

CHAPTER 3: METHODOLOGY

Research Design

The following questions were addressed in this study:

1. What are the distinguishing problem finding features of externally-evaluated, exemplary, open inquiry science research projects?
2. How do parents, teachers, and mentors influence student problem finding?

A qualitative paradigm was used to conduct this study. A multicase study using a descriptive strategy to explain, identify, and document the phenomenological role of problem finding in open inquiry, was used. The focus was on the essence or basic structure of the problem finding experience. The process of phenomenological study first requires an intuitive understanding of the problem finding and open inquiry phenomenon while simultaneously holding personal beliefs tentative (Merriam, 1998). This is followed by investigations of examples of the processes “to gain a sense of its general essence” (p. 16). Relationships are then sought to interpret the problem finding phenomenon.

Phenomenological study might best be described by Moustakas (1994):

The challenge facing the ... researcher is to describe things in themselves, to permit what is before one to enter consciousness and be understood in its meanings and essences in the light of intuition and self-reflection. The process involves a blending of what is really present with what is imagined as present from the vantage point of possible meanings; thus a unity of the real and the ideal. (p. 27)

The study was conducted utilizing in-depth, opportunistically-developed, semi-structured interviews in conjunction with document analysis, demographic survey, and an affective instrument. In order to compensate for the limitations of a single-method research design, this study included triangulation of data sources and methods (Merriam, 1998). Triangulation of data was achieved through methods (interviews, document analysis, surveys) and sources (students, teachers, mentors, fair directors, documents).

Member checks with the subjects and peer and mentor examination of unprocessed and processed data were also utilized to verify the plausibility of the findings and interpretations as they emerged. In the development of the interview schedules, a participatory/collaborative strategy was used with high school research students to conceptualize and align questions within the study (Merriam, 1998). Multiple student cases, from both CSF and ISEF, were used to generate comparison groups to provide a replication strategy of single-case findings (Huberman & Miles, 1994).

Affiliations

The investigator began his career in teaching in 1995. After serendipitously attending the Connecticut Junior Science and Humanities Symposium (CT-JSHS) in 1998, he began working with students to conduct authentic independent research projects. So began the prolonged involvement in the authentic extended research process complemented with opportunities for students to publicly present their work.

He has had approximately 25 students present their work at the CT-JSHS from 1999 to the present. Three of his students have placed in the top five for platform presentations, earning a spot on the National delegation, to the National JSHS. One of the three earned top honors at the CT-JSHS and earned a bid for national presentation. He has also had five students finish in first

place for the poster presentations. He has served as an active member of the executive committee of the CT-JSHS since 2000.

After receiving advice from a colleague, in March of 2000, he took students to the Connecticut Science Fair, held at Quinnipiac University. The students' work was recognized, and approximately 50 of his students have attended the CSF from 2000-2008.

Appreciating the volunteer efforts of the CSF, he offered his services, and in 2003, was asked to attend the ISEF, that year held in Cleveland, Ohio, as a teacher representative for the state of Connecticut and the CSF. In 2005, he was asked to participate as a member of the Advisory Committee of the CSF. In 2006 he also became a member of the executive committee of the CSF, primarily involved in publicity and scientific review of projects.

He attended the ISEF in 2006 in Indianapolis, Indiana as a teacher-mentor, having his first student reach the pinnacle of state competition. In 2007, he also attended the ISEF, in Albuquerque, New Mexico, both as a principal investigator for Western Connecticut State University, under the auspices of this study, and again as a teacher-mentor, having his second student, finish top at the CSF. This student successfully placed third in the Environmental Sciences Category at the ISEF.

Target student-subjects

Students who participated in the study had completed their research projects and presented their results at either the 2007 CSF or the 2007 ISEF. Therefore, a completed, presented project was a mandatory factor for consideration of recruitment of subjects. Gender was not a limiting factor, because previous research indicated few identifiable sex differences in creative performance (Richardson, 1986). In order to participate in the CSF, a student's school must register by October of the previous year. The CSF region includes all Connecticut public

and private schools, schools from Brewster, NY, North Salem, NY and Fishers Island, NY, as well as any student whose permanent address is in Connecticut. Each school is permitted to submit a maximum of eight projects to the CSF directly. There are numerous regional fairs, which also submit projects to the CSF including Danbury's Science Horizons, the Bridgeport City Science Fair, and the New Haven City Science Fair. If a student does not have school sponsorship or is home schooled, but does meet the location guidelines, he or she may enter as an independent.

In order to participate in the CSF, students completed an application, which included demographic information. They also submitted a research plan, which was approved by the CSF Scientific Review Committee. All students had an adult sponsor and a parent or guardian sign for the project. In some cases, students had additional professional mentorship if their project fell within the scope of several potentially dangerous or ethical categories (i.e., recombinant DNA, human subjects, vertebrate animals, potential pathogens, restricted substances or chemicals).

The CSF is an affiliated regional fair of the ISEF. In order for a student to participate in ISEF, he or she must earn a top spot from his or her regional fair, such as the CSF. There is no alternative method of entry to ISEF. Each regional fair holds a charter, or multiple charters which gives students entry to ISEF. The CSF holds two charters to the ISEF, thus allowing them to send four individual projects and two team projects. Based on financial constraints and program philosophy, CSF sends only four individual projects to the ISEF.

CSF and ISEF provided student scores to help target a variety of quality projects for this study. A sample of 12 students were purposefully selected from approximately 500 students at the 2007 CSF held March 13-17, 2007 at Quinnipiac University in Hamden, Connecticut. They were selected based on CSF documents, including judging sheets, entry paperwork, and student

abstracts. Four students were 16 years old, 7 were 17 years old, and 1 was 18 years old. Eight were in eleventh grade and four were in twelfth grade. Nine attended a public high school, and three attended a private high school. Six were male; six were female.

A sample of 8 students were purposefully selected from the 2007 ISEF, held May 13-19, 2007 in Albuquerque, New Mexico. These students were in grades 11-12 or the international equivalent. Five students were American, and three students were international. Five students were male and three students were female. ISEF subjects were all major category winners (see Appendix A), which were the top 17 projects out of approximately 1,500 (SS, 2006).

The sample size of 20 individuals is in alignment with a target population for a multi-case phenomenological study (Sandelowski, 1995; Van Kaam, 1959).

Permissions

Permission for conducting the study was acquired from both the CSF and the ISEF. Each organization had its own requirements for accepting the study, interaction with students, and the transfer of secured data.

Connecticut Science Fair. Both the Chairman of the Board and the President of CSF were contacted by electronic mail and telephone to discuss the feasibility of the proposed study. The Chairman requested a copy of the proposal. After reviewing the proposal, the Chairman requested a presentation be made to the CSF Board of Directors so they could vote to approve the study.

In January of 2007, at the Mother House of the Daughters of Mary of the Immaculate Conception in New Britain, Connecticut, said presentation was completed at the CSF annual meeting. The president moved to accept the proposal as read and provided the necessary support for the study. Several additional questions were posed during discussion, and the motion passed

unanimously. The major concerns were ensuring that the CSF process was not interrupted in any way by this study. The CSF agreed to provide working space during the event as well as any requested data from the database. A written letter of approval was provided by the Chairman and was included in the institutional review board (IRB) application (see Appendix C). IRB documentation was provided to CSF subsequent to its receipt.

The CSF takes place annually at Quinnipiac University during the university's spring break. The 2007 fair took place March 13-17. The CSF receives, free of charge, annual use of the athletic facility during the fair week. The fair sets up its exhibition hall in the gymnasium, which has the capacity for holding up to 500 projects. Students arrived between noon and eight o'clock to set up their projects on the Tuesday of fair week (March 13). During the setup students checked in, were assigned a spot and project number in the exhibition hall, and then had their project approved by a member of the Rules and Safety committee. Upon successful completion, they checked out and received a t-shirt.

The investigator offered to take digital pictures of all students and their posters for CSF during project setup. CSF, in turn, provided a printed list of all eleventh and twelfth grade students, ordered by project number, and included fair category, project title, student's name, student's school, student's adult sponsor, student's address, student's telephone number, and student's electronic mail address. During the setup, the investigator asked the grade level of the high school students to see if they fell within the parameters of the study sample (i.e., grades 11-12). If they did, the students were told about the study and were provided with some literature about the study, which included a card-stock page overview, a copy of the informed consent, and a newspaper article highlighting the study (see Appendix D). This was the initial stage of recruitment.

Preliminary judging took place without students on Wednesday. Approximately 200 industry and academic professionals volunteered to judge. They were charged with scoring each project, based on a CSF judging rubric and placing it in a quartile. The top quartile of students' project numbers were posted on the CSF website and were required to attend finalist judging on Thursday (March 15). The finalist list was cross referenced to the eleventh and twelfth grade list, previously provided, to target specific students for recruitment.

Finalist judging began with student check-in at the entrance to the exhibition hall. Each student received a nametag, pin, and bottle of water. Students entered the exhibition hall alone. Parents, teachers, and mentors were not permitted in the exhibition hall at any time during judging. In fact, once the judging period began, parents, teachers, and mentors were not permitted in the athletic facility. CSF provided a hospitality suite on the other side of campus for those wishing to stay. CSF graciously allowed the investigator to enter the exhibition hall during judging to identify and speak with potential subjects. In return, the investigator again took pictures of all finalists for CSF.

During the judging period, the investigator identified himself as "not a judge," and would speak to target students about the study. Students were provided with two copies of the informed consent, a pre-stamped, preaddressed envelope, a copy of the newspaper article, and instructions for completing online surveys. Students were also asked to verify their electronic mail address and phone number from the database. Approximately 20 students were approached and asked to participate based on sample size suggestions of Sandelowski (1995). Follow-up telephone calls were made to those students who did not mail back informed consent, but expressed an interest in participating in the study.

An additional group of students from the lower quartile who did not make finals were also targeted for participation by telephone call. When the student's adult sponsor was also a teacher, that educator was also contacted to request student participation in the study. Rate of participation for non-finalists was far lower than that of finalists, 71% and 33%, respectively.

Those students who agreed to participate and submitted an informed consent were contacted by electronic mail and asked to complete online study documentation. Interviews were requested to take place at the student's school, and this was generally coordinated through both the student and the adult sponsor. Interviews generally took place in the early afternoon while the student was still in school, so the investigator could optimize the use of release time since the employing school district allows half-day personal days.

International Science and Engineering Fair. The CSF Chairman of the Board, on behalf of this study, made initial contact via electronic mail with Science Service, the sponsor and coordinator of ISEF. The CSF Chairman recommended working through Science Service's Director of Science Education Programs. The Director was amenable to having research conducted at ISEF as limited studies have previously been completed using ISEF populations (Walker, 1979; Bellipanni, 1994; Pyle, 1996). Discussions were held by telephone and electronic mail to map a strategy that would allow for successful recruitment of subjects without interference with the ISEF experience for the students.

The following conditions were placed on the study: (a) the study's proposal and Institutional Review Board approval was reviewed and approved by the ISEF Scientific Review Committee, (b) a confidentiality statement was signed to ensure that any student results given by Science Service were safeguarded (see Appendix E), (c) information from the Environmental Sciences Category was excluded, since the investigator had a student competing in that category,

(d) Science Service would provide special credentials to identify the investigator at the fair (see Appendix F), (e) recruitment of subjects would take place during public viewing, not judging, (f) Science Service would provide judging results, but would not provide contact information for students, (g) all interviews would take place after the completion of the ISEF, and (h) Science Service would provide a follow-up electronic mail message to encourage participation of the target student participation.

The 2007 ISEF took place at the Albuquerque Convention Center in Albuquerque, New Mexico from May 13-19. The fair took place on the convention center floor, hosting approximately 1,500 students. The volunteer host committee provided a range of both academic and social experiences for the students and adults attending throughout the city. Participants generally arrived on Sunday or Monday, set up their projects and had them cleared by a member of the Rules and Safety committee. Opening ceremonies took place Monday evening in the Tingley Coliseum. The ceremony was professionally staged and directed, complete with a 200-foot video display screen (see Iwahedi, 2007). Social events, workshops, and a session with Nobel Prize winners took place on Tuesday. Wednesday was dedicated to judging. Students reported to the exhibition hall at nine in the morning and were judged until half past six in the evening. The students were given an hour lunch break and a half hour snack break. All results were tabulated late into Wednesday evening to determine fair winners. Many presentations and sessions were observed for this study and detailed field notes were generated.

Judging results were provided for this study on Thursday at seven in the morning. The Education Director for Science Service provided 16 abstracts of the category winners, which listed the title of the project, the student's name, the student's school, city, and country, as well

as an abstract of the student's research. Information was rapidly organized, but more importantly, evaluated and assimilated so a credible conversation with the student was possible.

Public viewing was scheduled from 10 in the morning until 2 in the afternoon that same day. Students were required to be stationed at their projects to discuss their studies with the public. School visits are common during this session. During the public viewing session, students were recruited for the study in a similar fashion to CSF. Students were provided with two copies of the informed consent, a pre-stamped, preaddressed envelope, a copy of the newspaper article, and instructions for completing online surveys. Students were also asked to provide their electronic mail address and phone number from the database. Since recruitment took place during public viewing, unlike the CSF, which was during judging, and since all interviews would be scheduled by phone, instead of face to face, the investigator spent more time with each potential subject to increase rapport. The ISEF week ended with three awards ceremonies, where over five million dollars of prizes and scholarships were awarded.

Fifteen students were approached and asked to participate during the public viewing session. Follow-up telephone calls were made to those students who did not mail back informed consent, but expressed an interest in participating in the study. Interviews were requested at the convenience of the student after online instruments were completed. Interviews generally took place in the evening or on a weekend.

Survey Instrumentation

The Updated Science Research Temperament Scale (USRT). The USRT is an updated version of the Science Research Temperament (SRT) Scale (Kosinar, 1955). The SRT Scale was developed in the 1950s. It was intended to aid in the identification of personality traits that are associated with research productivity. There are 42 items on the instrument. For each item, the

subject is asked to select between two adjectives which best describe him or her. If neither word describes the individual, the subject is asked to select the nearest description. The pairs are based on 32 different words. Content was based on Cattell's (1943) list of traits. Standardization was based on 310 research scientists from 12 locations around the Chicago area. Correlation to productivity was based on a weighted rating system of published articles and patents. Reliability of this affective instrument is .76. An affective instrument has adequate reliability at .70 or above (Gable, 1986). Factor analysis was not computed for the original instruments, thus no subscales are currently available.

Since the instrument is over 50 years old, wording vernacular was updated with permission for several items and the item was reformatted (LaBanca, 2006). The USRT underwent updated validity and reliability testing in the fall of 2007 under a separate study with first semester introductory chemistry students (Chem 127Q) at the University of Connecticut. The new reliability of the instrument is .71. USRT data were used descriptively in this study.

The USRT was XML coded with php scripts for use as an online scale (see Appendix G). The webpage was designed using Dreamweaver MX version 6.0 (Macromedia, Inc, 2002). The php scripting was hand-coded based on the Level Ten FormMail template (Lorentz Consulting, 2003). Students were given the web address to complete the instrument. Upon clicking of the submit button, the data were mailed to an electronic mail address, then imported to a Microsoft Excel (Microsoft, 1999) spreadsheet for automatic tabulation.

Demographics Survey. A survey was developed to capture demographic information about individual student-subjects (see Appendix H). Categories on the survey included (a) personal information, including name, address, telephone number, electronic mail address, age and grade, (b) school information, including name, address, telephone number, principal name,

guidance counselor name, and currently enrolled courses, (c) most helpful teacher information, including contact information, area of expertise, and help provided, (d) parent information, including contact information and help provided for the research project, (e) mentor information, including contact and affiliation information, area of expertise, and help provided, and (f) other relevant information. The demographics survey was coded for online use, similar to the USRT Scale. Data were archived in a Microsoft Excel spreadsheet.

Semi-structured student interviews

Question development. Questions were initially developed as part of a pilot study conducted with CSF top finishers during the 2006 ISEF in Indianapolis, Indiana. Questions fell into three general categories: (a) the nature of problem finding, (b) the creative processes of science, and (c) the role of the scientist and the student-scientist as a creative individual. Questions were developed considering the taxonomy of ethnographic questions (Spradley, 1979). During the debriefing that followed each interview, subjects provided feedback on the quality and nature of questions as well as suggested new and alternative questions. The CSF president audited these interviews, and her suggestions were also considered in question modification.

In the fall of 2006, a high school applied research class of 15 students worked with the interview schedule and posted alternative interview questions on their class blog (LaBanca, 2008d). Focus grouping was conducted with the students to optimize and improve the question battery. Mock trials of questions were also conducted. Questions were then peer audited by four other science research teachers in Connecticut. The interview schedule was opportunistically modified based on field notes and respondent answers. Major revisions of the interview schedule are depicted in Appendix B.

Connecticut Science Fair student interview procedures. After informed consent was received and students completed the online versions of the demographic survey and USRT Scale, an appointment was made to conduct the interview. The interviews were conducted at the students' schools. Appointments were coordinated with the student as well as the teacher who acted as the adult sponsor for the project. Teachers followed their appropriate individual school procedures for having a guest in the building. Interviews were scheduled either during a student's unassigned period or during the mentor-teacher's class period. Informed consent, the objectives of the study, interview procedures and recording methods were reviewed with the student before the interview was conducted.

The subject first trained the Dragon Naturally Speaking 9.0 Preferred voice recognition software (Nuance Communications, 2007) using the Dragon headset and a laptop computer. The subject read a script for approximately six minutes to train the software to his or her voice. After training, the interview was conducted with the use of the voice recognition software in tandem with a Sony ICD-MX20 digital recorder with a SanDisk 512 MB Memory Stick Pro Duo and handwritten notes. The voice recognition software converted the speaker's words to text in a Microsoft Word file (Microsoft, 1999). An audio file was not generated with the voice recognition software, thus the redundant use of the digital recorder. The interview schedule was followed as opportunistically-modified from previous interviews. When clarification or more details were required, follow-up questions were utilized to encourage the student to elaborate.

Post interview, detailed field notes were generated. Digital recorder files were archived to the hard drive of a computer. Transcription began with the previously generated Microsoft Word file. The digital audio file was played through the digital recorder using headphones. Errors in the text file were corrected and edited to match the audio file. Completed text files were saved in

‘track changes while editing’ mode to clearly delineate any future changes made. Each file was electronically mailed to the subject for member checking verification and correction.

International Science and Engineering Fair student interview procedures. Based on question development and opportunistic changes that occurred during the CSF interviews, a stable interview schedule was used for all ISEF interviews (see Appendix B). Follow up questions were often used to clarify or further develop student responses.

All ISEF interviews were conducted by telephone, since subjects were spread across the United States and the world. Telephone interviews allowed for efficient, yet reliable, collection of data (Ibsen & Ballweg, 1974). Special consideration was given to style and technique using the telephone to ensure complementary results were comparable to the face-to-face CSF interviews. The only face-to-face rapport for ISEF subjects was developed during a short (15-30 minute) discussion during the public viewing session. Rapport can potentially develop effectively during a telephone conversation, since it is an interactive process (Lawler, 1994). It is assumed that the trustworthiness of experiences and beliefs provided during phone conversations is comparable to that obtained during an in-person interview. Indeed, research supports the contention that qualitative data are generally equally accurate by telephone and face-to-face interviews (Baxter, et al., 2003; Midanik, et al., 1999; Ibsen & Ballweg, 1974; Korner-Bitensky, Wood-Dauphinee, Shapiro, & Becker 1993).

Special questioning and speaking strategies were used to enhance data collection based on suggestions derived from the research literature. For example, when the goals, objectives, and nature of the study were explained to subjects, they were more likely to provide valid information (Singer & Frankel, 1982). Subjects who received assurance of confidentiality were more likely to answer sensitive items than those to whom confidentiality was not mentioned

(Singer & Frankel, 1982). An interviewer can be perceived as more empathetic, warm, and genuine when lengthy pauses on the telephone are avoided (Natale, 1978). However, short pauses or short interjections were important to cue the subject to take command of the conversation and provide detailed information. Affirmation of responses also improves telephone rapport (Natale, 1978).

Midanik, Hines, Greenfield, & Rogers (1999) report that telephone subjects use a very similar strategy for retrieval of information compared to face-to-face subjects. The most common similarity tends to be subjects anchoring and restating their information. A response is made immediately, followed by a reasonableness assessment, further recall, and a restatement of the original response. It is much rarer for a subject to anchor and then adjust. Context was also commonly used in both mediums. Subjects used anecdotal stories to explain their ideas. Subjects also often tended to define concepts to clarify what they were attempting to explain. Very rarely would subjects decompose information (i.e., explaining a general idea or concept then breaking down the concept into parts). The interview, therefore, used follow-up questions systematically to clarify and delve deeper into student responses.

Interviews were conducted as close to the ISEF as possible to reduce amount of error in the information recalled (Baxter, Thompson, Litaker, Guinn, Frye, Baglio, & Shaffer, 2003). A corded telephone handset was equipped with a RadioShack Mini Recorder Control #43-1237. The control attached to the telecom port and converted the audio signal through a 1/8" minijack. The minijack was plugged into a Sony ICD-MX20 digital recorder with a SanDisk 512 MB Memory Stick Pro Duo. Several interviews took place on a cellular telephone. In this case, the hands-free module of the cellular phone was equipped with a RadioShack Wireless Phone Recording Controller #17-855. The Controller had a port for a wired hands-free headset and an

output 1/8" minijack, which was connected to the digital recorder. This system required use of the wired hands-free earpiece/microphone. This system did not work with a wireless headset (e.g. Bluetooth). Both the corded landline and cellular systems exported sound in mono (left ear) only as a restriction and function of the RadioShack controllers. After the interview, field notes were generated. Audio files were archived to the hard drive of a computer.

Manual transcription of the audio file was generated via the recorder with headphones. An alternate strategy for transcription was developed for files with lower quality audio. Files were uploaded to the computer, and replayed through high-quality speakers. Digital voice editor (Sony, 2005) was used for listening. The software automatically equalized the sound file to compensate for background noise. The following user modifications were made to the software to aid in transcription in the *Tools/Options* window/*Transcribing Key* tab: (a) the start button was assigned to F10; (b) the stop button was assigned to F11; (c) the easy search forward button was assigned to F9 with a timeframe of 10 seconds; and (d) the easy search reverse button was assigned to F8 with an initial timeframe of 10 seconds, but was modified to 5 seconds to better access the files. Digital voice editor does work with foot control pedals, part #foot control unit FS-85USB, but they were not used in this application.

Completed text files were saved in 'track changes while editing' mode to clearly delineate any future changes made. Each file was electronically mailed to the subject for member checking verification and correction.

Semi-structured teacher and mentor interviews. CSF teacher interviews took place in person at the teacher's respective school. CSF mentor and ISEF mentor interviews took place by telephone. Informed consent and interview protocols were similar to those of the student

interviews. An interview schedule was developed to elucidate information for triangulation with the student interviews (see Appendix B).

Semi-structured fair director interviews. Fair director interviews took place by telephone. Informed consent and interview protocols were similar to those of the student interviews. An interview schedule was developed to elucidate information for triangulation with the student interviews.

Newspaper and popular press document analysis

A five-year guided news search of the Lexis-Nexis database was conducted to collect newspaper artifacts regarding the ISEF. The following search parameters were used:

1. Search terms: International Science and Engineering Fair, ISEF
2. Sources: all news, all newspapers, US newspapers and wire, all magazines
3. Date: previous five years (October, 2002-October, 2007)

The article title, source, and body text of each article was retrieved, copied, and converted into a Microsoft Word file.

A similar procedure was used to search the Education Resources Information Center (ERIC) database for ISEF artifacts.

Reflexivity journal

An online reflexivity journal blog (LaBanca, 2008b) was developed to maintain an audit trail and document tentative interpretations of the data (Merriam, 1998). A blog, or weblog, is an online journal: a personal chronological log of thoughts published on a web page using a user-friendly, word processor-based interface. Posts are displayed in reverse chronological order and each post has a link to allow comments and responses to the author. Blogs are simple to construct and use, because complex understanding of programming languages is not necessary. They are

free, and only a rudimentary understanding of a web browser and word processing program are necessary.

Because there were a large number of posts, the blog automatically archived data, making access more cumbersome. A chronological index of the blog with links to each post was created on a wiki (LaBanca, 2008c). A wiki is a collaborative website that users can easily modify via the web, again, using a user-friendly, word processor-based interface. Each post on the blog was identified on the wiki with a date, the title of the post, a priority level (no, low, medium, high), and a brief description.

Peer and mentor audits of the reflexivity blog were conducted periodically during the study. Auditors were given the wiki address and asked to post comments. An audit took place between the CSF and ISEF data collection, at the conclusion of data collection, before coding of data, and after coding of data.

In summary, there were many advantage to using the blog and wiki as a reflexivity journal. Data were always available asynchronously online. Data were easily accessible and well organized. Blogs and wikis are easy to set up and do not require advanced computer programming skills. Auditors provided comments easily without receiving cumbersome files either by electronic mail or paper. Auditors had access to other auditors' comments making their posts richer and more varied. Peer and mentor audit comments were effectively made, listed, shared, and compared both by the investigator and the auditors.

Analysis of data

A phenomenological multicase study must be sensitive to assumptions that might bias the study. Prejudices of the process or of the investigator must be considered through multiple, varied lenses. Metacognitive techniques, such as epoche, bracketing, and imaginative variation

can be used while analyzing the data. Epoche is the process of becoming aware of the self-prejudices and viewpoints of, in this case, the problem finding process (Merriam, 1998).

Bracketing, the process of setting aside what is known about a phenomenon, can be achieved by explaining the basis for the study, identifying presumptions based on the researcher's experiences, and disclosing assumptions about the methodology (Pitney & Parker, 2002).

Finally, imaginative variation challenges the researcher to view the problem finding phenomenon from multiple, divergent perspectives (Moustakas, 1990).

Qualitative analysis of the data occurred during and after collection. Emergent categorical themes were directly interpreted as interviews were conducted. Subsequent analysis was subject to an organized categorical aggregation (Stake, 1995). Data were preliminarily organized into case records (Patton, 1980). Content analysis of interview data were generated to search for patterns and categories (Spradley, 1979). Units of data were categorized and met the Lincoln and Guba (1985) criteria. First, a unit of data was heuristic, serving to indicate or point out revealing information relative to the study. Second, the unit of data was interpretable independent of other information, meaning the category was clearly delineated (Lincoln and Guba, 1985). The codes were organized to combine recurring regularities in the data to construct categories (Merriam, 1998).

Category construction was generated by analyzing an interview, related field notes, and documents. Each interview was cross-referenced with previously analyzed interviews to search for patterns. Categories were designed to reflect the nature of the research questions. The following criteria were used when generating categories: (a) categories were exhaustive allowing the placement of all data units, (b) categories were mutually exclusive, (c) categories were as sensitive as possible to best explain data, and (d) categories were conceptually congruent

meaning “the same level of abstraction should characterize all categories at the same level” (Merriam, 1998, p. 184).

All data were coded and categorized using *The Ethnograph*, computer software designed to make qualitative data analysis research easier, more efficient, and more effective (QRA, 2006). Entire case records were imported into the program. Each case was treated as an individual file within a project. Three projects were generated for this study: (a) student interviews, (b) adult interviews, and (c) popular press documents. A coding summary is provided in Table 5.

Table 5

Summary of categories generated in each project

| Project | Number of cases | Number of categories | Number of coded segments | Average number of coded segments per case |
|-----------|-----------------|----------------------|--------------------------|---|
| Students | 20 | 48 | 1426 | 71.30 |
| Adults | 6 | 31 | 294 | 49.00 |
| Documents | 98 | 4 | 100 | 1.02 |

Each file was independently coded, saved, and printed. Category segments were identified by highlighting. Each question was assigned a category to facilitate later sorting. After each project was completely categorized, cases were collectively compiled and sorted by category for cross-case analysis. Each category was assigned to a category cluster.

Categorized data was further analyzed by triangulation of both data sources and data methods. Patterns and categories of data records were compared and contrasted between cases

(Spradley, 1979; Miles & Huberman, 1984; Stake, 1995). Data that were critical to an assertion or a key interpretation were confirmed and validated by identifying that data across cases as well as confirming by peer and mentor audit (Stake, 1995). Several sections of significant data were verified by a panel of science content experts (n=6). All had graduate degrees in a natural science or engineering field.

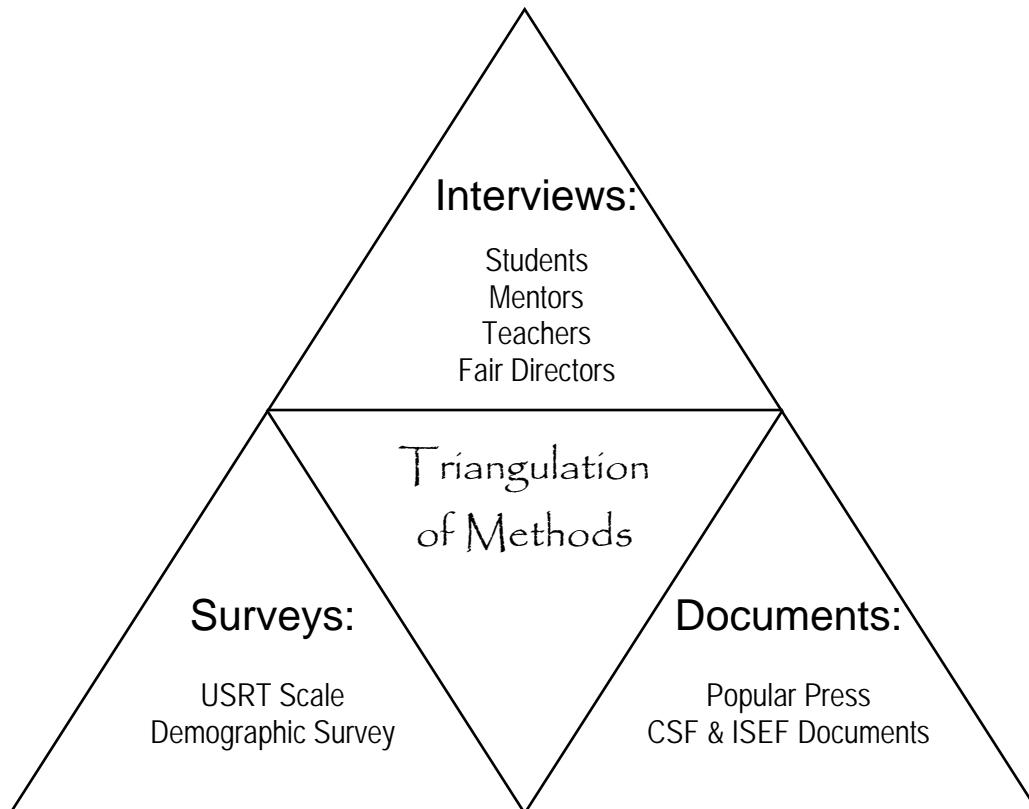


Figure 7. Triangulation strategy for methods

Multiple triangulation strategies were utilized to compare data sources and methods (see Figure 7). Data source triangulation observed if a phenomenon or finding remained the same for other individuals, times, or places in an attempt to see if what is observed carries the same meaning in different circumstances. Although investigator triangulation, using several different researchers for the study (Janesick, 1994), was not utilized, data were validated with a panel of

science research teacher-experts. Theory triangulation, using multiple theoretical perspectives as well as reviewers from alternative theoretical viewpoints was utilized to coordinate findings (Janesick, 1994; Stake, 1995). Theoretical triangulation was primarily achieved through peer and mentor review of the reflexivity journal. Methodological triangulation, using multiple sources, including interviews, documents, and surveys further validated the findings. Finally, interdisciplinary triangulation, utilizing multiple education disciplines during the research process, helped to broaden the understandings in the study (Janesick, 1994). The triangulation strategies provided checks for both credibility and dependability of collected data (Isaac & Michael, 1997).

A confirmability audit, utilizing a cross-validation technique was used to verify data coding, conclusions, and recommendations. An independent evaluator, knowledgeable in the precollege science research process and qualitative analysis reviewed and critiqued the findings. The expert concurred with 93% of the categories generated.

This study's design accounts for reduced sample size by allowing for an in-depth view of the problem finding phenomenon utilizing multiple sources and methods. Multiple strategies, therefore, were utilized to improve trustworthiness and transferability of the study (see Table 6) (Krefting, 1991).

Table 6

Summary of methodological strategies to improve trustworthiness

| Strategy | Criteria | Application |
|-------------|-------------------------|---|
| Credibility | Prolonged involvement | The researcher has been a teacher-participant in the open inquiry science research process and local, regional, statewide and international science fairs and symposia for eight years. |
| | Pilot interviews | Pilot interviews were conducted to frame the scope of the research questions and direct the focus of the research. |
| | Reflexivity | An online reflexivity journal was maintained throughout the study. |
| | Triangulation | Triangulation of data sources and methods was utilized in data analysis. |
| | Member checking | All interview transcripts were reviewed by their respective subjects. |
| | Peer/mentor examination | Doctoral cohorts, science research teachers, and mentors reviewed the reflexivity journal. |
| | Interview technique | Opportunistic questioning was utilized. Questions were removed or expanded based on previous responses. |
| | Structural coherence | Inconsistencies in the data were interpreted and explained. |

Table 6 (continued)

Summary of methodological strategies to improve trustworthiness

| Strategy | Criteria | Application |
|-----------------|-------------------------------|---|
| Transferability | Nominated sample | CSF and ISEF judging scores were utilized to identify potential subjects. |
| | Thick description | A complete description of the methodology was described including verbatim transcription of the interviews. |
| Dependability | Question development checking | Questions for interviews were developed in conjunction with research student participants. |
| | Triangulation | As described above. |
| | Cross validation | Coding consensus was achieved with the researcher and an independent evaluator. |
| Confirmability | Confirmability audit | Cross validation and peer and mentor audits were utilized. |
| | Triangulation | As described above. |
| | Reflexivity | As described above. |