The Creative Process of Problem Finding Manifested in Open Inquiry

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Abstract

Problem finding is a creative process where individuals develop original ideas for study. Secondary science students who successfully participate in authentic open inquiry studies must engage in problem finding to determine viable and suitable topics. A multicase study examined problem finding strategies employed by highly successful students who presented a project at a regional and international science fair. Behaviors are examined through lenses of inquiry, creativity, and situated cognition.

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Introduction

Secondary school teachers have long valued developing student problem solving skills. Students are often 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, 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 and analytical thought processes, problem finding is a creative process (Dillon, 1982).

Various instructional strategies of inquiry exist. 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. In guided 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. However, 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.

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.

Open inquiry science research enables students to learn in context. Brown, et al. (1989) suggested 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 (a) inquiry, (b) the creative process of problem finding, and (c) 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

A multicase qualitative study was conducted to examine the impact of problem finding on the quality of extended open-inquiry science research projects. Students participating in the 2007 Connecticut Science Fair (CSF) and the 2007 International Science and Engineering Fair (ISEF) served as subjects. These students, in conjunction with mentors, teachers, and fair directors, via interviews, surveys, and documents, provided the data sources for the study.

The purpose of the study was to address the following two 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?

Using an open inquiry strategy allowed students to determine their own problems for study then design their own methodologies and data analysis strategies to observe, explain, or discover phenomena. Science fairs have promoted open inquiry experiences for students by providing them with a forum for them to present their extended research projects to an authentic audience of practicing scientists. In this paradigm, the teacher's role changes, becoming more of a facilitator than a content expert who disseminates knowledge.

This study examined 20 of these young, budding scientists, 12 from the Connecticut Science Fair (CSF) and 8 from the International Science and Engineer Fair (ISEF). The students were purposefully selected based on the fairs' judging criteria. For CSF, students who were ranked as finalists (approximately 35 students), or top quartile, and those ranked as third honors (approximately 50 students), or bottom third were recruited for possible participation. At ISEF, the top 17 category winners were recruited for participation. Each participating student completed the Updated Science Research Temperament (USRT) Scale, a demographic survey, and a semi-structured interview.

CSF interviews were conducted face to face, while ISEF interviews were conducted by telephone. Interviews were analyzed for categorical themes. Categories were retrieved throughout a single case and across all cases. Categories were axially ordered into category clusters to construct overarching themes (Merriam, 1998). Units of data were thematically grouped to meet the Lincoln and Guba (1985) criteria. First, a theme was heuristic, serving to indicate or point out revealing information relative to the study. Second, the theme was interpretable independent of other information, meaning it was clearly delineated.

The categories and patterns from student interviews were triangulated with interviews with mentors, teachers, and science fair directors as well as content analysis of popular press and media, CSF, and ISEF documents. Triangulation of data was achieved through methods (interviews, document analysis, surveys) and sources (students, teachers, mentors, fair directors, documents).

Major findings

Definition of creativity in science. Creative thinking was a key feature for student problem finding. Students defined creativity as the ability and willingness to come up with a new problem or approach a preexisting problem from a new point of view. This flexible approach to questioning and posing new problems seemed to be the essence for the creative behaviors of these student-scientists. Their successes were derived from knowing that there was something new, innovative, and novel to discover, create, or build.

The majority of students and mentors defined creativity in terms of problem finding. Some students also defined creativity in terms of problem solving. Only a few used more of an amorphous definition focused more generally around curiosity and "thinking outside the box." For example, the following student indicates his definition for creativity in science, which is representative of the majority of the students and adults: "Creativity is coming up with an original idea that nobody's done before. Or somebody has looked at before and you look at it at your own angle or a new angle."

A schema for project classification. Each project fell into one of four categories: literature review, technical problem, technical problem with value, and novel approach to the problem. Students who conducted a literature review project used sources for all information and organized it into a report. These projects did not analyze any data, but rather examined primary and secondary sources of research and then organized the information for a presentation. Little, if any, inquiry took place during the process. This type of project is contrary to the expectations of the science fair process, which anticipates that students conduct an inquiry project (CSF, 2006; Science Service, 2006).

Technical projects met the next strata of classification. A technical project examined a well-known question with well-known outcomes. These types of projects used predetermined procedures and often have predictable results. These students, however, engaged in an inquiry activity. Although students participated in inquiry learning, these projects are often poorly received by the community of practice (i.e. practicing scientists and engineers), because they lack any new contribution to the scientific knowledge base. An authentic audience of judges from industry and academia, while appreciating a student's effort, rarely valued the contribution of this type of work (Bellipanni, 1994; Grobman, 1993). All too often, perhaps, these types of projects are very common at local and regional science fairs.

Students who completed a technical project with value started with a predetermined methodology, but generated new data that had the potential to contribute to the scientific knowledge base. Generally their projects produced a subset of data that filled a small, but unique niche. They collected data from a locale or source that has not previously or recently been studied or perhaps they optimized a process to make it work more efficiently. These projects had value, because there was an authentic community that appreciated, required, or used the data generated by the students.

Finally, the most successful types of projects tended to be those with a novel approach. In a novel approach project, the student researcher asked a novel question or determined a novel method to solve a preexisting problem. Students demonstrated an elegant insight to solving their novel problems and utilized creativity factors such as fluency and flexibiltity more effectively than their technical with value counterparts (Torrence, 1965).

Situated project classification. The schema presented here stresses the situated nature of successful open-inquiry coupled with creativity. When asked to evaluate student projects, members of the scientific and engineering communities of practice resolved the differences between a technical project with value and a novel approach project with little ambiguity.

Perhaps most important, students understood how to classify projects without prompting or presentation of a classification scheme, whether it be their own or another. They recognized that projects that had novel questions or methodologies would be received in a more positive light than those that did not. They also recognized that projects that had applicability, value to the general public, or were current hot topics would also be rewarded more positively.

Previous experience. Most students reported that they had participated in activities related to conducting a project prior to actually selecting their project. These experiences were often extensive and built the necessary, specialized, prerequisite skills for conducting a significant, innovative project. These experiences were extensive, and were always beyond the scope of the traditional science classroom curriculum.

Due to their previous experience, the students had a more sophisticated sense of emerging problems (Dillon, 1982) that might exist related to their topics of interest. Since the problems were more refined than existent problems, the students had a strong understanding of the domain culture (Csikszentmihalyi, 1990) associated with their particular field of interest.

Students' temperament for science research. The USRT Scale was used to measure students' temperament for science. The affective instrument measures personality characteristics in dichotomous pairs based on Cattell's (1949) lists of traits (LaBanca, 2006). Scores on the USRT were used descriptively. Fifteen of the 20 subjects (75%) scored higher than the instrument's mean average for science majors. The majority of the students had an affirmative indication to their positive temperament to science research, determined both by the USRT results and through their interview comments.

Students were asked to use three adjectives to describe themselves in terms of their inquiry projects. Using Renzulli's (1986) three-ring conception of giftedness as a comment classification framework, the students rarely referred to themselves in terms of their above average ability. They commonly used creativity terms in very similar frequency to their task commitment terms. Several students commented outside of the Renzulli domains, but their comments were focused on the application of their projects to an authentic audience, which is a goal of gifted behavior (Renzulli & Reis, 1986).

Mentors and teachers were asked to describe their students using adjectives, and the same classification scheme was used to interpret the results. Over two-thirds of the responses of the adults were in terms of task commitment. Above average ability and creativity equally split the remaining responses. Students were more willing to describe themselves as creative, while the adults most commonly recognized their task commitment.

Students having a positive self-concept of their creativity was seen as important. Indeed the student and adult definitions of creativity were almost exclusively defined as problem finding. Since the community of practice of practicing scientists and engineers used problem finding as a common definition and interpretation of creativity in open inquiry research, this process is an important, critical aspect.

Creativity associated with problem finding appeared to spill over to student self-regulation (Bandura, 1997; Pintrich, 2000; Tytler, 1992). Students, regardless of science fair rankings, demonstrated high motivation because they were allowed to be independent, self-directed learners. They recognized the value of their work for its own worth, and the experience they had that was not part of traditional classroom learning. This alternative, situated learning strategy gave students an autonomous stature to be directors of learning, utilizing teachers and mentors as facilitators.

Defining inquiry. A structured or guided inquiry approach to research is often bound by procedural frameworks, which compromise the independence and creativity of students. Students who engaged in open-inquiry experiences were not bound by these confines. They had an intuitive understanding of the idiosyncratic nature of inquiry and did not feel obligated to follow a linear, hypothesis-based testing strategy to solve their problems. Students recognized that inquiry was learning by questioning, which is very different from knowledge garnered from a textbook, as indicated by Shymansky, Hedges, & Woodworth (1990).

Inbound and boundary interaction with the community of practice. Students in this study demonstrated an exceptional ability to communicate well with others. Although communication with others transcends all facets of the research process, it was critical during the problem finding phase when students were attempting to develop an idea. It was important because students must determine the feasibility of a project in terms of time, resources, skill, personal expertise, and the expertise of others. They tended to broker relationships (Wenger, 1998) that best suited the person assisting them, whether it was full-fledged mentorships, or electronic communications to clarify understandings or ideas.

There almost appears to be a paradox between the “one person to a project” schema of the science fair and the social nature of situated learning (Brown, et al., 1989). This has sometimes been a major criticism of the science fair process: the science fair promotes competition and deters collaboration (Grubman, 1993; McBride & Silverman, 1988). These conflicts resolved themselves well, because the students in this study demonstrated that they did not work in isolation. They acted as project managers and facilitated the assistance of peers, expert adults, and not-expert adults to garner success. These students, as members of a community of practice, brokered relationships that were necessary based on their understanding, needs, and expertise. They realized and articulated that it was nearly impossible to conduct a quality project in seclusion.

Rarely were parents members of the community of practice, and as such, rarely were parents employed in the problem finding process. The students in this study demonstrated that quality projects began with quality ideas derived from the student's extensive and meaningful problem finding. Parents did not convolute the process, and when they interacted, it generally was to casually point their children towards perceived valuable information that might be associated with potential project interests. Even when parents were members of the scientific community, they played a very minor role. However, parents provided a rich, nurturing, and supportive environment which included emotional and, sometimes financial, support. Parents facilitated independence instead of imposing their own perceived values.

Conclusion

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 scope of the classroom, and often have a novel approach. 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

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. It is reasonable to hypothesize that teachers, previously not exposed to an authentic research experience, would benefit from participation in such apprenticeships also to more accurately provide their students with genuine opportunities. Different than a standard course laboratory experience, working on an authentic research project for an extended period of time requires skills, temperament, and attitudes that can best be acquired by first-hand research experiences.

In a similar fashion, students can also benefit from externship opportunities. Externships can range from single-day job shadowing, summer enrichment activities, to full-fledged extended research laboratory internships.

Nurturing problem finding. The problem finding stage is a critical first step that cannot be hurried. Considerable time, thought, and resources are needed during this phase of research. Teachers can function as facilitators by helping students realize that they must set their own priorities, schedules, and deadlines. For example, success for students in this study was demonstrated by their ability to monitor and adjust their learning, as well as their ability to interact in collaborative ways with teachers, mentors, and scientists. Authentic problem finding, and the research that follows, can take an extraordinary amount of time so opportunities to engage in research experience for multiple years has great potential value.

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. A program that allows students to conduct one or more projects over multiple years has the advantage of truly allowing students to fully develop and explore their creative ideas as well as perpetuating a classroom culture of varying levels of expertise. Older students with more experience might then have the opportunity to assume leadership roles within the classroom research environment. Here, again, teachers can play an important role by introducing their students to such opportunities and by encouraging them to participate in multi-year projects in collaboration with other students or as individual researchers.

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. The quality and nature of the product produced should meet the expected rigors and standards of the sponsoring organization.

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 as well as teaching professional approaches to verbal and written interactions with the community of practice.

Oral presentations, using presentation (e.g., PowerPoint) technology, have become a primary communication mode for students engaging in open-inquiry. The opportunity to regularly present their work to teachers and classmates builds spoken communication skills, and assists students in polishing and strengthening their thoughts and findings before formal presentations at science fairs and symposia. Teachers and students alike can use well-designed formative evaluation rubrics to provide meaningful feedback to presenters. The rubrics might contain indicators that include: organization of the presentation, clarity of subject knowledge, quality of graphics, grammar mechanics, eye contact with the audience, and elocution.

There are times when a teacher may need to model effective presentation techniques, and there are times when the teacher may need to take a more Socratic approach and work in conjunction with other students to provide the student investigator with helpful feedback in the form of thought-provoking questions and constructive criticism. Questions and feedback that encourage self-evaluation and introspection can play a pivotal role. Students surely "learn by doing" but they may learn even more when a teacher helps them to "reflect on the doing."

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.

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