Going deeper one step at a time:
The development of a scientific inquiry process in a high school setting

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Abstract

This paper examines the first phase of a design experiment that will use principle based professional development as a means to promote a knowledge building culture. A partnership was created between a university researcher, a classroom teacher and her grade eleven students who recognized the potential of a curriculum based collaborative project as a means to deepen understanding by fostering inquiry and understanding of the scientific method. Participants volunteered to be part of this study and included grade eleven students in two different subject areas (N=30 from a total cohort of 32) who were required to investigate a scientific topic of their choice. Three data sources are documented in this initial phase of the study: 1) teacher notes and observations, 2) detailed individual student logs, and 3) student group findings after conducting their experiments. Trails of evidence will illustrate links between the discourse generated among participants and efforts to implement reform, bridging practice with theory. Implications for the next phase of this particular design experiment, the building of community and curriculum decision-making is presented.

Background

Bereiter (2002) stated, "Design research is constituted within communities of practice that have certain characteristics of innovativeness, responsiveness to evidence, connectivity to basic science, and dedication to continual improvement" (pg. 321). Today, the research community recognizes that when people are engaged in collaborative inquiry, engagement becomes an advanced form of professional development especially when supported through partnerships that involve schools, universities and communities of practice. This paper represents the beginning efforts of a partnership between a university researcher, a classroom teacher and her grade eleven students who recognized the potential of a curriculum based collaborative project designed to deepen understanding through inquiry and understanding of the scientific method.

Theoretical Framework

Three frameworks have been used to inform this design experiment. First, Knowledge Building research guides the principles underlying this study in the hopes to improve instructional design, extend the application of results and identify new design possibilities. Second, problem-solving research informed how teachers and students resolved uncertainty and challenges faced when exploring scientific problems. Finally, sociocultural factors are examined to help determine the influences impacting development of teachers' and students' thinking.

Methodology

The research is emergent in nature, exploring processes involved as students take on scientific problems they care about. The study will track and examine preliminary outcomes from a compulsory curriculum based project to identify important factors that may contribute to improving lesson design as well as improve the depth of both student and teachers' understanding. The usefulness of design research has been addressed by a number of researchers dealing with complex educational environments (Brown, Collins, & Duguid, 1989). Additionally Borko (2004) comments, "*Design experiments, with their repeated cycles of design, enactment, analysis and redesign can be particularly useful to study the impact on the development of professional community and the learning of individual teachers*" (p. 12).

Participants

As this study will explore both student and teacher learning, participants include a classroom teacher, a university researcher as participant observer and grade eleven students enrolled in the International Baccalaureate program at a Windsor-Essex high school (N=30 from a total cohort of 32). The classroom teacher expressed interest to begin exploring Knowledge Building principles and was provided with an overview and relative research by the university researcher. The classroom teacher and university researcher maintained journals recording impressions and observations. The students are enrolled in grade eleven chemistry and biology classes and require successful completion of a compulsory project that is divided into three phases: 1) the planning stage, 2) the action phase, and 3) the presentation phase. Chemistry students are expected to complete one action phase and biology students are expected to complete two action phases, one as a chemist and one as a biologist. As a collaborative group project, students were divided into small groups of three or four participants. Ten classroom hours were allocated to collaborate in the design and implementation of a science experiment based on a topic of the students' choice, limited to attributes and characteristics of either food or water.

Data Sources

The data include quantitative measures such as frequency tables to illustrate patterns of interaction as a result of overall qualitative ratings. Three data sources are used in this initial phase of the study: 1) teacher notes and observations, 2) detailed individual student logs, and 3) student group findings after conducting their experiments. Trails of evidence over the three phases, (the planning stage, the action phase and the presentation phase) will illustrate links between the reflections and findings generated by participants.

Data Analysis

Research suggests that active participation reflecting a commitment to advance conceptual understanding creates the possibility for conceptual movement (Wenger, 1998). Adopting a perspective that reality is socially constructed, as suggested by Berger and Luckmann, (1967) a phenomenological approach (Bogdan & Biklen, 1982) is used in order to make an “attempt to understand the meaning of events and interactions to ordinary people in particular situations” (p. 31). Data were examined to identify topics and patterns that would assist in determining the nature of the participants' interactions as phenomenon from their experience and point of view.

The compulsory science project is intended to be student-driven and the classroom teacher’s notes and observations were analyzed for points of influence, including feedback from the prescribed assessment criterion as outlined by the curriculum (Appendix A). A framework to code student participants’ nominal data was developed based on categorizations developed by Searle (1976). As an analytic tool for inquiry, this framework helped to explain actions taken or not taken by participants. Further, it was thought that this approach may be helpful to identify intended meaning of discursive statements, explanations and ideas found in the context of student logs and displays of group experiment findings:

Table 1: Coding Framework:
Categories of communicative acts or statements as forms of scientific inquiry

Code	Sub-Category	Description
1.1	Assertive	commits to the truth of the expressed proposition e.g. assertions, suggestions or conclusions
1.2	Directive	reflects attempts to garner action by others e.g. forms of requests, questions, next steps
1.3	Declarative	expresses a position that may be a change in the current state of affairs
1.4	Expressive	expresses attitudes and emotions towards the proposition
1.5	Commissive	reflects commitment to some future action

To illustrate a progressive trajectory in attempts to improve knowledge as the main goal of this design experiment, the research by Bereiter (2002) has helped to identify forms of interaction as to how teachers and their students work with ideas. Deep level constructivism is represented as a way to describe how people work with ideas in a Knowledge Building community. Building on this research, the following framework was developed (De Froy, 2006) to analyze the data:

Table 2: Coding Framework:
Categories of how teachers and students work with ideas

Code	Sub-Category	Description
2.1	Foundational Knowledge	Finding out what is already known, acquiring mathematical language, accessing resources, learning "how-to-do-it"
2.2	Sub-skills Of Research	Practicing critical thinking, using scientific method. Thinking often uses sets of step-wise procedures, teacher-designed activities, assessing results. Incorporated collaboration, provided emotional support and encouragement. Over time they learn to assemble information into competent original research and curriculum design.
2.3	Shallow	*Participating* in learning communities, project based learning,

	Constructivism	guided discovery. Saw knowledge as socially constructed, used collaboration, shared knowledge based in real world content, and varied information sources to understand the deeper meaning behind the language of chemistry and biology
2.4	Deep level Constructivism	Active goal of *improving knowledge*. Instructional strategies include the identification of unsolved problems of understanding, theorizing, building models, monitoring, evaluating progress and reporting, refining ideas at deeper levels.

Data was analyzed first by coding nominal data following the above two frameworks supported by corresponding quotes for each participant. Second, significant incidents declared by individual participants were identified. Third tracking files from student logs were used to capture common recurring themes. Excerpts from the logs and interview data are used to illustrate changing conceptions of science, teaching and learning over the duration of this project. Evidence of movement on specific concepts representative of the subjects' thinking is represented as 'trails' reflecting a form of trajectory. (Hutchins, 1996; Scardamalia & Bereiter, 2002; Wenger, 1998).

Results and Discussion

Tables will be presented in the final paper to illustrate the total number of statements that reflect the above mentioned categories that reflect communicative acts as forms of inquiry and how teachers and students work with ideas. Statement totals within categories will be averaged as a percentage of the total number of statements in all categories. If there was no data for a participant, no score will be given so it will not impact the overall rating. In this way, the data will be biased toward finding the highest reflective level reached for each participant, regardless of the quantity of entries. Qualitative data will be used to identify corresponding quotes of student participants and the classroom teacher.

The discussion will also explain the findings as viewed through the lens of the above-mentioned categories. Educational and design implications will be presented for the next phase of this study to further principle based professional development as a means to promote a knowledge building culture.

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Appendix A

Personal Skills (Project Assessment)			
Levels/Marks	Aspect 1 Self Motivation and perseverance	Aspect 2 Working within a team	Aspect 3 Self-Reflection
Complete / 2	Approaches the project with self-motivation and follows through to completion	Collaborates and communicates in a group situation and integrates the views of others	Shows a thorough awareness of their own strength and weaknesses and gives thoughtful consideration to their learning experience
Partial/1	Completes the project but sometimes lacks self-motivation	Exchanges some views but requires guidance to collaborate with others	Shows limited awareness of their own strengths and weaknesses and gives some consideration to their learning experience
Not at all/0	Lacks perseverance and motivation	Makes little or no attempt to collaborate in a group situation	Shows no awareness of their own strengths and weaknesses and gives no consideration to their learning experience

Manipulative Skills (Summative Assessment)			
Levels/Marks	Aspect 1 Following Instructions	Aspect 2 Carrying out techniques	Aspect 3 Working Safely
Complete / 2	Follows instructions accurately, adapting to new circumstances (Seeking assistance when required)	Competent and methodical in the use of a range of techniques and equipment	Pays attention to safety issues
Partial/1	Follows instructions but requires assistance	Usually competent and methodical in the use of a range of techniques and equipment	Usually pays attention to safety issues
Not at all/0	Rarely follows instructions or requires constant supervision	Rarely competent and methodical in the use of a range of techniques and equipment	Rarely pays attention to safety issues