Impact of Problem Finding on the Quality of Authentic Open Inquiry Science Research Projects

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Abstract

Problem finding is a creative process whereby individuals develop original ideas for study. Secondary science students who successfully participate in authentic, novel, open inquiry studies must engage in problem finding to determine viable and suitable topics. This study examined problem finding strategies employed by students who successfully completed and presented the results of their open inquiry research at the 2007 Connecticut Science Fair and the 2007 International Science and Engineering Fair. A multicase qualitative study was framed through the lenses of creativity, inquiry strategies, and situated cognition learning theory. Data were triangulated by methods (interviews, document analysis, surveys) and sources (students, teachers, mentors, fair directors, documents). The data demonstrated that the quality of student projects was directly impacted by the quality of their problem finding. Effective problem finding was a result of students using resources from previous, specialized experiences. They had a positive self-concept and a temperament for both the creative and logical perspectives of science research. Successful problem finding was derived from an idiosyncratic, nonlinear, and flexible use and understanding of inquiry. Finally, problem finding was influenced and assisted by the community of practicing scientists, with whom the students had an exceptional ability to communicate effectively. As a result, there appears to be a juxtaposition of creative and logical/analytical thought for open inquiry that may not be present in other forms of inquiry. Instructional strategies are suggested for teachers of science research students to improve the quality of problem finding for their students and their subsequent research projects.

Research Questions

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?

Rationale

- Problem finding (PF) not extensively studied in science (Hoover & Feldhusen, 1990&1994; Smilansky 1994; Subotnik, 1988)
- PF not extensively examined in learning psychology (Jonassen, 1997; Shymansky, 1990)
- PF studies in science primarily in classroom (Roth studies: 1993, 1997, 1998, ; Prince, 2004)
- Science fair studies primarily descriptive – not focused on cognitive structures (Bellipani, 1994; Pyle, 1996)

Key Operational Definitions

Inquiry is the "diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work" (NRC, 1996, p. 23). Inquiry can also refer to activities of students in which they develop knowledge and understanding of scientific concepts, and methods to study the natural world.

Open Inquiry is a student-centered instructional approach for learning that begins with a student's question, followed by research, design, experimentation, and communication of results. Open inquiry requires higher order thinking and direct, practical work with concepts. A key feature of open inquiry is having students ask their own questions (Martin-Hansen, 2002).

Problem finding is a science student's ability to define or identify a problem (Kay, 1994). The process involves consideration of alternative views or definitions of a problem that are generated and selected for further consideration (Fontenot, 1993). Problem finding requires students to set objectives, define purposes, decide what is interesting, and ultimately decide what they want to study (Leavitt, 1976).

Reverse engineering is the process of discovering the functional principles and processes of a device, object, or system through analysis of its structure, function, or operation. It often involves taking the device apart and analyzing its workings in detail for the purpose of making a new device or program that does the same thing without copying anything from the original (Rekoff, 1985).

The **community of practice** is a process of social learning that occurs when individuals and practicing scientists and engineers collaborate over an extended period of time to share ideas, find solutions, and innovate (Wenger, 1998).

Inbound trajectory describes a neophyte who invested in the community of practice and was heading towards full participation. These students gained experiences and expertise that often led to the development of a meaningful project.

Boundary trajectory describes a full member of the community of practice who brokers relations and expertise with other individuals in the community. Some students in this study achieved boundary trajectory.

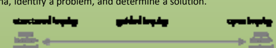
Theoretical Constructs

Secondary school teachers have long valued developing student problem solving skills. Indeed, problem solving has become an integral part of instruction across curriculum areas. Students are challenged to use a variety of strategies to identify problems and their implications, develop action plans, utilize a variety of relevant sources, information, and data to address the problems, and formulate solutions . Problem solving techniques can be highly idiosyncratic. However, in perhaps too many educational settings involving problem solving, teachers provide students with the problem or question, and sometimes even the methodology for determining the solution. This approach may be due to curricular requirements, time factors, or the limited scope and goals of particular learning modules or the inability of teachers to effectively employ inquiry-oriented instructional techniques.

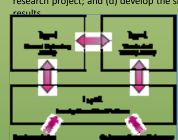
What, therefore, seems lacking are opportunities for students to problem find: to develop their own unique ideas for study. While problem solving requires primarily logical/analytical thought processes, problem finding is a creative process (Dillon, 1982).

In order to implement inquiry learning successfully, teachers must understand what inquiry is, understand the structure of their scientific disciplines, and be skilled in inquiry-teaching. Since it can take many forms, it is critical that educators understand different forms of inquiry, and the value of implementing each.

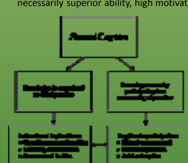
Structured inquiry is a guided form of inquiry, generally directed by a teacher (Martin-Hansen, 2002). This is typically exemplified by a hands-on learning experience where students follow the step-by-step directions provided by the teacher, sometimes referred to as "cookbook." When students engage in guided inquiry they have more responsibility and independence than when using structured inquiry. A teacher poses a question, often curricular in nature, and students work to develop a solution by designing their own methods and data analysis procedures. In open inquiry, students become responsible for asking their own questions, designing and conducting experiments, then analyzing and reporting the results. In essence, a creative element is added because students must problem find before they can problem solve. Students are challenged to observe raw phenomena, identify a problem, and determine a solution.



From a teaching and learning perspective, the major pedagogical goals of high-quality extended scientific open inquiry are to provide students with the opportunity to assume more and more responsibility for their own intellectual development by becoming independent learners (inquirers) who: (a) interact with practicing scientists; (b) participate in a significant research experience; (c) select, develop and conduct an independent research project; and (d) develop the skills of reporting, presenting, and sharing research results.

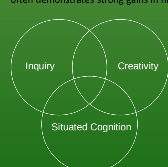


In the gifted education literature, the Enrichment Triad Model (Renzulli, 1977), although not science-domain specific, parallels the Martin-Hansen (2002) inquiry model. Consisting of three levels of activities, Type I activities are general interest, though not typically found in the regular curriculum, and Type II are categorized as how-to activities. Open inquiry science research falls under the general domain of Type III. The model suggests that students assume the role of first-hand inquirer, create original authentic products (in this case, authentic scientific research) and share it with an appropriate audience. Renzulli's (1986) three-ring conception of giftedness suggests the student exhibiting gifted behaviors will possess above average, though not necessarily superior ability, high motivation, and creativity.



Open inquiry science research enables students to learn in context. Brown et. al. (1989) suggest that activities in context are integral to learning in their situated cognition learning theory. The main tenet of the theory is that learning knowledge and skills occurs best when they are in a context that reflects the way they will be used in real life (Collins, 1988). The situated cognition model states that knowledge is conceived as lived practice (Driscoll, 2005). In essence, the sociocultural setting and activities of individuals drives the acquisition of knowledge. Learning for students occurs as they participate in a community of practice.

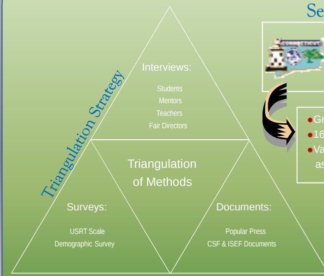
Open inquiry learning environments appear to intersect concepts of inquiry, creativity, and situated cognition. A student who has the opportunity to both find and solve authentic problems participates in a more holistic approach to science education and, as a result, often demonstrates strong gains in higher order thinking and positive self-efficacy.



Because of the limited studies of open inquiry as a lens to understanding problem finding, an investigation was warranted. Assuming a conceptual framework focused around the three main themes of inquiry, the creative process of problem finding, and situated cognition learning theory, student perceptions, understandings, and uses of problem finding in an authentic open inquiry environment were examined. Since a situated cognition approach was utilized, the social effects and influence of others (e.g. mentors, teachers, parents) were also examined.

Methodology Overview

(Qualitative Paradigm)



Semi-structured Interview Sample

12 student presenters From CT Science Fair

Eight student presenters from International Science Fair

- Grades 11-12
- 16-18 years of age
- Variety of quality, as determined by judges

Purposeful selection of six mentors and teachers and two fair directors for triangulation

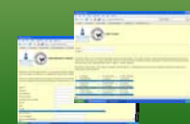
Approach

Multicase Study with Phenomenological Approach

Descriptive Strategy

Explain, identify, and document the phenomena of problem finding in open inquiry

Electronic Survey & Affective Instruments



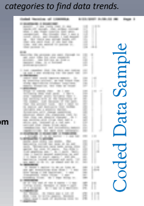
Techniques to Improve Trustworthiness

Strategy	Criteria	Application
Credibility	Prolonged engagement	[illegible]
	Pilot interviews	[illegible]
	Reflexivity	[illegible]
	Triangulation	[illegible]
	Member checking	[illegible]
	Peer/mentor examination	[illegible]
	Interview technique	[illegible]
	Structural coherence	[illegible]
Transferability	Nominated sample	[illegible]
	Thick description	[illegible]
Dependability	Question development checking	[illegible]
	Triangulation	As described above.
	[illegible]	[illegible]
Confirmability	Confirmability audit	[illegible]
	Triangulation	As described above.
	Reflexivity	As described above.

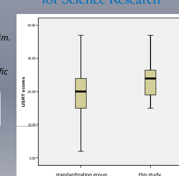
Reflexivity Blog

A blog was used to maintain reflexivity. Peer and mentor audits were conducted and feedback responses were posted to the blog. Blog address is **problemfinding.blogspot.com**

Each interview was transcribed verbatim. Data was categorized by emerging themes using **The Ethnograph**. *The software allows for extraction of specific categories to find data trends.*



Students' Temperament for Science Research



Each student-subject was evaluated for temperament for science research using a reliable and valid instrument, **The USRT.** *This affective instrument allows subjects to select personality traits which best describe them. The instrument was standardized using freshmen undergraduate science majors.*

Analysis and Discussion

After coding, the following axial categories emerged from the data:

Category	Concept	Explanation
Creative thinking	Definition of creativity by student scientists	Science research students and mentors define creativity almost exclusively as problem finding.
	Classification of problems and subsequent projects	A scheme developed from the data indicating that projects could be classified by their type: novel approach, technical with value, technical, or literature search.
Entry point characteristics	Temperament for science research	Students viewed science as both a logical/analytical and creative process. (see figure below, center, right)
	Previous experience	Many students engaged in specialized cognitive apprenticeship experiences (job shadowing, internships, working in labs, learning to use specialized instrumentation, discussions with practicing scientists) before finding problems
Reflexive behaviors	Motivation	Many students described their motivation for conducting a project, describing their passion for scientific inquiry. Their descriptions often focused on descriptive characteristics of the creative scientist and their perception of the rewarding experiences associated with it.
	Descriptions of self	Students defined themselves in terms of Renzulli's three ring conception of giftedness: above average ability, creativity, task commitment. Student terms tended to code CR and TC, exclusively, while mentors and teachers used all three.
Inquiry strategies	Nature of scientific inquiry	Students understood the idiosyncratic nature of conducting research. They not feel there was a standard formula to arrive at a solution. Rather, they developed logical, analytical, and creative strategies to solve problems. The students did not choose to define their problem finding or solving as a step-by-step sequence. Their questions drove their research, not some predetermined prescriptional method.
	Background research	Pre-experimentation background research, in order to build a knowledge base, was a common, critical factor for students. Many used multiple resources: online databases, university libraries, books, and experts in the field.
Situated learning	Ability to communicate well	Students conducting research have an uncanny way of being able to communicate their needs effectively. They interact, not only with their peers and teachers, but also with professionals in academia and industry. Some build mentorship partnerships with these adults, some only seek information to clarify their understandings or ideas.
	Applying knowledge	Students recognize that the knowledge they are gaining from an open-inquiry project is often more sophisticated than a traditional academic class. The information they seek and learn transcends isolated facts of a textbook, because it is in context. The information has relevance to both them and the community of practice.
	Application of the research and relevance to the greater community	Students recognized that projects should have value beyond the classroom, teacher, or school walls. In other words, their projects had authentic audiences: real people or organizations that would value the information that was generated from the project.
Critical thinking	Specialized understanding	Students developed a complex understanding of the content related to their project. This understanding was often much more specialized than the content knowledge associated with a traditional science class.
	Deep understanding	Students understood the nature of their projects viewed through different lenses. This deep understanding usually went beyond scientific knowledge. This was more of a conceptual understanding with scientific, social, political, interpersonal, theoretical, and practical realizations.
	Reverse engineering	Because students often lacked the worldly experience of domains of science that a formally trained scientist would, they often had to critically and creatively figure things out without personal expertise or experience. This critical process came in the form of working backwards. Reverse engineering, within the scope of inquiry and creativity, took the role of knowing or having information and decoding for a useful purpose within the scope of a project.
Teaching approach	Role of parents	The majority of students did not utilize their parents during the problem finding phase. Most accessed their parents in a utilitarian fashion. Parents were often involved in the mechanical processes of editing work, helping with layout of posters, or listening to talks. However, parents provided a supportive, nurturing, enriching environment to promote their child's independence and creativity
	Role of teachers and mentors	Mentors perceived their role in the problem finding experience as a support function, trying to facilitate student idea generation rather than direct students. For all students, regardless of level of success at a fair, teachers and mentors were calculating in their strategy to allow students to develop their own ideas rather than present them with an avenue of study.

Conclusions

Connecting the data. Problem finding in science is a uniquely creative process that can inspire and direct open-inquiry research. Students who problem find well, do so by utilizing a situated cognition learning framework. Their problems, and subsequent projects, have value to a greater community outside of the classroom, and often have a real audience. Students commonly and effectively find their problems using resources from previous, specialized experiences. They have a positive self-concept and a temperament towards creative, logical, and analytical perspectives of science research. Good problem finding is derived from an idiosyncratic, nonlinear, and flexible use and understanding of inquiry. Finally, problem finding is influenced and assisted by the community of practice, to whom the students have an exceptional ability to communicate with effectively. These students and their problem finding strategies can serve as models for other neophyte researchers who wish to successfully pursue an open inquiry project.

Implications for educators. Teachers and students as researchers. Science teachers are more likely to be effective guides and mentors for students engaging in research if the teachers themselves value and have had first-hand experience with research projects. *Nurturing problem finding.* The problem finding stage is a critical first step that cannot be hurried. Considerable time, thought, and resources are devoted during this phase of research. *Special research courses.* Science teachers can be encouraged to offer special research courses in which students have opportunities to pursue open inquiry activities that transcend the traditional science course offerings. *Fairs and symposia.* Many organizations sponsor events for students to present their research to an authentic audience of industry and academic scientists and engineers. If students and teachers collaboratively choose to participate in an event, they need to be sensitive to the expectations of the audience that will receive their presentations. *Facilitating communication and sharing.* High quality problem finding and problem solving require high quality communication. Teachers can be helpful by modeling effective oral and written communication skills and by coaching their students through practice presentations and rehearsals.

Summary. This study provided support for the contention that a successful open inquiry experience fostered creativity in students by allowing them to problem find. The problem finding process was idiosyncratic and required an extensive amount of time. Students worked through this process independently, but brokered and managed relations with others to advance their understanding and knowledge, and ultimately their projects.