was scared of it. And so I've kind of gotten a little less fear thinking its going to be related to something to do with astronomy so I think I will try at least. So I'm hoping to learn how to dosome of this analysis. And Inever would have tried to do that if it werent for citizen sky. So that is probably, maybe that is one of thebig changes from before I did citizen sky and now. The other is the confidence I'm feeling at being a leader. Because I feel like maybe things arent going full blast at our team but I feel like people are working together, people are happy, people are trying to put forth whatever they can and we can put together something we are proud of. And I'm feeling good about being able to be a leader in that respect which I've never been able to do before. Those are two really big things that have changed for me, I think.

Attitude Misc.

I see myself as an educator, someone who spreads the word on the project and maybe a team leader. And I'm hoping once something starts happening here with epsilon aurigae again that I can go out and do some observations. All I've done is work here and going out there and telling other people about the project and getting them involves and working on this team and that's kind of been what I 've done. It isnt what I set out to do but its how it evolved. I really do what want to get to learning how to do observations.

Role

interest in science: Yeah, its made it even greater. Because its become a

General Comments

pretty important part of my life (laugh). These people - its partly the

people too its not just the science, it's the combination of the two. The excitement of being part of creating something. You've couldn't have found a better project for me to work on. I really enjoy trying to get other people working on the citizen sky stuff.

Interview #6

Question

The NASA and Berkeley StarDust@Home project. I've been a charter duster (laugh). So that is one thing I've done. And then I have been a fairly avid amateur astronomer in thelast 20 years but that did not involve any specific project. I'm happy to report with delight that the citizen sky project spurred a broader interest in the AAVSO so I've broadened by observing program so I've contributed a number of observations and to a data validation project. One difference... is that Citizen Sky seems to have been launched by a specific event, namely the epsilon aurigae eclipse, but as an outgrowth of a well established venture - the AAVSO, with the potential to expand citizen sky beyond epsilon Aurigae. Whereas stardust@home is a project that involves around one space mission and task. With StarDust@Hoem the aerogel collectors are finite so we know which have been scanned and not so its a closed ended project in that respect.

Prior Astronomy & Difference w/CS

I would say yes. I dont recall seeing anything on there that would seem to imply any specific moral judgement one way or the other about the endeavor of making the observations, recording them and feeding them in an aggregate database.

Amoral

In the whole process of going about and enlisting broad based public participation and generating observations i think was a stroke of genius. Its something that was definitely novel, innovative and a unique part - another aspects that comes up that may not be a direct part of citizen sky but is a broader part of the global involvement of scrutinizing the epsilon aurigae eclipse is that some of the origination of some of the information has been disseminated through the citizen sky web site - the first direct imaging of the disk - even getting information out and coming up with those ideas as a way to explain the data we have seems to me is a direct display of creativity and I've also seen, maybe not specifically to citizen sky project... that some of the ideas that have proven correct have been advanced in part on aesthetic grounds. Given that there may be several possible theories that fit the data, what is the most elegant or beautiful of the choices comes up quite a bit in the process of advancing the theory.

Creative

Lets see, uh, I guess I would have to say potential so more than directly so at this stage of the project. Um, and I guess what I mean by that is I've been participating in the project and following its progress over the past months what I've seen is this stage where most of the effort is focused towards the necessary grunt work of just compiling the data. At some point we'll have enough additional data -newer data - then it becomes possible to go back to analyzing it and coming up with some

Developmental

refinement on what was able to be concluded from the previous database. So I would say that I anticipate seeing that aspect as being one of the fruitful outcomes of citizen sky and that process is currently underway but hasn't yet manifested itself in any finite way. Consistency: Inability to replicate a result would call the result into question and going back years for an example that would be the work on cold fusion... i think that is a very important principle that is essential to preserving the factual integrity or intellectual consistency of scientific knowledge. At the same time, I perceive that there is risk of a misapplication of the principle in the sense that the awareness of the principle can provide some scientists with incentive either to reject new experimental results for an established database or a theory has been popular or accepted. That can create therefore some irrational degree of resistance to potentially valid data and.. retard scientific advance.

Parsimonious

One of the main contribution of the citizen sky project into the broader scientific community is to expand the observations being brought to bear on the study of this eclipse. So, in a way, a major motivation of the project is the principle of repeatability of observation. Repeatability: It is likely to be true in the long run but there are many examples in science where personalities, vested interest or politics have delayed the acceptance of independently validated multiple observations that went against a particularly perceived (?) theory. 22:20

Testable

I have seen it on display probably more in the blogs and posts online than in the direct structure of setting up and recording observations themselves. At the same time I would also say that the concept that you describe there underlies the entire citizen sky project in terms of the motivation for establishing the project and determining how the project fits into the global scientific endeavor. AP: Would you consider it an interdisciplinary project? User: (laughs) that's a very good question. partially yes and partially no. It is certainly interdisciplinary in that it is actively soliciting involvement from people in all walks of life and the direct activity of making and reporting observations, though, is fairly narrowly confined to one discipline. On the other hand, in terms of potential I see interdisciplinary links because the approach that has been utilized in the project can be applied to a variety of disciplines. Not necessary all disciplines.. i imagine someone could identify one where this approach wouldn't work so well, but there are many where it would. And in terms of the kind of information being brought together in the citizen sky project I could well imagine that the applications of what's going on could span several distances.

Unified

News: I think the main factor was for citizen sky I got more involved in the broader observing programs of the AAVSO and that sort of generated - i should preface it by saying for the past four years due to a variety of obligations combined with the long severe winters Wyoming has i began to neglect my astronomical hobby... when i began observing variable stars and analyzing stars with zapper that rekindled my interest. And at the same time I became aware of other exciting discoveries, including the direct imaging of the disk around epsilon aurigae i thought was quite dramatic and things like that resulted from... i came across it completely by chance and that has led to alot of this other involvement and interest.

Attitude 1

	Everyday: One thing that comes to mind, and it may not be the only thing that comes to mind, I should mention that I am about to turn 58. (bike racing example) My son is going to school and attending scientific courses and talks and hearing about what he is learning which in many cases is well beyond what I had heard, has also sparked interest in science.
Attitude 2	
Attitude Misc.	
Role	
General Comments	

Interview #7

Question	
Prior Astronomy & Difference w/CS	No, nothing that wasn't specifically public outreach.
	I would say yes. The goal to me is to acquire knowledge about epsilon aurigae. I seem to recall there being a survey on citizensky.org where that was one of the topics addressed.
Amoral	
	oh wow, yes. There are so many different ways to acquire the photometric data, many, including the use of dslr, have largely been pioneered in this project. Friends of mine and I get into discussions all the time about what you're goal should be when processing an image. Should you go for the aesthetic, or scientific accuracy? In the case of this project, scientific accuracy is critical to the success of the project. However, typically when I image, I am doing it for my own personal satisfaction, so I want the picture to look pretty. I know some people who go to great pains to remove meteors from their pictures, which decreases the scientific value of the final shot, yet increases the aesthetic part to them...for me, doing so hurts the aesthetic as well, so in a lot of ways it is a matter of preference. The scientific accuracy however doesn't have or shouldn't have any variability to it.
Creative	
	As a teacher, I often have a very difficult time explaining this concept to students. I do see this aspect on display in the project. The theories about what we know regarding Eps Aur have changed significantly since the mystery was first noted. Even since the project started it has changed with the announcement that there is in fact, spectral evidence of a companion star, which caused a refinement on the mass estimate of the parent body. Did I say that right? Main body I think would have been better there.
Developmental	
	That's a bit harder to wrap my head around, so I'll have to say yes. The Eps Aur system is very complicated. A simple free floating disk that periodically passed in front of it would have been nice, but then with the hole in the middle...a consistant hole that get larger and more defined as time goes on made it harder to model. So more data was needed to find a better model that worked and fit all the detectable parameters. AP: Do you see the epsilon aurigae theories as increasing or decreasing in simplicity? User: At first it was decreasing it seemed. The discovery of a companion star in the disk however greatly simplified
Parsimonious	things. Which was kind of the whole point, there has to be something

	explains all the quirkiness of the system in a more simplified way. All the questions brought up at the conference seemed to come back to one thing...but there is no evidence of a second star
Testable	yes, you cover this with the ten star tutorial to make sure that everyone is submitting their data in the same fashion. With the check system included in the website to weed out erroneous data (such as students entering in a visual magnitude of 10.5 just to get a grade) you are able to preserve the integrity of the data. I remember that being of great concern with some of the teachers that students would just make up data and enter it. Consistency: I agree with that statement. I wouldn't say that the feelings have changed. My father is a chemist and I'm a science teacher, so that almost comes with the territory. Repeat: Yes, I agree with that statement and no, they have not changed as I've participated in CS.
Unified	Citizen Sky attempts to get everyone involved. I think the unified aspect is at the very heart of the project. The concept of CS is that everyone has something to contribute. AP: Do you see elements of other disciplines of science in Citizen Sky? User: Can't say that I see any biology (yet) but I see chemistry playing a greater role farther down the line as all the images of the system start to come together to analyze and find out what the composition of the disk it.
Attitude 1	Seek: No, I've always actively sought it out. It is probably the one thing I consistently do in my leisure time.
Attitude 2	Knowledge: I always felt before that variable star observing was too advanced for me. That along with the thought that "who want would to sit and stare at a star night to night to see if it is a little brighter or dimmer?" sounds boring. It's not so boring now.
Attitude Misc.	
Role	
General Comments	I wish I had more time to spend on it. I loved going to Chicago and would have tried to go to San Francisco, but the budget and time didn't allow for it (school starts early for this year)

Interview #8

Question	
Prior Astronomy & Difference w/CS	Currently I participate in Galaxy Zoo . I have involved myself with those programs almost exclusively.I have signed up for programs to study Epsilon Aurigus .Unfortunately , I have not had the time to do both.I have also completed 2 Astronomical League awards the Lunar 1 list and the Messier list(Binocular).To compare Galaxy Zoo and the Astronomical League - The zoo feels less personable :however,I have now discovered 3 type 1a supernova.Thru the Astronomical League I have learned more about the sky in terms of where things are.

Amoral	No.
Creative	Yes. I check my emails and or when an announcement is made through newspapers,magazines or tv. AP: Can you give me an example? User: I recently was interested in what Galaxy Zoo calls Green Peas . These are galaxies that when first found in SDSS images resembled Green Peas .A call went out for other Zooites to help find galaxies that resembled Green Peas . A list of 7,000 Potential Peas was developed ,A criteria for what would define a Pea was developed .The list was whittled down to 200 to 250 galaxies .Essentially a new type of galaxy was discovered .Peas have a star formation rate some 50 times faster than the average galaxy if I remember correctly.
Developmental	I do not know . AP: Can you describe to me where you have seen the "developmental" nature of science on display in any other amateur astronomy project? User: No.
Parsimonious	No.
Testable	No. AP: Can you describe to me where you have seen the "testable" nature of science on display in any other amateur astronomy project? User: No. Repeat: I hope this is true.
Unified	Yes .When a discovery by Citizen Sky, is announced in the press or online.
Attitude 1	Knowledge: Yes I am codiscoverer of 3 type 1a supernova and one of the first people to visually (looking thru a large 16 in telescope)observe Charon the moon of Pluto.
Attitude 2	News: Yes! I actually do this to learn.
Attitude Misc.	Collaboration always has 2 benefits for astronomy -1)Confirmation of any discovery .The more people who observe a phenomena the better the odds of correct identification.2)For the individual observer confirmation of a discovery increases there own confidence in their observations.Yes,collaboration is important. One must not forget the contribution of the individual.Where would Astronomy be without the contribution of the individual?From Galileo to Newton to Herschel to modern observers such as David Levy all were individual observers(these collaborate or have collaborated with others as the case may be but were known for their individual observations.).
Role	I feel like I am a volunteer .
General Comments	

Interview #9

Question	
Prior Astronomy &	It is the only project I've participated in that seeks to not only do a project

Difference w/CS

from soup to nuts with citizen scientists, but also is trying to train them, on the job, as it occurs.

I would think that the entire Citizen Sky project is amoral (that sounds bad in a layman's context, but...). The point of the Citizen Sky project is to find out facts, or create a fact-based thesis about what is eclipsing this particular star. There is no morality in that. It is neither good nor bad. It is the gaining of knowledge, which I think is where Citizen Sky, by its design, is. We are gathering the knowledge, we are not saying how it should be used at any point, I don't think.
AP: Have you ever had to consider this issue during your time in the CS project? Has it ever come up?
User: No, I don't think so. I have largely characterized the activities we are doing as amoral by their very nature. Perhaps I've not thought things through in depth, but while I see value in what we're doing down the road in that it should add to our knowledge base on the characteristics or the lifecycle of stars, and that may have moral implications down the road, I have not seen what we are doing in Citizen Sky give me pause as to how what we are trying to find out being used for good or evil.

Amoral

Not as much yet as I expect and hope I will. Right now we've largely been in the data gathering stage. I think this is largely almost mechanical. However having said that, there are creative and imaginative aspects to this data gathering as well. People have used different aspects and ways to gather the data. Our initial thrust was on naked-eye observing, I think, but people took that and we saw an expansion with regard to DSLR and even using robotic telescopes to gather data. That's creativity. I expect to see more of this when we move into the analysis and publishing aspects of the project.

Creative

I think this developmental nature of science is the very beating heart and soul of Citizen Sky!! It really is its reason for being. We don't really know what is eclipsing this star every 27 years! Every new generation of astronomers have gotten a crack at trying to figure it out. Now we get our crack and Citizen Sky is this generation's vanguard. We have a theory on what is eclipsing the star, but we're trying to gather data to support that theory or not. Nothing could be more developmental, I don't think.

Developmental

I think so. Whatever is eclipsing Eps Aur does not seem to be a simple globular body. As data is gathered I think the astronomers looking at the data are trying to find the simplest explanation based on the data. Given that, with regard to eclipsing binary stars, this explanation is pretty complex - a dust ring around a star orbiting Eps Aur - but it may be the minimum scenario needed to match the data we're gathering. And that may not be the end of the story, either. I do see in Citizen Sky the tendency to try to be simple, but not be scared off by complexity, both in what we're doing and how.
AP: Do you think there is an effort to try to keep the epsilon aurigae theories to a minimum and/or to simplify them? User: I haven't seen a large change from the overriding current dust ring theory, but as I understand it, some recent observations have seemingly granularized the dust cloud rather than having it just be dust. So I see us keeping to the theory that we have and modifying it as the data makes us. This is a conservative approach which I think enhances parsimonious explanations. Of course there are times when theories have to be chucked out, yes, but we've not reached that point with Eps Aur. Nor may

Parsimonious

we.
AP: Do you think the theories that currently exist are as simple as they can be (as far as you can understand them)? Do you think astronomers are making an effort to create cimpler theories than complex ones? User: I think the astronomers are trying to create the theories that will hold up to what the data is presenting us. Their challenge is to make the theories as simple as the data will hold. I think that there are times when people will "overcreate" things and we have to watch out for this because its not always obvious, especially for the people doing it.

Well, at this point I see that we've been in the data gathering phase so I don't see that much of what we've done is "testable" on a theory level. On the other hand, the project has taken pains to make sure that the data we gather is able to be compared with other data no matter how its taken. We've taken results of naked-eye photometry, CCD photometry, DSLR photometry, and tried to train people with regard to proper error estimates, etc. so that this data could be compared with other data sets. In this way, and at this time, we're taking pains to assure that what we're doing is able to be repeated properly.

Testable

Sure. One of the best examples I can think of of this would be the theory change that moved the dust cloud from being dusty to being more granular. That explanation is not just an aspect of photometry but of geology. We've also been attempting to take...rats! forgot the word! - spectral readings of the eclipse. This speaks to a cross knowledge of chemistry as well. AP: Do you feel the CS project or more or less "unified" in this way, than other astronomical projects you have worked on? User: I think so because CS is, more than any other project I've been involved in, taking a look at the "big research picture." The point of this project is not just to gather photometric data, but to teach and train people to analyze that data and to then present it scientifically. In order to do that you have to draw on other bodies of scientific knowledge - even if just for reference - other than basic photometry.

Unified

News: To some degree CS has let me more into the blogosphere and the web with regard to news. At the same time I've had to enhance my way of critically reading such news and be able to try to deal with the sources it is coming from. AP: Do you feel your confidence in your ability to read news more effectively has been affected by your CS participation? User: Yes, because the forums have had discussions with regard to the validity of sources and methods. You don't usually get that just reading blogs or the web and those discussions have been interesting along those lines.

Attitude 1

Knowledge: I don't think my knowledge of astronomy has been affected, no. But there has been a big effect on my confidence and knowledge of HOW TO DO astronomy. And I'm looking forward to that aspect increasing as we continue with the future aspects of the project.

Attitude 2

Attitude Misc.

Well, honestly as this point I have to say I think I've been a run-of-the-mill participant. I'm hoping that can become more value-added over the next couple of years. I do have what may be a slightly more advanced knowledge of astronomy in general than the average person in the project and I'm hoping that I'm trying to "mentor" folks in a very small way.

Role

	I think our most challenging aspect will be to keep people engaged through the project's life. A three year project, for people who have other primary focuses in life, is large. Further, I think that the data gathering aspect has been the easiest to teach and train people in. Data analysis and publication will be harder. It'll be interesting to see what the possible participation drop-off rate will be. Hopefully not large!
General Comments	

Appendix C.

A screen shot of the most active ten threads on the Photometry forum.

Topic	Replies	Views	Created	Last reply
Sticky: Welcome to Photometry!	26	889	by DocArne 07/04/2009 - 08:30	by nanko 04/16/2010 - 17:52
Catching cosmic rays with a DSLR	0	24	by Aaron Price 10/01/2010 - 19:59	n/a
Long Term DSLR Photometry *updated*	10 10 new	125	by Des Loughney 09/15/2010 - 06:02	by Des Loughney 09/27/2010 - 14:56
software tools to process pictures –Metop flare, star recognition *updated*	1 1 new	77	by yabby 09/21/2010 - 12:35	by Bikeman 09/26/2010 - 06:30
DSLR Photometry Software *updated*	26 1 new	1104	by bkloppenborg 10/06/2009 - 15:58	by gball2552 09/23/2010 - 11:58
Hoe do you undertake photometry across a number of frames – Eps Aur for example. *updated*	2 2 new	142	by astrojohn 09/01/2010 - 11:57	by bkloppenborg 09/12/2010 - 13:51
DSLR and telescope?	5	137	by Maurice 08/03/2010 - 13:06	by Maurice 08/04/2010 - 14:06
DSLR photometry technique on the BAA Blog	0	104	by robin_astro 07/22/2010 - 08:16	n/a
Eps Aur photometry with small telescopes .. anybody?	1	209	by Bikeman 05/29/2010 - 06:59	by Joann 06/27/2010 - 08:35
DSLR Photometry/ Exposure Times	1	216	by Des Loughney 05/23/2010 - 13:12	by Bikeman 05/24/2010 - 06:56

Notice the highlighted thread, which has had 26 posts to it and has been active for almost a year.

The following is a selection of messages posted to the thread. It includes the first five messages posted by project participants along with two posted by a staff person (bkloppenborg). Staff posts are excluded from this analysis.

First post that started the thread:

Forums / The Science / Photometry / DSLR Photometry Software

DSLR Photometry Software

View | Edit | Outline | Track

bkloppenborg

Offline

Joined: 07/06/2009
Posts: 191
Teams: Citizen Sky Staff, DSLR Documentation and Reduction, Historical Perspectives, VStar Software Development

Posted: October 6, 2009 - 3:58pm

I'm creating a tutorial on DSLR photometry that will eventually be posted on the CitizenSky website and was wondering what software people use for DSLR/CCD photometric reductions. I would like to compare and contract the software. If you have a favorite reduction program, could you post it with the following information:

Product Name
Manufacturer URL
Operating System(s) on which the software runs
Cost
Features (i.e. input formats)
Your likes and dislikes.

Thanks,
Brian

Reply | report to Mollom | Subscribe to: This post | Subscribe to: Posts of type Forum topic | Subscribe to: Posts by bkloppenborg

This is a follow up post where the original author replied to their own message to ask a new question.

From browsing the forms it

bkloppenborg

Offline

Joined: 07/06/2009
Posts: 191
Teams: Citizen Sky Staff, DSLR Documentation and Reduction, Historical Perspectives, VStar Software Development

Posted: October 10, 2009 - 5:43pm

From browsing the forms it appears that most people use one of the two packages:

API4WIN http://www.stargazing.net/david/aip4win/
MaximDL http://www.cyanogen.com/maxim_main.php

Any other options? Anything free?

delete edit reply report to Mollom

This is the first reply to the thread by aproject participant. The rest of the messages are posted by other participants.

Free software

Bikeman

Offline

Joined: 07/21/2009
Posts: 155
Teams: DSLR Documentation and Reduction, Mira Fourier Coefficient Team, VStar Software Development

Heinz

Posted: October 10, 2009 - 6:38pm

Hi!

IRIS is free:

http://www.astrosurf.com/buil/us/iris/iris.htm

The user interface can be counter-intuitive sometimes, but it has a very neat scripting engine that allows batch processing even for rather complex workflows.

CU

delete edit reply report to Mollom

Tutorial

Huberthautecler

Offline

Joined: 10/24/2009
Posts: 9
Teams: DSLR Documentation and Reduction

Posted: October 27, 2009 - 6:17pm

Is this tutorial for AIP4WIN already available? I have got AIP4WIN today. I have problem's getting the green channel.

regards, Hubert
http://www.vvs.be/wg/wvs/

delete edit reply report to Mollom

Obtaining Green Channel Image

Tom Pearson

Offline

Joined: 06/06/2009
Posts: 46
Teams: DSLR Documentation and Reduction

Posted: October 28, 2009 - 1:52pm

Hi Hubert,

Here is how I obtain a green channel image:

1. Take images in the RAW format.
2. Open AIP4WIN, select "Preferences" / "DSLR Conversion Settings"
3. Choose the "No conversion" radio button.
4. Select the "Save" button at the bottom.
5. Open your image.
6. Select "Split Colors" / "Color->RGB"

This should produce three new images, one each in red, green and blue. Also, for some reason, I have to repeat step four above every time I open AIP4WIN.

Good Luck!
Tom

delete edit reply report to Mollom

Some Doubts

Bikeman
Offline

Joined: 07/21/2009
Posts: 155
Teams: DSLR Documentation and Reduction, Mira Fourier Coefficient Team, VStar Software Development

Posted: October 28, 2009 - 5:07pm

Hi Tom,

I do have some doubts that this works as intended, at least for the version of AIP4WIN that I'm using (2.3.0):

The "no conversion" setting means that the raw image is imported as a grey-scale Bayer-image: half of the pixels encode the green channel, one fourth of them red and blue respectively.

Splitting this grey scale image in three RGB channels should result in three completely identical images, because the color-splitting is unaware of the Bayer-matrix encoding of the colors in this image. When zomming in on e.g. zeta Aur, you should be able to see Bayer-matrix pattern in the supposedly green channel image. This should not wreck the photometry too much tho, but effectively you are doing photometry on the sum of Green + Green + Red + Blue Bayer-Filter images, not just the green one, if I'm correct. You can easily check my hypothesis by comparing the three RGB channel images you get after splitting: if they are identical, I'm right :-)

CU
Heinz

delete edit reply report to Mollom

You're right!

Tom Pearson
Offline

Joined: 06/06/2009
Posts: 46
Teams: DSLR Documentation and Reduction

Posted: October 29, 2009 - 12:30pm

Hello Heinz,
You are quite right. I did the test as you suggested and, sure enough, all three color separated images were exactly the same.
I'll go back to simply color separating the raw image without using the "No conversion" setting.
Thanks very much for the tip.
Tom

delete edit reply report to Mollom

Bibliography

American Association for the Advancement of Science. (1990). *Science for All Americans*. New York: Oxford University Press.

American Association for the Advancement of Science. (1993). Benchmarks for science literacy. Project 2061. New York: Oxford University Press.

American Association for the Advancement of Science. (2010). Benchmarks Online. Retrieved from http://www.project2061.org/publications/bsl/online/index.php?chapter=14 on March 30, 2010.

Anderson, D. (2003). Public computing: reconnecting people to science. *Presented at the Conference on Shared Knowledge and the Web, Residencia de Estudiantes,* Madrid, Spain, Nov. 17-19 2003.

Andrich, D. (1978). Scaling attitude items constructed and scored in the likert tradition. *Educational and Psychological Measurement*, 38, 665 – 680.

Arbaugh, J. B. (2000). An exploratory study of the effects of gender on student learning and class participation in an internet-based MBA course, *Management Learning,* 31, 503–519.

Ballard, H. L. & Huntsinger, L. (2006). Salal harvester local ecological knowledge, harvest practices and understory management on the Olympic peninsula, Washington. *Human Ecology*, 34, 529-547.

Barret, E. & Lally, V. (1999). Gender differences in an on-line learning environment. *Journal of Computer Assisted Learning*, 15, 48-60.

Berkeley Open Infrastructure for Networked Computing (2009). *Bossa*. Retrieved 09 Dec. 2009 from: http://boinc.berkeley.edu/trac/wiki/BossaIntro

Bloom, M. A. (2008). *The effect of a professional development intervention on inservice science teachers' conceptions of the nature of science.* Unpublished doctoral dissertation, Texas Christian University, Ft. Worth.

Blum, K. D. (1999). Gender differences in asynchronous learning in higher education: learning Styles, participation barriers and communication patterns. *Journal of Asynchronous Learning Networks*, 3, 46-66.

Bond, T. G. & Fox, C. M. (2007). *Applying the rasch model: Fundamental measurement in the human science*s. 2nd Ed. Lawrence Erlbaum Associates, Inc. Mahwah, NJ.

Bonney, R., Ballard, H., Jordan, R., McCallie, E., Phillips, T., Shirk, J., and Wilderman, C. C. (2009). Public Participation in Scientific Research: Defining the Field and Assessing Its Potential for Informal Science Education. A CAISE Inquiry Group Report. Washington, D.C.: Center for Advancement of Informal Science Education (CAISE).

Boone, W. J. & Scantlebury, K. (2005). Rasch analysis in science education research. *Science Education*, 2, 253-269.

Brandt, C., Shirk, J., Jordan, R., Ballard, H. L. & Tomasek, T. M. (2010, March). Beyond citizen science: science learning and public participation in environmental research. Symposium conducted at the meeting of the National Association of Research in Science Teaching, Philiadelphia.

Brossard, D., Lewenstein, B. & Bonney, R. (2005) Scientific knowledge and attitude change: The impact of a citizen science project. *International Journal of Science Education*, 27, 1099-1121.

Cakir, M., Xhana, F., Zhou, N. & Stahl, G. (2005). Thread-based analysis of patterns of collaborative interaction in chat. In Artificial Intelligence in Education (C-K. Looi, et al. (Eds.) IOS Press. Fairfax, VA.

Carifio, J. & Perla, R. (2008) Resolving the 50-year debate around using and misusing Likert scales. *Medical Education*, 42, 1150-1152.

Center for Informal Learning and Schools. (2005). ISIs and schools: A landscape study. http://www.exploratorium.edu/cils/landscape Retrieved: August 14, 2009.

Cesarksy, C. (2007, December 20). *UN declares 2009 the International Year of Astronomy*. [Press Release]. Utrecht, Netherlands: International Astronomical Union.

Cifelli, R. (2005). The community collaborative rain, hail, and snow network: informal education for scientists and citizens. *Bulletin of the American Meteorology Society*, 86, 1069-1078.

Cohn, J. P. (2008). Citizen science: can volunteers do real research? *Bioscience*, 58, 192-197.

Cooper, C. B., Dickinson, J., Phillips, T., and Bonney, R. (2007). Citizen science as a tool for conservation in residential ecosystems. *Ecology and Society,* 12, 11 [online] URL: http://www.ecologyandsociety.org/vol12/iss2/art11/.

Cornell Ornithology Lab (2009). Defining citizen science. http://www.birds.cornell.edu/citscitoolkit/about/definition Retrieved: August 14, 2009.

Cornwall, A. & Jewkes, R. (1995). What is participatory research? *Social Science and Medicine*, 41, 1667-1676.

Cummings, J. N. & Kiesler, S. (2005). Collaborative research across disciplinary and organizational boundaries. *Social Studies of Science*, 35, 703-722.

DeBoer, G. (2000). Scientific literacy: Another look at historical and contemporary meanings and its relationship to science education reform. Journal of Research in Science Teaching, 37, 582–601.

De Wever, B., Schellens, T., Valcke, M. & Van Keer, H. (2006). Content analysis schemes to analyze transcripts of online asynchronous discussion groups: A review. *Computers & Education*, 46, 6-28.

Dierking, L. D., Falk, J. H., Rennie, L., Anderson, D., Ellenbogen, K. (2003). Policy statement of the "informal science education" ad hoc committee. *Journal of Research in Science Teaching*, 20, 108-111.

Dringus, L. P. & Ellis, T. (2005), Using data mining as a strategy for assessing asynchronous discussion forums. *Computers and Education*, 45, 141-160.

Duestua, S. Noel-Storr, J. & Foster, T. (2009). *In support of astronomy education research.* Subcommittee on the Status of the Profession Education and Public Outreach Infrastructure Study Group, The Astronomy and Astrophysics Decadal Survey: National Academies.

Eisenhart, M., Finkel, E., & Marion, S. F. (1996). Creating the conditions for

scientific literacy: A re-examination. *American Educational Research Journal*, 33, 261–295.

Evans, C., Abrams, E., Reitsma, R., Roux, K., Salmonsen, L. & Marra, P. P. (2005). The neighborhood nestwatch program: participant outcomes of a citizen-science ecological research project. *Conservation Biology*, 19, 589-294.

Falk, J. H., Storksdieck, M. and Dierking, L. D. (2007). Investigating public science interest and understanding: evidence for the importance of free-choice learning. *Public Understanding of Science*, 16, 455-469.

Fernandez-Gimenez, M. E., Ballard, H. L., and Sturtevant, V. E. (2008). Adaptive management and social learning in collaborative and community-based monitoring: A study of five community-based forestry organizations in the western USA. *Ecology and Society*, 13(2). [online] URL: http://www.ecologyandsociety.org/vol13/iss2/art4/

Ferris, T. (2002). *Seeing in the dark*. New York: Simon & Schuster.

Fraknoi, A. (2005). Steps and missteps towards an emerging profession. *Mercury,* 34, 19-25.

Garrison, D. R., Anderson, T. & Archer, W. (1999). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, 2, 87-105.

Garrison, D. R., Anderson, T. & Archer, W. (2001). Critical thinking, cognitive presence, and computer conferencing in distance education. *American Journal of Distance Education*, 15, 7-23.

Garrison, D. R., Cleveland-Innes, M., Koole, M., & Kappelman, J. (2006). Revisiting methodological issues in transcript analysis: Negotiated coding and reliability. *The Internet and Higher Education,* 9, 1-8.

Google. (2010). Google Scholar Query Retrieved from http://scholar.google.com/scholar?q=related:95jRENNwriUJ:scholar.google.com/&hl=en&as_sdt=40000000 on September 1, 2010.

Hall, D. & Genet, R. (1985). Photometric support for future astronomical research. In Stencel, R. (Ed.) 1982 – 1984 Eclipse of Epsilon Aurigae. NASA Conference Publication 2384. Tucson, AZ.: NASA.

Hand, E. (2010). Citizen science: People power. *Nature*, 66, 685-687.

Henri, F. 1992. Computer conferencing and content analysis. In *Computer supported collaborative learning,* ed. C. O'Malley, 117–136. Heidelberg, Germany: Springer-Verlag.

Hopkins, J. (1985). Optical photometry. In Stencel, R. (Ed.) 1982 – 1984 Eclipse of Epsilon Aurigae. NASA Conference Publication 2384. Tucson, AZ.: NASA.

Howard, E. & Davis, A. K. (2004). Documenting the spring movements of monarch butterflies with journey north, a citizen science program. In *The Monarch Butterfly: Biology & Conservation* K. S. Oberhauser & M. J. Solensky (Eds.) Cornell University Press: New York.

Howe , J. (2006). The rise of crowdsourcing. *Wired*. Retrieved March 17, 2007 from http://www.wired.com/wired/archive/14.06/crowds.html.

Hsi, S. & Hoadley, C. M. (1997). Productive discourse in science: gender equity

through electronic discourse. *Journal of Science Education and Technology*, 6, 23-36.

Huang, S. (1965). An interpretation of epsilon Aurigae. *Astrophysical Journal*, 141, 976.

Huang, S. (1974). Interpretation of epsilon Aurigae. III. Study of the light curve based on disk models. *Astrophysical Journal*, 181, 485-491.

Huxley, A. (1880) "Science and Culture." http://www.gutenberg.org/ebooks/7150

Jamieson, S. (2004). Likert scales: how to (ab)use them. *Medical Education*, 38, 1212-1218.

Jeong, A. C. (2003). The sequential analysis of group interaction and critical thinking in online threaded discussions. *The American Journal of Distance Education*, 17, 25-43.

Kelly, G. J. (2007). Scientific literacy, discourse, and knowledge. In C. Linder, L. Östman & P. Wickman (Eds.), *Promoting Scientific Literacy: Science Education Research in Transaction*. (pp. 47-55). Uppsala, Sweden: Uppsala University.

Knapp, T. R. (1990). Treating ordinal scales as interval scales: an attempt to resolve the controversy. *Nursing Research*, 39(2), 121-123.

Lakshminarayanan, S. (2007). Using citizens to do science versus citizens as scientists. *Ecology and Society* 12, 2 [online] URL: http://www.ecologyandsociety.org/vol12/iss2/resp2/

Lederman, N. G., Wade, P. D. & Bell, R. L. (1998). Assessing the nature of science: What is the nature of our assessments? *Science and Education*, 7, 595-615.

Linn, M. C., Davis, E. A., & Bell, P. (Eds.). (2004). *Internet environments for science education.* Mahwah, NJ: Lawrence Erlbaum Associates

Meichtry, Y. J. (1992) Influencing student understanding of the nature of science: Data from a case of curriculum development. *Journal of Research in Science Teaching*, 29, 389-407.

Meichtry, Y. J. (1993) The impact of science curricula on student views about the nature of science. *Journal of Research in Science Teaching*, 30, 429-443.

Mendez, B. J. H. (2008). SpaceScience@Home: Authentic research projects that use citizen scientists. In Garmony, C, Gibbs, M. G. & Moody, J. W. (Eds.), *EPO and a Changing World: Creating Linkages and Expanding Partnerships*, (219) San Francisco: Astronomical Society of the Pacific.

Miller, J. D. (1983). Scientific literacy: a conceptual and empirical review. *Daedalus* 112, 29–48.

Miller, J. D. (1998). The measurement of civic scientific literacy. *Public Understanding of Science*, 7, 203-223.

Miller, J. D. (2004). Public understanding of, and attitudes toward, scientific research: what we know and what we need to know. *Public Understanding of Science*, 13, 273-294.

Muraki, E. (1990). Fitting a polytomous item response model to Likert-type data. *Applied Psychological Measurement,* 14, 59-70.

National Research Council (2009). Learning Science in Informal Environments. Washington, D.C.: National Academies Press.

National Science Board (2008). Science and Engineering Indicators. Arlington, VA (NSB 08-01; NSB 08-01A). Retrieved 7 Dec 2009 from http://www.nsf.gov/statistics/seind08/.

National Science Foundation. (2009). Award Abstract #0840188. STARS: Science Through Astronomical Research of Stars. Retrieved December 7, 2009 from http://nsf.gov/awardsearch/showAward.do?AwardNumber=0840188

Norris, S. P. & Phillips, L. M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education*, 87, 224-240.

Kloppenborg, B. (2009) Literature review: Epsilon aurigae. historical sketch. Retrieved from http://www.citizensky.org/forum/literature-review on Sep. 1, 2010.

Kloppenborg, B., Stencel, R., Monnier, J. D., Schaefer, G., Zhao, M., Baron, F., et al. (2009) Infrared images of the transiting disk in the ε aurigae system. *Nature*, 464, 870-872.

Knapp, T. R. (1990). Treating ordinal scales as interval scales: An attempt to resolve the controversy. *Nursing Research*, 39, 121-123.

Lakshminarayanan, S. (2007). Using citizens to do science versus citizens as scientists. *Ecology and Society* 12, 2 [online] URL: http://www.ecologyandsociety.org/vol12/iss2/resp2/

Linacre, J. M. (2002). Optimizing rating scale category effectiveness. *Journal of*

Applied Measurement, 3, 85-106.

Lintott, C. J., Schawinski, K., Keel, W., van Arkel, H., Bennert, N., Edmondson, E., Thomas, D., Smith, D., Herbert, P., Virani, S., Andreescu, D., Bamford, S., Land, K., Murray, P., Nichol, R., Raddick, J., Slosar, A., Szalay, A., and Vandenberg, J. (2009). Galaxy zoo: Hanny's voorwerp, a quasar light echo?, *Monthly Notices of the Royal Astronomical Society*, 399, 129-140.

Ludendorff, H. (1903). Untersuchungen über den Lichtwechsel von ε Aurigae. *Astronomische Nachrichten*, 192, 4606.

Ludendorff, H. (1912). Bearbeitung der Schmidtschen Beobachtungen des Veränderlichen ε Aurigae. *Astronomische Nachrichten*, 164, 3918-3920.

Naidu, S. & Järvelä, S. (2006). Analyzing CMC content for what? *Methodological Issues in Researching CSCL*, 46, 96-103.

New Track Media. (2010). Reader Demographics, Rate Card #51. Retrieved January 25, 2010 from http://www.skyandtelescope.com/about/advertiserinfo/3305436.html?page=1&c=y.

Payne, C. H. (1928). A suggested spectral classification of O stars and of nebulae. *Harvard College Observatory Bulletin*, 855, 1-7.

Percy, J. (1999). Amateur-professional partnership in astronomical research and education. *Publications of the Astronomical Society of the Pacific*, 111, 1595-1596.

Raddick, M. J., Bracey, G., Gay, P. L., Lintott, C. J., Murray, P., Schawinsky, K., et al. (2010). Galaxy zoo: Exploring the motivations of citizen science volunteers. *Astronomy Education Review*, 9, 1.

Raddick, J. (personal communication, September 3, 2010).

Rahm, J., Miller, H. C., Hartley, L., & Moore, J. C. (2003). The value of an emergent notion of authenticity: Examples from two student/teacher-scientist partnership programs. *Journal of Research in Science Teaching,* 40, 737-756.

Roberts, D. (2007). Scientific literacy/science literacy. In S.K. Abell & N.G. Lederman (Eds.), Handbook of research on science education (pp. 729–780). Mahwah, NJ: Lawrence Erlbaum Associates.

Rodino, M (1997) Breaking out of binaries: reconceptualizing gender and its relationship to language in computer-mediated communication, *Journal of Computer-Mediated Communication,* 3, 3.

Rourke, L., Anderson, T., Garrison, R. D. & Archer, W. (1999) Assessing social presence in asynchronous text-based computer transcripts. *Journal of Distance Education*, 14, 50-71.

Rubba, P. A. and Andersen, H. O. (1978). Development of an instrument to assess secondary school students' understanding of the nature of scientific knowledge. *Science Education,* 62, 449-458.

Silvertown, J. (2009). A new dawn for citizen science. *Trends in Ecology and Evolution*, 24, 467-471

Somers, A. B., Matthews, C. E., Carlone, H. (2009). The turtle connection. N. C. Partners in Amphibian & Reptile Conservation. Retrieved December 7, 2009 from: http://www.ncparc.org/TurtleConnectionSummary.pdf

Stencel, R. (1985) Preface. In Stencel, R. (Ed.) 1982 – 1984 Eclipse of Epsilon Aurigae. NASA Conference Publication 2384. Tucson, AZ.: NASA.

Struve, O., & Zebergs, V. (1962). *Astronomy of the Twentieth Century.* New York: Macmillan.

Thomson, R. & Murachver, T. (2001). Predicting gender from electronic discourse. *British Journal of Social Psychology*, 40, 193-208.

Trumbull, D. J., Bonney, R., Bascom, D. and Cabral, A. (2000). Thinking scientifically during participation in a citizen-science project. *Science Education*, 84, 265-275.

Vygotsky, L. S. (1964). *Thought and Language.* Cambridge, MA: MIT Press.

Wang, M., Sierra, C. & Folger, T. (2003). Building a dynamic online learning community among adult learners. *Educational Media International,* 40, 49-61.

Wee, Y. C. & Subaraj, R. (2009). Citizen science and the gathering of ornithological data in Singapore. *Nature in Singapore*, 2, 27-30.

Wilderman, C. C. (2004). Portrait of a watershed: Shermans Creek. A technical status report. 73 pp.

Wilson, R. E. (1971). A model of epsilon Aurigae. *Astrophysical Journal*, 170, 529.

Wood, F. B. (1985). Historical overview. In Stencel, R. (Ed.) 1982 – 1984 Eclipse of Epsilon Aurigae. NASA Conference Publication 2384. Tucson, AZ.: NASA.

Wright, B. D., & Masters, G. N. (1982). Rating scale analysis. Chicago: MESA Press/University of Chicago.

Wright, B. D. (1993). Equitable test equating. *Rasch Measurement Transactions*. 7, 298-299.

Wright, B. D. & Lincare, J. M. (1994). Reasonable mean-square fit values. *Rasch Measurement Transactions,* 8, 370.

Wright, B. D. (1996). Time 1 to time 2 comparison: racking and stacking. *Rasch Measurement Transactions,* 10, 478-9.