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# What do Students Gain from a Week at Science Camp? Youth perceptions and the design of an immersive, research-oriented astronomy camp

Deborah Anne Fields [a]

[a] University of California, Los Angeles, USA

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## RESEARCH REPORT

# What do Students Gain from a Week at Science Camp? Youth perceptions and the design of an immersive, research-oriented astronomy camp

Deborah Anne Fields*
*University of California, Los Angeles, USA*



This study explored American high school students' perceptions of the benefits of a summer astronomy camp, emphasizing a full cycle of the research process and how the organization of the camp contributed to those perceptions. Semi-structured interviews with students and staff were used to elicit the specific benefits that campers perceived from their experiences and examine them in relation to the stated goals and strategies of camp staff. Among the perceived benefits that students described were peer relationships, personal autonomy, positive relationships with staff, and deepened science knowledge. These perceived benefits appear to influence the kinds of identities students constructed for themselves in relation to science. Gee's concept of 'affinity space' is used to consider how features of the camp's design, especially those that promoted student autonomy, contributed to students' positive perceptions, and to draw implications for the design of informal science learning experiences that can link youth with larger communities of scientists.

## Introduction

In a time when disenchantment with the sciences in schools is up and enrolment in many countries is down (Lyons, 2006), informal, inquiry-based science education opportunities may provide ways for youth to increase and maintain their interest and identification with science over a long period of time (Gibson & Chase, 2002). As Kay Andrews (2001) notes about 'extra' educational programmes in the UK, 'Research suggests that involvement in science clubs provides the 'little bit extra' that can be the all-important difference between going on with science or not' (pp. 160–161). Recognizing this, the National Science Teachers' Association of the USA issued a

*Psychological Studies in Education, University of California, Los Angeles, 740 13th St. Apt. 22, Manhattan Beach, CA, 90266-4868, USA. Email: stareyes@gmail.com

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statement describing the ways in which informal science education is relevant and needed, whether in the form of camps, museums, field trips, multiple media (such as videos and television), or learning at home. Informal science education, they say, can increase the time students engage in science, extend to 'the affective, cognitive, and social realms', provide opportunities for students to form different sorts of relationships with adults, afford the sharing of 'moments of intellectual curiosity' between care providers and children, give more direct access to career role models in the sciences, and emphasize creativity and enrichment (National Science Teacher Association, 1998, p. 17). These types of characteristics, in addition to the relative flexibility of informal science education programmes, may allow youth to develop identities positively related to science and connect those identities to the rest of their lives.

One popular but understudied form of informal science education, particularly in the USA, is 'science camps': programmes where students spend a relatively short but intensive period of time while school is not in session. Situated between two theories of designing camps, this study directly examines the features of a science camp that campers find valuable and their reasons for such value, specifically focusing on how camp staff organized the camp and its activities to provide experiences that led campers to these perceptions. This study adds to our understanding of what comprises a successful science camp, and provides insights into alternative pathways to engage students in science.

## Conceptual Framework

The small body of literature on science camps contains mostly anecdotal accounts of how to start your own science programme rather than thorough descriptions, programme evaluations, or other research on these programmes. Science camps themselves are part of a broader genre of informal education, namely camps. Participating in camps during the summer when school is out of session is a very popular form of education and entertainment in the USA. Camps are largely advertised on websites as providing youth with motivational, leadership, and hands-on experiences, often in exotic locales such as mountains, wilderness, and universities, the latter of which is most relevant to the astronomy camp studied in this paper. It is difficult to say how popular or extensive science camps are as a part of this genre of education. Searches on sites and booklets (e.g., www.campsearch.com or Duke University's *Educational Opportunity Guide*) designed to help parents decide on the best (publicly advertised) camp for their children show 300–400 science camps in the USA, Canada, and abroad focusing on subjects ranging from 'surfing and marine biology' to astronomy, chemistry, mathematics, new media technology, and computer science. Yet this number does not include any local camps that are promoted by word of mouth and do not draw a national attendance. The science camps vary in terms of residential status (overnight versus daytime only), duration (1 week–3 months), age (child to adult), association with a university or independent organization, and type of activity (most advertise hands-on laboratories or experience in the environment). Some camps are quite costly (up to US$1,700 for the 13-day *Space Camp* in Huntsville, Alabama), while others are designed as opportunities for low-income youth and run almost solely on grants and public funding.

### *Science Camps and Communities of Practice*

A number of science camps, like the Advanced Astronomy Camp, are situated in various ways with 'real' scientists or 'real' laboratories for the purpose of drawing youth into the culture and practices of professional scientists, particular communities of practice (Wenger, 1998). These camps fall into two separate groups based on the ways they try to accomplish this goal. The first group has focused on student-led research with access to the tools and technologies associated with laboratories (Gibson & Chase, 2002; Hay & Barab, 2001; Knox, Moynihan, & Markowitz, 2003; Schenkel, 2002). These camps emphasize the research and thought processes associated with creating and performing a full cycle of research, complete with presentation. The second group has emphasized individual (Bell, Blair, Crawford, & Lederman, 2003; Richmond & Kurth, 1999) or small group (Barab, 2001; Hay & Barab, 2001) mentorship of youth partnered with professional scientists in their laboratories while participating in an overseeing programme. The goal of such camps is for youth to be drawn into the identification with, and practices of, professional scientists by associating with them and assisting in their research. All of the studies found that access to professional laboratories or scientists increased student interest in science and generally led to higher confidence in doing and pursuing science.

Hay and Barab (2001) provide an illuminating contrast of the benefits and drawbacks of these two types of science camps, which they call constructionist (Papert, 1980) and cognitive apprenticeship (Collins, Brown, & Newman, 1989), respectively. Their constructionist camp focused on student-led research projects in virtual worlds through state-of-the-art technology, while the other emphasized a formal cognitive apprenticeship model (Collins et al., 1989) where students contributed to professional scientists' research. Hay and Barab found that while the constructionist or tool-centric camp facilitated student ownership of the research project and creative and critical work through student-designed projects, students failed to connect and identify with the larger community of practice of scientists. In contrast, the cognitive apprenticeship camp connected students to the community of practice of the scientists but lacked the development of critical skills and understanding of the larger projects, which the authors attributed to lack of ownership in the creation and design of the projects. They point out that the lack of foreseeable 'opportunities to develop and advance their own research agenda … undermines some of the authenticity of the science practices being carried out, and, potentially, the transformative potential of the camp experience' (Hay & Barab, 2001, p. 96).

Yet these two types of learning models (constructionist and cognitive apprenticeship) for camp designs do not need to be mutually exclusive. A camp situated among professional scientists and their tools *and* focused on a student-led research cycle poses a significant opportunity for learning. Such a camp would include student-led projects that contain the full cycle of a research project, from design to presentation, prepared for an outside audience (Heath & McLaughlin, 1994), access to the tools of a particular scientific community of practice (diSessa, 2000), and involvement with professional scientists who model behaviour, scaffold learning, collaborate on projects that learners could not do on their own, give information in context alongside relevant experiences, and help learners take on the identity of a scientist.

*Science Camps as Affinity Spaces*

Science camps with student-led research situated amongst a professional community of scientists build on the notion of 'affinity spaces'. As defined by Gee (2004), these are designed places where people collaboratively interact with each other primarily in relation to a common interest or affinity. Other characteristics include having a common endeavour or interest, enabling people of various skill levels to participate in the same activities, adapting the core organization through interaction, encouraging the development and sharing of specialized knowledge, honouring tacit knowledge, and allowing many different forms of participation and status in the space (for a fuller description, applied mostly to virtual affinity spaces see Gee, 2004, pp. 77–89).

A science camp built on the theory of affinity spaces would draw both students and professionals based on common interest, for instance astronomy or biology. Based on Gee's framework, participants would be able to define their own routes of participation and ways to achieve status within the shared space. Research projects could facilitate this, encouraging individual expertise as well as shared knowledge amongst all participants. Similarly, prior knowledge and information from outside sources (websites, books, science magazines) would be valued as participants found ways to lever those for the benefit of the shared space and research projects. Knowledge would not only be located in individuals, but also distributed across tools and resources. Further, unlike traditional mentorship camps, leadership would be porous and leaders would be resources rather than authorities. In other words, the line between leaders and participants (or professors and campers) would be blurred, in part due to the variety of expertise and different routes of participation, and leaders would not just direct people but would help them meet their personal goals. For instance, campers could teach each other based on their own expertise. A camp where not just professionals and campers but also people at various stages of becoming professional scientists (such as undergraduate and graduate students) might further facilitate porous leadership.

Another reason to design science camps as affinity spaces is an intriguing potential for the development of a projective identity. Gee (2004) makes a case that in such spaces people take on virtual (or imaginary or temporary, if you will) identities that intermingle with their 'real' identities, or who they are outside of that space. Although his illustration of this potentially transformative interplay of identities is grounded in video or computer games, he argues that it would be much more powerful if learners create virtual and projective identities that can be carried into the real world; for instance, taking on the virtual identity of a scientist in a classroom or other space, merging it with a real-world identity, and creating a projective identity of a certain type of scientist that will have a history and future. Gee claims that affinity spaces in particular assist in the formation of such projective identities:

> Thus what others have designed … becomes part of myself, my real-world identity—my own uniqueness when and if I engage in the virtual identity as a project of my own, and not just a role to be played by the rules of the game/classroom (for a win or a grade). (2004, p.114)

If this is so, then an affinity space related to science such as a science camp, especially where professional scientists and less experienced youth and students share a common affinity for science, has the potential to help youth imagine and develop projective identities as scientists, some of which might even carry over into long-term engagement with science. Such a science camp could actually have a strong impact on youth's identification with a larger scientific community and their visualization of themselves with the capability to become scientists.

## Description of the Advanced Astronomy Camp, Summer 2002

The Advanced Astronomy Camp is one of several summer astronomy camps held at the observatories on Mt Lemmon, Arizona in the USA, directed by an astronomer at the University of Arizona. During this 8-day camp, high school age youth (14–18 years old) live in the astronomers' dorms and conduct research using astronomers' equipment, charge coupled devices, photometers, and spectrometers on four telescopes: the 60-inch reflector, the 40-inch reflector, the Kuiper 61-inch reflector on Mt Bigelow, and a 12-inch reflector.

The Advanced Astronomy Camp emphasizes youth-designed projects within the 'laboratory' of astronomers (the observatories and associated equipment on a mountain-top), yet still intentionally draws youth into the culture and community of astronomers through the staff who are undergraduates, graduate students, post-doctorates, and professionals in astronomy and related science fields. The director's goals (and thus his design for the Camp) are that youth will have fun while learning the whole process of science: generating research questions, struggling with equipment, interpreting collected data, and finally presenting their methodology and conclusions. In doing so the youth get to know people (the staff) at every stage of becoming scientists. Table 1 describes the director's articulated goals for the Camp and how the activities or design of the Camp fit those goals.

### *Campers*

Thirty-three youth from over 20 states in the USA and from one Southeast Asian country attended the Advanced Astronomy Camp in 2002: 16 participants were

Table 1. Director's goals and design of the Advanced Astronomy Camp

| Director's goals for campers | Design and activities |
|---|---|
| To experience the whole process of science and have a stake in the process: | Research projects: |
| Form the start of an idea | Camper created proposals |
| Submitting a proposal | Proposal review process (Telescope Allocation Committee) |
| Getting real observations | Data collection on professional telescopes |
| Grappling with equipment | Campers put in charge of telescopes as soon as possible |
| Struggling with interpretation of data | Campers analyse data, with help of staff as needed |
| Making a final presentation | Final evening of presentations with critiques and questions by staff and peers |
| To understand what a career in science might be like, what kind of people they might become | Staff: |
| | Staff who are at various stages in becoming scientists (undergraduates, graduate students, post-doctorates, professionals) |
| | Informal interactions between staff and campers |
| | Mars Projects (designing space missions) |
| To see that science is fun, a process of exploration: | Variety of activities: |
| Enjoy the outdoor setting of astronomy | Watching sunsets, mountain hikes |
| Think about science in general terms | Daily Fermi problems (estimation) |
| To make friends | Draw people with a common interest: |
| | Essay application (insures an interest in astronomy) |
| | Self-selected small groups for research projects |

women and six campers received full or partial scholarships. The Camp does not collect race and ethnicity information on campers. Some youth had subscribed to popular magazines such as *Astronomy* or *Sky & Telescope* for years, while others had virtually no knowledge of even the most well-known constellations. All campers were required to have taken two years of high school mathematics, typically basic algebra and geometry, providing a background for data analysis at the Camp. All complete applications were accepted on a first-come, first-served basis until the Camp was full.

### *Staff (Counsellors)*

In addition to the director and myself (I served as a staff member during the Camp), there were eight staff members: four women and four men. Each of the staff was recruited through contact with the director, either by involvement in the astronomy programme at the University of Arizona or by prior attendance at an astronomy camp, or in my case through a family relationship: the director is my father. The staff included three undergraduates (majoring in physics, geology, and science education), one National Aeronautics Space Administration (NASA) scientist, three graduate students in astronomy, and one post-doctorate who formerly obtained his Ph.D. at the University of Arizona. Much as traditional camp counsellors, staff members were responsible for living in the dorms with the campers, assisting with Camp activities, and looking after their physical, emotional, and mental well-being. They also had responsibilities for giving lectures, operating and teaching the campers to use the telescopes, and generally helping the Camp to run smoothly.

*Activities*

A typical day at the Advanced Astronomy Camp 2002 included the following. After a full night of research observing at the telescopes, campers slept until brunch at noon. During brunch, an astronomy-themed movie or television episode was picked out by the campers, such as the episode of *The Simpsons* where Bart discovers a comet or a portion of *Cosmos* with Carl Sagan. After brunch, campers gathered in the small gym to share their experiences from the previous night's observations. Then the director introduced the Fermi problem of the day; for example, 'At any given time how many flat tires are there in the United States?' Fermi was a physicist known for thinking of all kinds of problems in terms of estimation. The director introduced these problems as a purposeful effort to illustrate how to think about problems in general terms rather than becoming mired in intricate calculations.

After a brief discussion about the Fermi problem, the director or one of the staff delivered a lecture on astronomy. Some examples of lectures include 'Spectroscopy and Light', 'The Lives and Deaths of Stars', and 'The ~Ologies of Mars'; these were either of general importance to the field of astronomy (e.g., spectroscopy) or based on a graduate student's expertise. Following the lecture, campers used the remainder of the afternoon to work on their projects or enjoy the mountaintop facilities. Sunset watching and a casual competition to see who could be the first to sight the planets or stars coming out followed dinner. After sunset the campers headed to the telescopes where they conducted their research.

There were two primary projects at the Camp in 2002: the Mars Debates, and research projects. In the Mars Debates, campers were put into groups to take a side about some aspect of doing a sample return mission to Mars. In their arguments, they were encouraged to research the pros and cons of such a mission, including the energy needed, astrobiological consequences, cost, and design of spacecraft and instruments. Staff who had worked on various aspects of Mars missions assisted campers in this research and helped them understand some of the practical logistics of designing a mission and building a spacecraft.

The second and more important activity to the life of the Camp was the self-directed research project, which began on the first day of the Camp as campers started recruiting people to their groups for particular research interests. The director and staff offered assistance to each team in developing a research question and trying to make it feasible. Each research group put together a one-page 'proposal' outlining their research question, the telescope and instruments needed, and when their object was visible in the sky. This required some background research and assistance from the staff.

A Telescope Allocation Committee composed of the staff reviewed the research proposals and scheduled time on the telescopes. This purposely replicated the same type of process used by professional astronomers in their research proposals. Two examples of research projects are the SS433 Binary System Accretion Disk and the Extra-Solar Planetary Eclipse. In the Accretion Disk project, group members measured the speed of the rotation of the accretion disk around a dense object (black hole or neutron star) by observing the Doppler-shifted light in the spectrum lines of the disk using the spectrometer on the 60-inch telescope and then calculating the observed rotation rate of the disk. In the Planetary Eclipse project, members successfully measured the dip in the light from a star as an orbiting planet moved in front of it using the photometer on the 40-inch telescope.

For most of the seven nights at the Camp, the research groups collected data; and during the final two nights, they started to analyse their data mostly via computers and image processing. The staff members who had the most expertise in a related area assisted them. By the second to last day of the Camp, many campers expressed great anxiety about finishing their projects on time and spent almost all day long on the computers, even asking to forego the planned liquid nitrogen ice cream celebration before the final presentations. The groups finally presented their projects to the rest of the Camp and fielded questions from campers and staff. Not all of the projects succeeded in their research goals due to weather conditions, equipment capabilities and error, and human error.

## Methods

To understand how participants valued their experience of the Advanced Astronomy Camp and how that related to the intentions of camp staff, I interviewed 10 of the 33 campers (see Table 2), four of the eight other staff members (see Table 3), and the Camp director in the summer of 2002. While interviewing all Camp participants would have been ideal, time and resources limited the data collection. In addition to the interviews, I observed and took notes for the entire Advanced Astronomy Camp while serving on the staff. While this role inevitably had limits, it facilitated the development of trust and allowed me to establish a common history with both the campers and staff. Further, because campers willingly applied to attend the Camp and because relationships between campers and staff were purposefully informal, few issues arose in regard to serving as an authority figure. Prior to the Camp, I selected a sample of campers to interview that was representative of the Camp in terms of age, gender, and previous astronomy camp experience (see Table 2). This allowed for a breadth of opinion and experience of the youth. In the table of the campers interviewed (Table 2), pseudonyms are used for all research participants except for the director, at his request.

Table 2. Camper descriptions

| Camper | Grades | Gender | Prior attendance |
|---|---|---|---|
| Pam | 11 and 12 | Female | Yes—advanced camp |
| Stacy | 11 and 12 | Female | No |
| Kris | 11 and 12 | Female | No |
| Sarah | 9 and 10 | Female | Yes—beginning camp |
| Adrienna | 9 and 10 | Female | Yes—beginning camp |
| Kevin | 11 and 12 | Male | No |
| James | 11 and 12 | Male | No |
| Ralph | 11 and 12 | Male | No |
| Todd | 9 and 10 | Male | Yes—beginning camp |
| Brian | 9 and 10 | Male | Yes—beginning camp |



In addition to the director, I randomly chose staff members to interview. Their educational experience ranged from being a current undergraduate to a current post-doctorate and all had studied astronomy, geology, or physics. Most of them had also served as staff members at Astronomy Camp before (see Table 3), and a few had even been campers themselves in high school.

In semi-structured interviews, I asked campers questions regarding three themes anticipated to be relevant to their experiences: affective aspects (confidence, community, a memorable story), science knowledge, and future goals (careers and higher education). These questions were developed before the Camp began, through conversation with the director and previous campers. In addition, all interviews were transcribed and sent to participants so that they could review what they said. All interviews were returned and approved by the participants without any subtractions of text.

A two-step open coding process (Charmaz, 2000) was used to analyse the interviews. While the interview questions were originally directed toward several potential ideas of what campers might find valuable about the camp, the themes growing from the conversations did not necessarily stem from particular questions. For instance, campers shared about one theme, the importance of their peers, in answer to questions about what they took away from the camp, what the best aspects of it were, and what they learned about science in addition to direct questions about their peers. The initial themes were considered of major importance if they were

Table 3. Staff descriptions

| Staff | Educational experience | Prior experience at astronomy camp |
|---|---|---|
| Amanda | Graduate or postdoctorate | 4–11 years |
| Paris | Graduate or postdoctorate | 4–11 years |
| Ben | Undergraduate or B.Sc. | 0–3 years |
| Mike | Undergraduate or B.Sc. | 0–3 years |

found in all of the campers' or staff's interviews. In the process of the first coding, themes grew more defined as subthemes were identified and outlying responses began to become clear. After outlining these new subthemes, the transcripts were coded a second time to see how these held with the interviews. Subthemes were considered significant if all or most (≥80%) of the campers or staff said something regarding them.

## Findings

### *Campers*



Four themes summarize what campers found valuable about the Camp. The first was the importance of peer relationships, where campers spoke about the positive atmosphere created by their peers, how they learned from other campers, and a sense of commonality with their peers. Second, the campers spoke positively about having personal autonomy in choosing their own research projects and using the professional equipment and technology. Third, campers enthusiastically discussed how approachable and knowledgeable the staff members were and how well they explained things. Finally, campers said they had not only gained new knowledge about astronomy, but also learned about the practical constraints of doing research and developing an understanding of science as dynamic and changing over time.

All of the four main themes I identified in the interviews are interrelated and strongly relevant to the design of the Camp. The first three themes also map onto the characteristics of affinity spaces described earlier. The theme of peer relationships draws significantly upon the shared interest or affinity among campers. Similarly, the illustration of personal autonomy demonstrates the different types of expertise campers developed throughout camp and some of their personal routes of participation and status. Further, the theme of positive relationships with staff speaks to the role of staff as resources and to the Camp as a shared space for people with a range of expertise in astronomy. While I will briefly illustrate each of the themes with examples, I will pursue the fourth theme, what I call science knowledge, in the greatest detail, in order to explore the depth of the comments youth made about how their understanding of science had changed.

*Peer relationships.* All of the campers spoke extremely enthusiastically about their peers and how important their peers were to their positive experiences at the Camp. Most of the campers expressed a strong sense of commonality with their Camp peers based on similar interests in astronomy. For instance, when asked 'What are some of the most significant things that you're going to take with you from this week?', Kris said:

> Probably the understanding that there are people out there like me … Like I'm kind of known as the resident nerd [at home]. And, like I don't shy away from that title, except that, it, I'm like the only one around like it. … And it kinda made me feel very, not, not alone anymore.

While all of the youth expressed the importance of having a shared interest in astronomy, five campers expressed the feeling that one was not alone, as Kris did. This knowledge that others of their age were also interested in science validated the campers' prior and continued identification with science and may have been important for the persistence some youth expressed in terms of future hopes of pursuing science.

The feeling of commonality also established a foundation that enabled the campers to learn from each other. All campers voiced ways that they learned from their peers: asking casual questions about astronomy, learning about someone's college application process, and simply having someone come up and help them identify constellations. In particular, some youth expressed learning about others' opinions about religion and science, politics, and the origins of the universe. Consider what Adrienna said about this:

> It was, also you kind of learn about other people's opinions, like the whole thing about did the Big Bang happen … And you also get like, to know more about what you think is right, even though we don't know … Yeah, 'cause for a long time, you know, I just thought it was one way, because that was really cool, but you know, it wasn't technically accurate, at all.

Sharing and respecting a common interest in astronomy allowed the campers to express differing opinions about normally controversial topics in casual conversations throughout the Camp, and in Adrienna's case this helped her broaden her understanding of the nature of science.

*Personal autonomy.* Campers also articulated a sense of responsibility and empowerment at the opportunity to use the equipment and technology at the Advanced Astronomy Camp, choose their own research projects, and generally have personal autonomy over their time on the mountaintop. These types of agency manifested in some of the campers' reactions to the trust or 'youth-centeredness' (Heath, 1999) the staff showed by putting youth in charge of equipment and projects. For instance, Kevin, one of the youth involved in the extra-solar planetary eclipse, described how this allowed him to develop an expertise with the 40-inch telescope:

> Letting us use expensive equipment that most astronomers would kill to use. And it puts you in a position like, wow, you know, I can't believe I'm using this, I can't believe I'm getting to do this … just learning how to use it, and, you know, being able to say that I could work, you know, forty-inch telescope better than, maybe some astronomers out there.

Kevin's mastery of a quirky telescope (hand-operated in one direction—declination) was very important to what he claimed he would remember after the Camp, and demonstrates one kind of specialized expertise developed at the Camp. In fact, later in his interview, Kevin said that he would be able to show off his new abilities to his family with his dad's small telescope, demonstrating that he was already projecting an identity of expertise with telescopes in general onto parts of his life outside the Camp.

In addition to using special equipment, all youth talked about the agency to choose their own research topics as empowering, something I will refer to later when discussing science knowledge. Pam connected it to both the 'freedom' in managing one's own time and in designing the research projects:

> The second strongest point, I think is there's so many, um, the freedom we have, and like, letting us do our projects. You know, it's not, you're gonna do this project, and everything. We form our own groups, we have our own ideas, they tell us yes or no, but if they say no, they say, well why don't you try this, or this isn't going to work because of that, so you could do a different angle.

Ownership over the design and implementation of the research projects not only led to positive feelings of agency, but also enabled youth to contribute to the formal content or organization of the Camp (an attribute of affinity spaces), teach other youth through their specialized knowledge of an individual project, and take responsibility for explaining the results of their projects, the latter of which has important implications for some of the science learning youth expressed.

*Positive staff relationships.* In the first few interviews, I found that campers often mentioned the staff in relating their positive experiences at the Camp, so I added a question to my interview protocol asking campers how they felt about the staff. In answering this question, all of the campers discussed how the informal and egalitarian relationships helped them approach staff for questions and make themselves understood. Stacy explained it this way:

> The main strengths? I think the [staff members'] relationship with the campers. It's it's really a relaxed atmosphere, really comfortable, one in which everyone's equal. So it's it's really great. No one's afraid to ask questions, or make suggestions, or things like that.

Because of the informal atmosphere at the Camp, the leaders were resources rather than bosses, and the youth had opportunities to become leaders by giving suggestions and helping each other, both characteristics of leadership in affinity spaces. In addition, each of the campers also spoke enthusiastically about how much the staff knew and how well they were able to explain difficult concepts. Here is Sarah's comment on the subject:

> [The staff] just know a lot and they're willing to share a lot, so. They're good at explaining it to kids … they can explain in a way that makes a lot of sense, but it's not like the toned down things we get in school that's not correct all the time. So then you get easy to understand without being simplified so, that works.

Informal relationships with various levels of experts also led to several youth expressing insider knowledge about how astronomers do research and which colleges and graduate schools they would prefer to attend as well as a deeper knowledge of the complexity of astronomy. In other words, the informal environment led to the association and collaboration of people with various levels of expertise in astronomy (and a range of degrees in between since campers and staff had varying years and types of experiences) in the same space.

*Science knowledge.* One of the most striking outcomes of the interviews is the way that campers spoke about how their understanding of science had changed. Two questions in the interview were designed to elicit talk about anything campers learned about science:

- How has the Camp added to or changed your understanding of science and astronomy?
- What are the most interesting or important things you have learned about astronomy, science, or other areas at the Camp?

Note that I did not solicit information from the campers about inferential reasoning, the changing and bounded nature of science, the general 'process' of science, or the practicalities involved in research, all of which were spoken about in the interviews in addition to basic knowledge gained. For this reason, it is impossible for me to say whether all the campers I interviewed learned something about each of these areas because I did not ask such specific questions. If campers mentioned these things, it was because they thought these changes were important experiences they had at the Camp.

In answering these questions or just talking about what they got out of the Camp, all of the campers spoke of the new knowledge they gained, such as learning how to operate telescopes, use right ascension and declination coordinates to find objects in the sky, or just know more about quasars or nebulae. I have categorized this subtheme as basic knowledge, although beneath the surface some of these subjects require deeper understanding. For instance, using right ascension, declination, and sidereal time to find objects requires a spatial and geometric understanding of the sky and how it appears to rotate as the night goes on. While this knowledge gain may appear simple, most of the youth took several days to feel comfortable applying these concepts to naked eye or telescopic astronomy.

However, in addition to gaining basic knowledge about astronomy, 9 out of 10 campers I interviewed expressed learning that there was more to science than they had previously realized. This includes the 'process' of doing science (six campers), the inferential use of data (three campers), how the data relate to the conclusions in science textbooks or popular science magazines (three campers), and how there are no constants or firm things in science that cannot be disproven (four campers). For example, Kris described learning about the 'process' of science:

> I think a lot of it was, the process of like, how stuff like that [science] happens. Like I never realized there was so much work that went into those people who, end up with articles in *Sky & Tel* … like let alone, get telescope time, but they sit and sit behind a telescope for eight hours a night, and, then they have to, like sit around a computer for three times that to figure out what it was they were looking at. And um, I never realized there was so much work that went into it all. And I mean, even despite all the work and all the, the hard times and everything, it was still, it was still awesome.

For many of the youth, like Kris, learning how much work went into data collection and analysis was very surprising but still rewarding. In fact, many expressed a greater sense of respect for science as a result, finding school science over-simplified.

Further, some campers discussed learning about the inferential use of data, like Ralph:

> Well I said how things work and how you get information and how you use that information. Such as, finding this, taking this spectrum and finding out what spectral lines are the largest and interpreting that.

In addition, a few youth like Adrienna (see quote above) and Todd discussed learning part of the process of doing science as well as the changing nature of science at the Camp: 'everything's changing so, and there are no constants really, everything could be upset the next day'.

Related to learning about the process of science were the many practicalities and errors that youth encountered in doing their own research: human error, mechanical error, cloudy nights, and the limits of equipment and time to name a few. All youth discussed facing these practicalities as significant for learning about science. When I asked James to tell a story about a significant time at the Camp, he described his role in the SS433 accretion disk research project:

> [O]ne thing I remember most was uh, the way that we're doing our project is that we're using a spectrograph to look um at SS433, which is this really dim quasar in the middle of nowhere, and uh, so what you have to do is that you have to line up the the little slit of the spectrograph onto the, onto the object. And you have to keep it there because it's gonna, it drifts a little because the at—just the shimmers of the atmosphere and of course it's spinning and the telescope doesn't track perfectly and it's so dim and you can't see the slit on the black background and it's really tricky to keep it on the slit while, um, you're taking the exposure. So, my job was that I was the guy that had to do the paddle and constantly tweak it to try to keep in on the slit for like uh, you know like, a dozen half, a dozen ten minute exposures. So, so I would sit there for you know for like ten minutes with my eye glued to this eyepiece desperately trying to keep it on the slit when you can't see the slit and can hardly see the object, and [laugh] so it was really rough. But um, it turns out I did a better job than I thought, and we really did get pretty good spectral lines.

In the story above, James recognizes the limits of his equipment and his abilities in addition to the impact of natural conditions, such as the atmosphere. Knowing that success was questionable contributed to the suspense of the project and to learning about the many possible flaws, as well as the uncertainty inherent in doing research.

While James and his SS433 team succeeded, for several research projects these limits or errors led to inconclusive results. Several campers discussed their failures: leaving the camera shutter closed for eight 10-min exposures, not being able to figure out when their object was going to be visible, getting inconsistent numbers that made them question whether they were doing something wrong with the equipment, and the sheer amount of time it took to gather and analyse data compared with the limited conclusions they were able to reach.

All of the above represent types of scientific reasoning that Chinn and Malhotra (2002) identify as absent in many school curricula. While most of these are either directly or implicitly connected with designing and doing a complete cycle of research (proposal to presentation), some are also related to casual discussions with staff members or with other youth, as Adrienna expressed. It is interesting that each of the main themes from the coding described above interrelates to the others. Peer relationships established with a common interest facilitate certain discussions about the nature of science and identification with astronomy; agency over the design of research projects and tools encourages new types of scientific reasoning; and informal access to experts in the field allows for learning a process of scientific research that mimics the 'real' process that professional astronomers do as well as inside knowledge about the activities and thought processes of astronomers. All of them have an impact on campers' construction of virtual identities as astronomy researchers.



### *Staff*

The staff and director spoke of several things they thought important about the design and intention of camp. First, they stressed that they wanted the youth to learn the process of doing science and experience the time, error, and difficulty involved in gathering, analysing, and interpreting data. Next, they expressed two strategies of stimulating confidence in the campers: drawing out individuals and helping each have a sense of achievement through succeeding in their projects and developing better understandings of scientific concepts. Third, each staff member also shared about the special niche that they filled at camp, including their expertise with particular equipment and telescopes, their ability to provide leadership and a fun atmosphere, their passion for reaching out to withdrawn campers, or other specialized knowledge. Interestingly, most staff members also discussed learning teaching skills from the director through their camp experiences, while the director talked about his goals for the staff's learning in addition to his goals for the campers.

*The process of science.* It was important to the staff that campers decide on their own research questions, delve into a project using the facilities and equipment available, and bring their self-designed project to completion. Consider the director's comment about his goals for the campers:

> I want them to see, to experience the whole process of science, from the start of an idea to getting real observations, to maybe fighting with equipment, struggling with the interpretation of the data, and making a presentation. I would like them to see that science is fun, it's uh, a process of exploration, it's not too much different from what people do in ordinary life.

In the staff's eyes, doing the 'whole process of science' in an environment with professional tools was key to understanding and feeling like one was doing 'real' astronomy. As Ben illustrated:

> Students get that opportunity to study astronomy, in the most real environment that you can get … It, you know, it allows creativity too, where you get to create what you're gonna do. Decide, hey, we're gonna do this and do it. It makes it more like real science …

Comparing the staff's intentions to the campers' experiences described above, it is clear that the staff's goals were fulfilled in this respect. Being a part of the design, implementation, and presentation of research led to the campers' feelings of agency and affiliation with doing astronomical research.

*Developing confidence.* Despite the campers' fervour about the peer relationships they developed, the staff never tried to develop friendships between the youth. Instead they tried to instil confidence in the campers by drawing the kids out or by using the science that kids were doing to help them develop a sense of achievement. One of the ways the staff did this was by putting youth who seemed like outsiders in charge of telescopes or drawing them forward for demonstrations, a purposefully youth-centred approach that relates back to the campers' expressions of autonomy with regard to professional instrumentation. In addition, the whole research project was designed to give youth some sense of accomplishment, whether or not the project succeeded in its goals, as Paris described:

> Now a lot of groups that I worked with had extraordinarily ambitious plans … that a group of professional astronomers would be hard pressed to do, on our equipment, in a week … So hopefully in the end … they actually did gain some confidence and did understand and perceive that what they had done is unusual and very difficult, and that they should have a lot of confidence and a lot of self-respect, not only for what they did accomplish, but for the motivation that they have.

So when the campers described feelings of accomplishment and expertise like Kevin did with the 40-inch telescope, this was validated by the staff, who also felt like the youth had actually accomplished something valuable and worthwhile in terms of science.

*Filling a niche.* I asked the staff members how they felt they fit in with the larger picture of the Advanced Astronomy Camp, and they shared the special niches they thought they filled, ranging from having expertise with particular equipment and telescopes, being able to provide leadership or a fun atmosphere for the campers, reaching out to the quieter young people, and providing a particular knowledge base. Interestingly these are quite similar to campers' themes related to relationships, agency, and knowledge. This relates to yet another aspect of affinity spaces—that individual and specialized knowledge is valued, and that knowledge is distributed across people and tools. Not only the campers, but also the staff, felt like they contributed some sort of expertise to the space—and because of this they could be both leaders and learners.

Beyond the general awareness conveyed by the staff of a niche that they filled, the director communicated a deeper reason for having diverse staff members:

> I'd like [the campers] to get to know the [staff] pretty well, because, through them they can see, um, what re—what real scientists are like, or people aspiring to be scientists at different stages of their careers. College, graduate school, post-doc, faculty, we model all of the range of uh, academic experience, and all these people come from different

> backgrounds, they have different hobbies, different likes and dislikes, … and I think it would be good for the students to see that.

The director certainly seemed to have accomplished his goal. Because the staff members were at different stages of becoming various sorts of scientists, many of the campers formed projective identities and visualized themselves in similar ways in the future: searching for research opportunities at college, knowing what sorts of classes to take, recognizing the diverse types of expertise they needed to be an astronaut on Mars, and even envisioning finishing a Ph.D. in astronomy.

## Discussion

To what degree did the design of the Advanced Astronomy Camp align with what the youth found positive about their experiences? Campers' autonomy, diversified expertise, the 'process of science', and affinity among campers were all purposefully incorporated into the fabric of the Camp and noted as important to youth experiences.

### *Autonomy and Expertise*

From the director's opening comments at camp, where he invited campers to contribute to the week's schedule, the demand that students form groups and carry out their own research projects, and the way that camp staff provided assistance in response to students' requests, it is clear that the camp was designed to promote student autonomy coupled with a community based on common interest in astronomy. It is also clear from the interviews presented above that campers appreciated and valued this agency and that it was developed through the trust and youth-centredness the staff demonstrated in putting youth in charge of equipment, projects, and their own time at the Camp.

Mastering a tool or piece of technology also brought a sense of ownership, expertise, and feeling of belonging to the campers. This may explain why youth spoke so highly about using the equipment and technology at the Camp and why they took so much pride in their abilities to manage specific kinds 'better than some astronomers' (Kevin). The staff also located their niches in terms of expertise with instruments and purposefully encouraged the campers to operate the telescopes and high-tech instruments such as the spectrometer without assistance. diSessa (2000) points out the important roles of tools within a scientific community, from telescopes to computers and textbooks to ways of thinking: 'Tools are badges of membership, symbols of commitment and accomplishment' (p. 39). Here, too, we see how designed features of the camp are used to bring campers into the culture of doing astronomy through tool use. In an important way, what it means to be an astronomer is to have expertise at using the equipment that astronomers use to explore space. As campers noted in their interviews, this opportunity to develop skill with professional tools sufficient to explore a personally meaningful research question was a crucial feature of the camp for these youth.

*The Process of Science*

Doing a full cycle of a research project from idea to presentation, as in Hay and Barab's (2001) constructionist camp, had a significant effect on campers' understanding of science and on their feeling of accomplishment. This was a clear intention of the director, who listed it as one of his goals. The importance of doing the entire process is affirmed by Heath and McLaughlin (1994), who found that collaborative projects bounded in time and prepared for presentation to an audience were vital to successful community youth organizations. The types of thought that the projects required included much of what Chinn and Malhotra (2002) identified as taking place in the minds of scientists but not normally found in school curriculum: choosing a research question, selecting multiple variables to investigate, facing concerns with methodological errors, doing comparative research, making indirect inferences, devising indirect procedures to address their questions, and deciding between multiple theories for explanations. As youth made their own decisions in choosing, researching, and interpreting their projects, some began to understand from a first-person perspective (perhaps because of that first person perspective) how practicalities affect scientific research and how 'hard' scientists had to work for the conclusions stated so simply in school textbooks.

*Affinity*

One of the things that campers talked about the most in their interviews was their friendships with their peers and how this was one of the strengths of the Camp. While the staff did not purposefully try to promote friendships among campers, the application process ensured that campers would have shared interest in astronomy, and the projects enabled relationships to develop through shared work. A closer look at the interviews revealed that the Camp exhibited all of the characteristics of what Gee (2004) calls 'affinity spaces': having a common endeavour or interest, enabling people of various skill levels to participate in the same activities, adapting the core organization through interaction, encouraging the development and sharing of specialized knowledge, honouring tacit knowledge, and allowing many different forms of participation and status in the space.

In addition, many of the youth attributed their changing understanding of science to conversations they had with their peers about topics such as the Big Bang. It is possible that, through interactions with their peers, some of the campers engaged with ideas different from their own and began to change not only their understanding of the concepts in question, but also their beliefs about the nature of science. While students attributed some of their science learning to working directly on their projects (error, practicalities, time spent), other realizations were attributed to conversations with peers. Gee (2004) argues from studies by Piaget and Tomasello that 'In dialogue with equals, children appear to compare and contrast perspectives more deeply and reflectively, learning thereby not only how to take particular perspectives through language, but also how to reason about such perspectives and perspective-taking' (p. 55). Unfortunately, data collection on this project was not systematically aimed at addressing this question, making strong conclusions problematic. This points to potential for further study on peer interactions and perspective-taking in conjunction with doing research science as a way to encourage learning about the nature of science. Bell et al. (2003) found that 'doing science' was not enough for high school aged youth in apprenticeships with professional scientists to learn several of the more important aspects about the nature of science. Involvement in an affinity space based on shared interests in science and engagement in research may lead to greater gains in understanding the nature of science.

Finally, one very interesting aspect about the campers' interviews is that all of them mention some future projection of themselves that they directly relate to the Camp. These range from Pam, who said that, as a result of her experiences at the Camp, 'I'm definitely gonna go and seek out a lot more research opportunities' in college and 'I'm determined to get my Ph.D. Determined!' to Kevin, who, while he still wanted to be a surgeon, felt that he would be able to show off his new abilities with the telescope in front of his dad, an amateur astronomer: 'I'll really be able to go home and really show off about it.' In fact, Kris claimed that a recent class in astronomy had 'damaged my science psyche' but the Camp had more than remedied that—restoring her long-desired dream to be an astronaut and making that goal 'even easier to reach' through her new insider knowledge about how the field worked and her experiences with completing the whole process of science research. These types of future or projective plans relate to projective identity formation facilitated by affinity spaces as described by Gee (2004). Indeed, Gee argues that whether or not youth pursue a projective identity in science, it is important that at least at one time they have imagined the capability within themselves to do something such as become a research astronomer, attend undergraduate and graduate school, or even travel to Mars.

## Conclusion

The Advanced Astronomy Camp 2002 was a unique programme shaped and formed by the professional astronomical facilities on Mt Lemmon, AZ and the director who purposefully designed the Camp to mirror the processes that professional astronomers engage in to do research. While this experience is not fully duplicable, several characteristics of the Camp discussed by the campers and the staff have notable design implications. First, the Camp offers a 'proof of concept' that constructionist and cognitive apprenticeship learning models can be integrated into a single informal science programme. Unlike camps documented in previous studies, all of which either focused on start-to-finish youth-generated research projects or on integrating youth into a community of professional scientists (Hay & Barab, 2001), the Advanced Astronomy Camp united the two and added a further element of drawing youth based on a common interest in astronomy. This analysis not only demonstrates that such a convergence of goals is possible, it suggests that it may be particularly useful (i.e., that the benefits campers experienced were linked to key aspects of *both* learning models co-present in the same camp). Based on campers' self-reports, science learning was not localized to either the research projects, the association with staff at various stages of becoming scientists, or in conversation with their peers, but was attributed to all three.

Second, since the characteristics of the Advanced Astronomy Camp locate it within the description Gee (2004) gives of 'affinity spaces', other affinity spaces based on common interest in some form of science should be explored and designed to facilitate identity and community formation that link youth with larger communities of scientists. In particular, encouraging youth autonomy and diversified expertise through youth-designed projects supported by adults is known to provide meaningful and motivating experiences in community youth organizations (Gee, 2004; Heath & McLaughlin, 1994), but the possibilities of developing these in science education have yet to be fully explored and investigated. Finally, further investigation is needed to understand the impact that identity construction at a short-term science camp can have on youth's long-term identification with and possible pursuit of science. While this study demonstrates that campers formed projective identities associated with science at the Advanced Astronomy Camp, we need research on how those identities impact their lives beyond the world of the Camp.



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