

A RHIZOANALYSIS OF THE ONTARIO SCIENCE CENTRE SCIENCE SCHOOL'S  
INNOVATION PROJECT: A CASE STUDY

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A DISSERTATION SUBMITTED TO  
THE FACULTY OF GRADUATE STUDIES  
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY

GRADUATE PROGRAM IN EDUCATION  
YORK UNIVERSITY  
TORONTO, ONTARIO

November, 2013

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## Abstract

This case study research examines the Innovation Project of the Ontario Science Centre Science School, Toronto. This is a formal education institution situated within an informal science centre. Groups of six students each engaged in a semester-long project to design an exhibit for the Ontario Science Centre. These groups were designed to be complex. Qualitative data from interviews, group meetings, and social media postings were collected and analyzed for two groups. A comparatively new analysis technique, rhizoanalysis, was implemented and resulted in physical maps representing the interactions among students as they engaged with the Innovation Project. The conclusions indicate that the Innovation Project design and the leadership of teachers from the formal education sector may have inhibited the students engaging with the Innovation Project fully, as was intended. Nevertheless, rhizoanalysis proved to be an effective way to discover new information about student interactions during group work.

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## Chapter I: Problem to be Investigated

### *1.1 Statement of the Problem*

Science education occurs both inside and outside the classroom. There is an inherent conflict between these two loci, one that encompasses both the methodology through which science is encountered and the intended outcomes of the education process. The formal classroom is both normative and authority-governed. There is a standard curriculum that must be met and to which teachers must adhere. An evaluation determines the student's level of proficiency in completing the material covered.

Informal science education can occur in any setting, but informal science education is the *raison d'être* of interactive science centres. In such settings, science education is open-ended, is free of curriculum constraints, allows for free choice of subject matter, and is not evaluation driven. However, a fundamental change tends to occur when groups from traditional schools visit science centres. The organized school programming developed for and delivered to these groups is formal, usually occurring in a classroom that has been placed within the science centre. The more open, independent learning that is characteristic of informal science education does not necessarily transfer to the formal and organized education simply because of the school's field trip to a science centre.

This research examines the noted conflict, with particular reference to a formal school inside an informal science centre. As there is within this work an attempt to create an open-ended, free-choice experience for students, the methodology chosen was itself free-form and adaptable. One part of this research must, therefore, determine if the methodology itself, rhizoanalysis, is able to best represent the experience the students undergo.

The Association of Science and Technology Centres (ASTC) has 600 member institutions in 45 countries. These institutions are premised on an idea of informal, free choice, science education in which visitors engage with their choice of exhibits and programming. Formal science education, in primary and secondary and university classrooms, is, by contrast, mostly characterized by a mandatory set of expectations. It is my hypothesis that there are inherent tensions for teaching and learning at the intersection of these two spheres when the formal and informal philosophies and practices collide at the locus of science centre programming for schools. This friction arises because a science centre's mission does not fully align with the mission of a school system, though both profess to be partners in the creation of a scientifically literate, innovative society.

If formal and informal science educations are circles in a Venn diagram, then this research intends to define and map the space occupied by these overlapping circles through the examination of a unique project: a formal school of the Toronto District School Board and Toronto Catholic District School Board operating in the informal Ontario Science Centre (OSC), Toronto, Ontario. Through an investigation of the understandings of the students' occupation of this space while they perform a group project called the Ontario Science Centre Science (OSCSS) Innovation Project, the contours of the space will be delineated.

I believe that in order to describe the content of the space the students occupy, it is necessary to invoke the paradigm of the "rhizome" as introduced by Deleuze and Guattari (2004). A rhizome is a network of connections between and among loci. In nature, a fibrous root system would be considered a rhizome. For the students, as they work on the Innovation Project, they are not occupying a void; instead, they are building linkages and connections among themselves, their ideas, the faculty, and the institution. These linkages and connections, when

delineated and described, have a shape and structure that is discernible. The resulting rhizome can be diagrammed and mapped.

An important aspect of this research must address the question of whether rhizoanalysis is the most appropriate qualitative research technique for the analysis of the data collected. Masny (2013) points out that rhizoanalysis depends on an “assemblage reading” rather than analysis of individual components of the data. Sense, according to Masny emerges from this assemblage reading, and the sense, therefore, is in the “map.” Part of the conclusion will determine if the emergence of sense from assemblage reading was true in this research.

Having reviewed the work of Davis and Simmt (2003), it was clear that the student groups working on the OSCSS Innovation Project were designed to be complex groups. Complex systems are part of complexity theory; within them are no hierarchies, and engagements among individuals in the group do not follow specified, pre-ordained patterns. Each interaction between and among individuals is free to follow a different pathway, and the outcome is, therefore, not predictable. Roles of individuals in a complex system may themselves be constantly changing, and they are never fixed by the system or pre-determined by the members. Whether such complexity was successfully designed into the structure of the groups will be reviewed as part of this research.

Through the interactions of the members of a complex group, a structure may be created that is greater than what the sum of the individual members of the group would seem to make possible. This outcome that Davis and Simmt (2003) call “emergence” occurs only in complex systems. Students engaged in work in complex groups can build knowledge that is greater than the sum of the individual knowledge that students can learn or share from previous experience. It



is the complex interaction itself that provides the means for this increase in the knowledge that the students create.

The innovative process of the social building of new knowledge through emergence is what van Aalst (2009) calls “knowledge creation.” In many formal classroom situations, knowledge transmission occurs from the teacher to the students. In complex group situations, students begin to create knowledge that results from the interactions within the group. In this context, knowledge creation, then, is a social process involving students and teachers.

The product of this social, iterative process of knowledge creation by a group is a branched hybrid structure that Deleuze and Guattari (2004) call a “rhizome.” This rhizome defines and delineates the conceptual space within which the students are working, providing a framework for understanding and conceptualizing the knowledge creation that the students have experienced.

To summarize, the interactions of a complex group can result in emergence. If the complex group is made up of students, then the emergent structure is knowledge, and this process of emergence is called knowledge creation. The emergent structure itself is a network of connections called a rhizome.

### *1.2 The Innovation Project*

The Ontario Science Centre Science School (OSCSS) Innovation Project is a cross-curricular, summative project occurring within the OSCSS. The OSCSS is a grade 12 school in the province of Ontario. Thirty students from across the province attend the school for one semester to complete their pre-university math and science courses. The students are chosen from a competitive application pool of approximately 140. The application consists of a series of written questions, at least two teacher recommendations, and possibly an interview. Students are

chosen by the staff of the OSCSS. The school is publicly funded by the Toronto District School Board and the Toronto Catholic District School Board. Students coming to the OSCSS from outside Toronto are registered in one of these two boards, and provincial funding follows each student.

The Innovation Project is undertaken by all of the students. They are divided into five groups of six students each. Each group has a teacher within the OSCSS assigned to work with it. The project goal is to design an exhibit for the Ontario Science Centre's Weston Family Innovation Centre, a space within the Ontario Science Centre that has its own philosophy: children should be exposed to innovation in their formative years if they are to become part of the innovative society of tomorrow. The exhibits of the Weston Family Innovation Centre are designed to allow visitors to experience the skills of technological innovation. These skills have been identified as creativity, risk-taking, collaboration, and iteration through perseverance. The students are not given any parameters for construction of their Innovation Project or the topic for their exhibit. Each Innovation Project involves the development and design of an exhibit that fits with the philosophy of the Weston Family Innovation Centre as outlined above. As the Project is presented to the exhibit team at the OSC, there is an opportunity for student-led ideas to become actual exhibits within the Weston Family Innovation Centre. This has happened with a project from a previous year.

### *1.3 The Innovation Project Groups were designed to be Complex*

Davis and Simmt (2003) offer suggestions for using complexity principles in the organization of a mathematics classroom. The OSCSS Innovation Project at the Ontario Science Centre Science School has been designed with these principles in mind, and so group

interactions within the teams performing the project might be best understood if they are examined from this perspective.

The students within a group working on the OSCSS Innovation Project are the agents of a complex system as defined by Davis and Simmt (2003). First, there is difference within the group: students come from a range of ethnic backgrounds and from all over Ontario. Generally, students will not have known each other beforehand, and as the selection of groups, through any one of three methods, occurs early in the year, students cannot be fully aware of the skills and attributes of the other agents within the system. The three possible methods of group selection are random name selection, the students choosing the members of their group, or the teachers selecting the groups. As the project has been in existence for several years, each selection method has been used in the past at least once within the OSCSS.

Second, there is redundancy within the group, in that all of the students have the same educational background: they are successful science students who have completed the grade 11 science courses needed as preparation to be at OSCSS.

Third, in order to be a complex system, the OSCSS Innovation Project group must exhibit decentralized control. The students, as agents in a complex system, must themselves determine the function and structure for the group, but this should occur without the imposition of a hierarchy. Determining function and structure can be difficult for students as there is a teacher designated to work with each group, but the teacher's function has been strictly curtailed so that he or she acts not as an advisor to the group but as a gatekeeper. The Innovation Project design expects teachers to keep track of student progress toward goals, to keep attendance at meetings, to check that online posts have been made, and to ensure that, generally, work continues. The

teacher's function within the group is not to evaluate, set goals, or determine functions for students.

The complex classroom creates a proscriptive environment within which it is necessary to define the boundaries where work occurs; it is the function of the teacher to maintain these boundaries. Most classrooms in regular schools are prescriptive environments where students are given a particular set of instructions to follow. The proscriptive system within the OSCSS ensures that the groups involved in the Innovation Project demonstrate the fourth characteristic of complex systems, organized randomness. The interactions that the students undergo are only partially prescribed and are limited only by the boundaries delineated by the Innovation Project and the teacher. Within the boundaries of this complex system itself, the groups were envisioned without a pre-determined hierarchy and with control being entirely decentralized. This was the intention.

Finally, the collaborative nature of the group and its interactions, both in person and online, allows for feedback. The actions of each student have an effect on the other students within the group. Effective feedback can be positive or negative, reinforcing directional decisions in the first place, or reverting to a steady state in the second. The group interactions have both stimulus and response. For effective feedback, the response becomes a new stimulus and evokes further response.

As the students within a group in the OSCSS Innovation Project demonstrate all five criteria, one may say that each group forms a complex system. If the groups are complex, then there may be an emergent product from the groups. Any emergent product of an Innovation Project group will be the product of knowledge creation as defined by van Aalst (2009).

#### *1.4 Research Questions*

- (1) What knowledge do the students create together as they work in their group on the Innovation Project?
- (2) How might the resulting rhizome be traced and mapped in order to be represented graphically and form an image of the knowledge created?
- (3) Does this rhizome reflect the knowledge that the students have created through the Innovation Project?

This research was undertaken with a number of objectives in mind. The Innovation Project was created especially for the Ontario Science Centre Science School, but it had to meet requirements within the Ontario Ministry of Education Secondary Science Curriculum. In this way, it is hoped that other institutions might take on a similar project within different, possibly more formal, environments. The first research question reflects this curricular link.

My analysis is guided by a distinction drawn by van Aalst (2009) among three modes of discourse: “Knowledge creation,” which is a socially-situated discourse, as distinguished from knowledge-sharing and knowledge-construction. In this case, it is important to ask what knowledge do the students create together as they work in their group on the Innovation Project?

In other words, a new learning environment has been created for the Innovation Project. This learning environment presumes complex groups and a socially-situated discourse. Within a proscriptive experience, and with freedom to define goals, what knowledge do the students involved in the Innovation Project actually create? This question is important because the knowledge created falls within the realm of a science course with a particular curriculum. If the Innovation Project is to be implemented in the future in other situations, it is necessary to determine what the students have gained by going through the process.

This act of knowledge creation means that the students are creating a rhizome as outlined earlier. Does this rhizome reflect the knowledge that the students have created through the Innovation Project? In a final meta-interview, would the students themselves recognize the knowledge they created in this rhizome?

The rhizome is more than a metaphor here. The students are creating a network of social interactions that represent the knowledge they are creating. It is the purpose of this research to represent those interactions, but, in so doing, it is necessary to ensure that the rhizome described represents the knowledge the students have created. The test for this is to ask the participants in the research if they recognize the rhizome delineated by the research as a representational model of their process and result.

How might the resulting rhizome be traced and mapped in order to be represented graphically and form an image of the knowledge created?

Masny (2013) suggests ways in which rhizoanalysis can be used to perform qualitative research of this type in new ways. Citing St. Pierre (2011), Masny suggests that in rhizoanalysis, data are not read in the traditional way but rather are non-representational. She mentions in particular the difficulty in working with traditional methods of data analysis that begin by creating themes and categories and then coding data. Masny suggests that rhizoanalysis disrupts this traditional approach of, quoting St. Pierre, “data, method, member check and peer debriefing,” and instead is an assemblage of participants and researchers. “In sum,” Masny writes, “a rhizome becomes a map to analyze and report data” (p.342).

This research was designed and undertaken before St. Pierre’s (2011) publication, but the researcher reached some of the same conclusions, as will be seen later. Initially, the data were coded, however, it was determined that this did not allow the students’ voices a genuine

opportunity to be expressed, and important parts of the assemblage, the rhizome, were being omitted. Therefore, a new approach had to be determined.

The creation of the map to analyze and report the data (Masny, 2013) is a significant challenge. If we accept that the knowledge created by the students is rhizomatic in nature, is there a way to delineate and describe this rhizome? The resulting graphic representation should somehow describe the complexity of the rhizome and the interactions of the students without over simplifying; yet it must remain intelligible. Further, it must accurately reflect the sequence of events, as there is a time dimension to the rhizome as well.

The research is, therefore, predicated on three ideas: that the groups of students working together are complex in nature, that the knowledge the students create is socially situated and emergent in form, and that this created knowledge can be represented by a rhizome. One question must, therefore, be whether these hypotheses represent what is happening in the Innovation Project Groups.

### *1.5 Significance of the Case Study / Rationale*

The study is the first of its kind combining the ideas of informal and formal science education with a rhizoanalysis of the resulting knowledge creation. Rhizoanalysis is a form of data analysis that attempts to understand the resulting data as parts of a complex network of interactions. A rhizoanalysis such as the one undertaken here goes further to attempt to graphically represent the results of the data analysis and to ask if the resulting graphic is a true representation of the process and product of the students' engagement with the Innovation Project.

Further, this case study represents a very early phase of the research related to collaborative discourse (Osborne, 2010) and science education. Osborne argues that students'

ability to engage in collaborative discourse and argument is fundamental to developing a critical understanding of science. He suggests further that students develop an incorrect and incomplete understanding of science when they believe that the explanations offered by teachers are true and do not subject them to collaborative thought.

The Ontario Science Centre Science School (OSCSS) is itself experimental. The school follows the Ontario Ministry of Education grade 12 university-level science and mathematics curriculum. Teachers are given wide latitude in pedagogical approach, assessment, and evaluation within their classrooms.

The Innovation Project is new within the OSCSS. It was created to answer a specific question: “Why have a formal educational institution, i.e., a school, within the informal setting of a science centre?” Another central question asks, “What about this milieu is sufficiently different for the students, especially as most of their class time is spent in regular classrooms within the science centre?”

The Innovation Project, through interactions allowed with the Ontario Science Centre (OSC) staff, and through discussion of the elements of exhibit design and development, provides answers to these questions. Working within the Ontario Curriculum, the Innovation Project manages to bring students and staff at the Ontario Science Centre together. It allows students an opportunity to explore science communication through the creation of exhibits that engage [or interact with] visitors in an informal setting. Finally, the Innovation Project helps students to examine their own learning and how they make choices within the environment of an informal learning centre.



The Innovation Project, and, in particular, the process of thinking about, designing, and developing an exhibit for the Weston Family Innovation Centre, provide the justification for having a school inside the OSC.

The Innovation Project itself is the product of a proscriptive group approach among the staff, in that their challenge to design an interdisciplinary project deviated from the constraints with which they were accustomed to designing projects. They were not given any parameters, nor were they given a scope. This project was to become part of the OSCSS curriculum each semester. The Innovation Project is the resulting assignment. Creation of the Innovation Project offers one possible answer to the questions about the rationale of having a school in the OSC and how it can be distinguished from formal classroom settings. In a series of meetings, the staff of the school decided to create a single project that would provide summative, cross-curricular evaluation toward calculation of the students' grades. The assessment of the students' progress through The Innovation Project would count toward the grade in each subject in which the students were registered. The Innovation Project was further designed to introduce students to the skills of innovation as articulated by the OSC in its Weston Family Innovation Centre.

The Innovation Project is designed to embody the philosophy of inquiry learning as understood by the teachers, in which students ask their own questions and develop methodologies to determine the answers to those questions. It is proscriptive while also being as open-ended as possible and while working within the framework provided by the Ministry of Education for senior science courses.

The rationale for this research is to examine and review the Innovation Project. The results of this study will demonstrate what knowledge the students are creating as they engage in the Innovation Project and will facilitate a review of the Project's implementation. This should

help determine if the project works as it was designed to by the teachers and if it is indeed replicable in other educational environments. OSCSS teachers have discussed bringing the Innovation Project into their regular classrooms upon their return from secondment into the school system. This case study supports the introduction of Innovation Projects into more institutions in other formal and informal science settings.

### *1.6 Anticipated Contributions*

The Ontario Science Centre Science School can act as a laboratory for pedagogical practice. The teaching staff members are seconded, which means that they remain employees of the school board from which they come, but, for the term of their secondment, they act as employees of the Ontario Science Centre. Their salary continues to come from their school board. Teachers in the Ontario Science Centre Science School are from the Toronto District School Board and the Toronto Catholic District School Board and will return to those boards. These secondments mean that experimentation and innovation in classroom practice, such as the Innovation Project, can be shared with a much wider teaching community.

Rhizoanalysis, as an approach to analysing and graphically representing student knowledge creation, will also be shared with a wider community. As van Aalst's work (2009) is so recent, the discourse of knowledge creation as opposed to knowledge sharing and knowledge construction is not yet common. It is expected that bringing this discourse together with a rhizoanalysis will allow for new approaches and greater understanding of the results of group project work in diverse settings, such as science fairs and English and musical collaborative composition.

Although the Ontario Science Centre Science School is itself unique, it follows the Ontario Ministry of Education grade 12 university science curriculum. In this respect, findings of

this research may be used to design projects, and analyses of the results may be conducted in hundreds of secondary schools across the province of Ontario and beyond.

Within education research, this marrying of ideas from rhizoanalysis, complex groups and their functions, and knowledge creation is distinctive. The researcher believes it will lead to future studies seeking to describe the knowledge that students create and to understand the work of complex groups more fully.

### *1.7 Research Methodology Overview*

The research methodology is qualitative and constitutes a case study. There are three major steps involved in this dissertation research. First is the collection of data, the second is the analysis of the data, and the third is the construction of a rhizome.

Data collection was planned in a number of different situations. In the data analysis section, changes from this plan are highlighted and explained. The Innovation Project occurs over a large portion of an entire semester, starting in September 2011 with the introduction of the project, and running through to presentations and interviews with the teachers in December 2011. The semester continues until the end of January 2012.

The first data were to be collected from an open-ended, qualitative interview with students to gauge their understanding of group work and the innovation project before its commencement. This interview occurred in September as students were adjusting to the project and to the OSCSS. The second set of data was intended to be derived from video recordings of the initial group selection meeting, followed by brainstorming meetings of the two groups being followed in the study. The third compilation of data was to consist of the collection of Wiki postings from those two groups' journals. Fourth, each of the students within the two groups were to be interviewed twice more to create the last data set. The earlier of these last two

interviews was to be an open-ended, qualitative interview to learn something of their experience of group work and knowledge creation. The earlier individual interview occurred in December. The latter was a meta-interview which examined the students' experience of being part of a research project. This interview was conducted with the students together as a group and occurred in January after the completion of all parts of the Innovation Project.

Data analysis consisted of two steps. The first of these followed Fairclough's (1992, 1995, 2003) discourse analysis and examined the data for themes and created what Deleuze and Guattari (2004) call a tracing. This provided the outline of the rhizome. The latter analysis, or rhizoanalysis, re-examined the data collected and created what Deleuze and Guattari call a mapping, the delineation of a rhizome. As a metaphor for tracing and mapping, one might consider a geographic map. The tracing consists of the features, for example roads and rivers. The mapping consists of the directions of flow (traffic or water), and details such as traffic conditions. A tracing can carry useful information, but true understanding comes through the mapping of the rhizome. To do this, I followed the procedure of Alvermann (2000), which is to code and to develop the data collected, resulting in a tracing. She then created a mapping by re-examining the data, looking for the lines between connection points rather than the points themselves as in a tracing. In this research, the researcher has looked at how the students worked with each other, both online and in meetings, to create a tracing that should map their knowledge creation.

In retrospect, it is clear that I later also followed a procedure outlined by St. Pierre (2011), which rejects coding and instead looks at data as an assemblage that disrupts the discourse analysis. The mapping of a rhizomatic structure must move beyond these traditional approaches which I initially assumed would be useful to the articulation of a rhizome. By

rejecting coding, and instead including all of the data of a particular type in a new kind of representation, new insights about student collaboration in science education would be found.

The final step of the methodology was to represent the rhizome graphically. In this research, a literal map was created.

### *1.8 Limitations of the Case Study*

This case study is bound (Baxter and Jack, 2008) in location, time, and space to a particular school, the Ontario Science Centre Science School (OSCSS) with grade 12 students only. The students have been selected through a competitive application and must have averages over 70%, and generally over 80%, in their math and science subjects. Students come from all over Ontario, but the majority are from Toronto or the Greater Toronto Area. Teachers in the OSCSS make the selection of students from the applications received. As the size of the school is small and the make-up of the student body restricted, the results are not generalizable.

Teachers involved in the study are seconded from the Toronto District School Board and the Toronto Catholic District School Board. The teachers are not selected randomly for the program either but, instead, are chosen through a competitive application process. Positions are advertised through the two Toronto school boards from which the teachers will be seconded, and all candidates are interviewed by staff of the Ontario Science Centre. All teachers in the school are involved in the Innovation Project, which is not optional for students or teachers. Thus, there is a limitation of the study relative to the type of teachers involved in this particular setting.

Ideas for the Innovation Project can be adapted and changed through interaction with the Exhibit Design and Development Team at the Ontario Science Centre. This team helps the students throughout the development of the project, from conception to completion. Exhibits designed by the students have been chosen to become exhibits on the floor of the Ontario

Science Centre, and work with some groups of students continues after the project, with the exhibit design and development team refining the Innovation Project into a finished exhibit that is ready for public display. It is possible, therefore, that the project develops in directions that are not exclusively directed by the students. Generalizability to other settings is limited due to the lack of access that other schools have to mentors of this kind.

This study does not seek to quantify the interactions of the students involved; instead, it tries to understand those interactions within a very particular context. The context is unique and may not be replicated elsewhere, and so the conclusions may be said to be bounded (Baxter and Jack, 2008). Nevertheless, a greater understanding of student interaction in this particular context may help to elucidate students' interactions in other locations, times, and spaces.

This study also develops a novel approach to rhizoanalysis and a new method of data representation. Although the rhizomes produced in this dissertation are specific to the type of data collected, the approach, with modifications, can be extended beyond this particular case study.

The case study is socially situated because all of the data collected for the creation of the rhizomes are based on communication among the group members with each other. The rhizomes are derived from data that were posted socially on Facebook to a network of individuals. The data can only be understood in reference to the society of students involved in the Innovation Project group under discussion.

## Chapter II: Literature Review

### *2.1 Formal and Informal Science Education*

The Ontario Science Centre Science School (OSCSS) is described as a formal school located within an informal science education institution. This unique arrangement requires that a clear distinction be made between formal science education and that which occurs within an informal science center.

Dierking, Falk, and Koran (1986) find clear distinctions between the kind of informal education that occurs specifically in museums and the formal education that occurs in more traditional classroom settings. In particular, they stress that museum learning is “free-choice” (p. 504), by which they mean that the individual establishes his or her own goals for a visit. They also point out that museum learning is socially situated, which they support with statistics that indicate that visitors spend almost as much time observing other visitors as they do observing and engaging with the exhibits.

Wellington (1990) also makes clear the distinctions between formal and informal education. Among the more relevant distinctions, and highlighted through this case study, is, first, that formal education is assessed. Formal science education follows a discrete curriculum, requires an assessment, and leads to certification. It is, with respect to its goals, closed. Wellington points out that informal science education, on the other hand, does not require assessment, does not lead toward meeting any particular goals, and, as a result, is more open-ended.

A second distinction that Wellington (1990) makes, which is also foregrounded in this case study, is that the “social aspect is less central” (p. 248) in formal science education. Informal science education, on the other hand, stresses social engagement among visitors and

those partaking in the informal experience. In this case study, the argument is made that the learning and the knowledge created by students in the Innovation Project is socially situated, which is, clearly, a characteristic of informal science education.

The third distinction Wellington (1990) makes that is central to this case study is between the “structured, and sequenced” (p. 248) approach of formal science education. By this, he means that formal science follows a defined curriculum as set by a central authority and does not subscribe to the less structured approach of informal science education. Formal education leads to, in Wellington’s words, a “teacher-centred” (p. 248) approach. By contrast, informal science education is “haphazard” (p. 248) and without curriculum. As such, it can become learner-centred.

Dierking, Falk, and Koran (1986) also argue that museum learning and museum educators have much less control over content. They point out that, “In the schools, content is very tightly regulated” (p. 505). In this study, the teachers feel pressured to follow a standardized curriculum that more tightly regulated the content.

Dierking and Falk’s (2010) research stresses the importance of informal science education. In *The 95 Percent Solution* (2010), they argue that a majority of what an individual learns about science occurs outside of the formal classroom setting. They contend that the desire to improve the public’s understanding of science led to the idea that science teaching had to improve. However, they point out that the average American spends less than five percent of his or her lifetime in a classroom, and that “an ever-growing body of evidence demonstrates that most science is learned outside of school” (p. 486). Of course, they also point out that not all of this informal education occurs in science centres and museums. Nevertheless, they argue



convincingly that access to quality informal experiences improves children's and, by extension, adults' understanding of science.

The conclusion that Dierking and Falk (2010) make is that science learning is an amalgam among complementary formal and informal science education experiences. They believe that informal science education has not been well understood and its contribution to overall science education insufficiently acknowledged.

This case study examines a formal science education school located in the Ontario Science Centre, an informal science education institution. Dierking and Falk (2010) stress the difficulty of evaluating the science education that occurs in informal settings, particularly, as both they and Wellington (1990) point out, informal education eschews assessment. Hence, this study attempts to map and trace students' social knowledge creation.

The Innovation Project, although it occurs within a formal school milieu, is designed to demonstrate some of the characteristics of informal science education outlined by Wellington (1990) and Dierking, Falk, and Koran (1986). First, the Innovation Project's evaluation guarantees a perfect grade to the students involved; therefore, student learning is, in a way, not being assessed. This allows for the more open-ended, less curriculum-driven approach of informal science education. Second, by its students working in groups, the Innovation Project encourages the socially-situated education that distinguishes informal from formal science education. Finally, the Innovation Project, as an example of free-choice science education, is designed to be learner-centred rather than teacher-centred.

## *2.2 Complexity and Emergence*

As stated earlier, the research is predicated on three ideas: that the groups of students working together are complex in nature, that the knowledge the students create is socially situated and emergent in form, and that this created knowledge can be represented by a rhizome.

Complexity Science is the study of complex systems. Sharing a common set of defining characteristics is what makes a system complex. If a system has all of the characteristics within this common set, then the system can be said to be complex, and its behaviour might be described and analyzed as such. According to Martin and Sturmberg (2009), problems in health care can be characterized as being simple, complicated, complex, or chaotic. They distinguish among these four on the basis of whether the protocol of response is known. A simple problem has a single source and a known protocol to an efficacious solution. A complicated system generally has a number of sources, which are related and whose solutions can be mapped separately and applied in a straightforward manner. A complex problem in Martin and Sturmberg's structure is one with sources both internal and external to the problem, and both individual and societal, which do not necessarily appear to affect one another. These complex problems are potentially understandable, but the protocol must be improvised to cope with each source, and, presumably, the response must involve a complex system. A chaotic problem is one in which there is no discernible order. It is my contention that all systems might fall broadly into one of the four categories Martin and Sturmberg suggest. The groups involved in the OSCSS Innovation Project most closely represent a complex system.

Martin and Sturmberg (2009) suggest that to cope with a complex problem, a complex system is needed. They contend that a complex system is an adaptive, self-organized social network with observable patterns that are neither predictable nor generalizable. A closer look at complex systems reveals that they share certain unique characteristics. They are "adaptive,"

which means that the complex system reacts to stimuli in an *ad hoc* manner as each stimulus arises. The pathways and procedures undertaken by the system are subject to change as the inputs change. Second, the complex system must be “self-organized.” For a system to be “self-organized,” there must be a division of labour, but this division is not imposed prior to the commencement of the system. Roles within the system may be fluid and depend on the roles assumed by other components within the system. Third, the patterns are “not predictable”; a complex system working in an *ad hoc* manner may not follow any pre-set protocol as it works through a set of stimuli. Finally, the system is “not generalizable,” which means, simply, that the pathways followed within one complex system do not carry implications for the procedures or structure of another system.

Anderson and McMillan (2003) apply the ideas of complex systems to team and group dynamics and, in fact, actually define a team as being a complex structure. For them, these teams must also be self-organizing, as Martin and Sturmberg (2009) suggest. Anderson and McMillan define a self-organizing team as one that is informal and temporary, has a strong sense of purpose, and forms spontaneously. In particular, self-organizing teams do not have a hierarchical structure or a managerial approach. No team member or group of members is able to tell or direct others as to their functions; instead, each member takes on roles and responsibilities through negotiation.

A complex problem, as defined by Martin and Sturmberg (2009), can bring into existence what Anderson and McMillan (2003) describe as a self-organizing team. The solution that the team develops, or the result that it produces, is said to be the product of what van Aalst (2009) refers to as emergence. Emergence, then, is a product of complex systems.

Applying this research to the classroom, Davis and Simmt (2003) posit their main thesis, which is that mathematics classes are both adaptive and self-organizing complex systems. They continue by describing the framework in which a complex system operates. To them, all complex learning systems have the following five attributes: internal differences, redundancy, decentralized control, organized randomness, and neighbour interactions. First, there must be internal differences within the class. The members of the complex class or team, often referred to as agents, must each come from different backgrounds in terms of experience and knowledge. They must also demonstrate differences in their learning styles and approaches to problems. Without this difference, emergence is not possible because only one pathway for a group to solve a problem would be available. Davis and Simmt make it clear that the kinds of variation that might exist cannot be known beforehand, and, as the team coalesces around a problem, differences among team members that had been overlooked may come to the fore.

Second, there must be some level of redundancy. Davis and Simmt (2003) suggest that for a group to feel like a team, there must be variation, but there must also be tremendous similarity so that a single identity of “we” can emerge. In the group of mathematics teachers that they examined, there might have been variations between each teacher’s experience and approach, but, as mathematics teachers, or agents, they all share similarities with other mathematics teachers. This kind of similarity is necessary for the creation of the complex learning system; it is the redundancy in the system.

Third, complex learning systems require decentralized control. Davis and Simmt (2003) reiterate Anderson and McMillan’s (2003) contention that there can be no hierarchy to the group. They contrast the student-centred classroom with the teacher-centred classroom and claim that perhaps neither is an appropriate description of the complex classroom, since the locus of

learning is neither the individual student nor teacher. According to Davis and Simmt, authority does not rest with the teacher, textbook, or curriculum but, instead, authority in a complex classroom rests with the agents, or, in this case, the students that comprise the complex system.

Fourth, complex learning systems have “organized randomness.” Davis and Simmt (2003), Anderson and McMillan (2003), and Martin and Sturmborg (2009) demonstrate that a complex system is not chaotic. It is not without rules, but the rules are set to create boundaries for the work of the system, not to define how the system or its agents work to complete a problem or task. Anderson and McMillan introduce the idea of prescriptive versus proscriptive classrooms. Prescriptive systems define the final outcome, and, quite often, the method of arriving at that outcome. Agents, or students in the classroom, are expected to perform tasks in particular ways to achieve a certain outcome. Proscriptive systems, on the other hand, define boundaries and prohibited activities, but they leave infinite options within the space of the possible for agents to change their own processes and those of the system. It is clear, however, why even within a proscriptive, and therefore a complex system, there is a need for boundaries; a complex system is not a chaotic system without rules.

The fifth and final attribute of complex learning systems are neighbour interactions. Davis and Simmt (2003) describe an interaction as the action of an agent that has an effect on the action of another agent. The possibility for feedback to occur must exist within the complex system. Martin and Sturmborg (2009) also discuss the importance of feedback in their description of the adaptive nature of complex systems. It is important to note that the stimuli to which a complex system adapts can be internal or external. Further, a hierarchical system cannot be present if these neighbour interactions are to be successful.

### *2.3 Collaborative Discourse*

Osborne (2010) regards collaborative discourse and argument as critical to science learning. This case study assumes that learning is socially situated and that the Innovation Project groups engage in learning through discourse. "...Learning to argue is seen as a core process both in learning to think and to construct new understandings" (p. 464). Osborne goes on to demonstrate that students who hear alternative viewpoints and discuss the merits of evidence have a clearer understanding of the subject under discussion. This differs from the traditional approach, in which, as Osborne notes, the teacher offers explanations, which are presumed to be true, rather than offering arguments in favour of the point. The provision of explanations is related to a monolithic view of science and will be discussed later.

Osborne (2010) makes a convincing argument that teaching students to reason, argue, and think critically enhances their conceptual learning. They must be provided the opportunity to participate in collaborative discourse and argument. The Innovation Project provides students within the OSCSS this experience; however, documentation supports that students had not engaged in this kind of learning earlier in their education experience and may have been unprepared to take advantage of it when it arose. Osborne contends that preparation to participate in this kind of discourse and argument is an essential ingredient for success. Syh-Jong's (2007) research compares the success of collaborative discourse in science education in Taiwan to traditional methods of education. He describes science education in Taiwan as being transmission-based and comprised of non-interactive teaching activities. Although Syh-Jong drew many conclusions about the superiority of collaborative discourse, one that supports findings of this case study in particular is that "... talk and writing in a collaborative group mutually stimulated students to construct knowledge for themselves" (p. 65). Although his

research is based on knowledge creation rather than knowledge construction, Syh-Jong stresses the socially-situated nature of learning and implicates collaboration specifically in that process.

Meyer and Woodruff (1997) found there are two particular types of discourse that lead to effective knowledge creation. One is constructive and generative, introducing new ideas, a process that is akin to brainstorming, which is one of the activities in which students engaged during the Innovation Project. The second is dialectic and persuasive, where students take sides and argue a position in hopes of convincing their peers. Meyer and Woodruff found that these two forms of discourse combined lead to shared coherent explanations of phenomena. Like Osborne (2010), they found that students had to be prepared to engage in these types of discourse. During the Innovation Project, students were given the tools to participate in effective brainstorming; if they did not take advantage of this opportunity, consistent with Meyer and Woodruff's (1997) and Osborne's (2010) findings, it may be due to their lack of necessary preparation.

The importance of argument in science education is, as Osborne (2010) suggests, dependent on students' preparation and their evaluation of their own arguments. Brickman, Gormally, and Lutz's (2013) Test of Scientific Literacy Skills (TOSLS) attempts to measure the effectiveness of students' learning gained through argumentation. Their conclusions show that students who engaged in project-based learning and collaborative discussion as outlined by Osborne (2010) performed more successfully on the test. Further, students who were taught through what Brickman et al. term traditional methods did not show significant gains on the TOSLS during a single semester. Their research demonstrates the importance of argumentation and collaborative discourse in increased scientific literacy. In this case study, there is, again, an

implication that students must be prepared for project-based learning as Osborne (2010) contends.

#### *2.4 Validity and Reliability*

In order to determine if the Innovation Project case study is suitable for replication, it is necessary to examine issues of trustworthiness relative to qualitative research. Validity and reliability are terms for trustworthiness in quantitative research. Validity is a measure of whether the results are correct (Leydens and Moskal, 2000). Does the rhizome that is traced and mapped accurately reflect the knowledge created by the students?

Reliability, instead, refers to the consistency of data collected. In this research, a reliable rhizome would appear the same regardless of the researcher performing the tracing and mapping. It is important to note, as Moskal and Leydens (2000) do, that any assessment or analysis that is valid is also, by definition, reliable. On the other hand, an analysis of this case study could be reliable and could yield similar results without being valid in quantitative research.

However, in qualitative research, there is a different approach centred in trustworthiness. Shenton (2004) demonstrates that there are four criteria required for determining the trustworthiness of qualitative research. Citing Guba (1981), Shenton lists these criteria as first, credibility “in preference to internal validity,” (Shenton, p. 64). Credibility comes first from adopting research methodologies that are accepted and understood. It is enhanced, second, by a thorough understanding of the environment of the organization at the heart of the research. The initial analysis of the data, through themed coding and recoding, is an accepted procedure. As the researcher, I meet these two bases for credibility. The methodology followed, through thematic development and coding of the data, is an accepted and well understood procedure of case study



research. Further, as the principal of the OSCSS, I have an intimate knowledge of the environment of the organization under investigation.

The second criterion for trustworthiness is transferability, “in preference to external validity” (Shenton, p. 69). As much qualitative research works with small groups, it is often the case that the research cannot be extrapolated to larger groups and situations. As Shenton says,

It is easy for researchers to develop a preoccupation with transferability.

Ultimately, the results of a qualitative study must be understood within the context of the particular characteristics of the organization or organizations.

(p. 70)

The rhizoanalysis found in this case study is transferable. The analysis that the researcher has taken could be used and adapted in a number of contexts to create rhizomes and maps that aid in the understanding of group dynamics and socially-situated knowledge creation. The data in no way purports to be extrapolated to larger groups or to small groups working within other contexts.

The third criterion for trustworthiness in qualitative research is dependability (Shenton, 2004), which equates to reliability in quantitative research. Shenton explains dependability as the ability to repeat the research and achieve the same result. I believe that the rhizoanalysis could be repeated by another researcher with the same rhizomes being drawn, given instructions. There would be changes in flavor, which is the designated meaning of the arrows on the map.

The final criterion is confirmability, which relates to the quantitative term of objectivity. This is, of course, impossible to achieve in qualitative research. However, insofar as the researcher achieves the following two goals, Shenton (2004) indicates that the data analysis achieves confirmability. The first of these goals is that the researcher reveal her own relationship

to the subjects of the research and any biases that she may have before beginning the research. The second is that hypotheses that were proved incorrect must still be included in the data. I believe that both of these goals have been met in this case study.

As this case study is categorized as qualitative research, it will not conform to the traditional quantitative definitions of validity and reliability. Having met Shenton's (2004) four criteria for trustworthiness in qualitative research, however, this case study can be deemed one of importance and as one that holds significance.

### *2.5 Knowledge Creation*

The emergent product of the complex group is created knowledge. When I began this dissertation process, I believed that groups performing the OSCSS Innovation Project would be involved in knowledge construction. However, the attributes of knowledge construction suggested in research by van Aalst (2009), Pea (1994), Papert and Harel (1991), and Paavola, Lipponen, and Hakkarainen (2004) were not evident in the project. Instead, the students engaged in what van Aalst (2009) calls knowledge creation. According to van Aalst there are three distinct modes of educational discourse, each of which is related to an accepted theoretical perspective: knowledge sharing, knowledge construction, and knowledge creation.

Pea (1994) suggests that knowledge sharing reflects the traditional transmission discourse in education. There is a unidirectional flow of information from a holder and source, the teacher, to students. While it is believed that only information can be transmitted this way, there is a tacit agreement that the information itself is, in fact, knowledge that the student now possesses and can use.

Knowledge construction is related to Papert and Harel's (1991) constructionism discourse in education, which posits that learners build knowledge through inquiry and investigation.

Knowledge construction assumes a situated discourse in which students might solve problems while working in a group or individually (van Aalst, 2009). Each step is related and situated within the context of prior knowledge, creating an edifice of learning. van Aalst points out that knowledge construction results in deeper and more complete understanding than knowledge sharing.

Finally, knowledge creation, according to Paavola, Lipponen, and Hakkarainen (2004), is the result of interactive learning mediated by shared objects. The term “knowledge creation” comes from research on innovation (van Aalst, 2009) and results from new ideas and new processes being developed through group interaction. For purposes of this study, the ideas themselves can be thought of as shared objects. The result of knowledge creation is new knowledge, not already-understood existing social knowledge. In effect, those creating knowledge are not merely reflecting gains and insights made first by others, but are, instead, making a new contribution to society as a whole (Paavola et al. 2004).

Bereiter and Scardamalia (2003) situate knowledge creation in the classroom. A class of students is considered a community, and the ideas shared by the community exist in discourse and not in the individual students’ minds. Van Aalst (2009) calls this type of community “emergent.” Emergence was introduced previously as the production of coherent sense-making structures from complex interactions of groups. Complexity results in emergence. The classroom engaged in knowledge creation has emergent ideas; these result in creation of the rhizome.

## *2.6 The Rhizome*

In social theory, a new vocabulary has emerged to create a cogent approach to the type of complex interactions represented by the Innovation Project. In this study, the work of Deleuze

and Guattari (2004), who proposed the ideas of the rhizome and the nomad as new ways of creating philosophical space, will be applied.

In *A Thousand Plateaus: Capitalism and Schizophrenia*, Deleuze and Guattari (2004) outline the idea of the rhizome. They argue that the rhizome represents the emergence of a better understanding of structures that are diffuse and of quickly-spreading networks. These structures do not depend on a central core (e.g., a tree trunk) but, instead, are made strong by the myriad connections that exist among their component parts.

Deleuze and Guattari (2004) posit that there are six principles that define the rhizome. The first two of these are connection and heterogeneity. Every part of a rhizome is dependent upon every other part, but these parts do not have similar structure. They may, in fact, be comprised of very different components.

Next comes what Deleuze and Guattari (2004) call multiplicity, the idea that a rhizome is made of the connections, the lines. For most structures, the component parts are the key; however, in a rhizome, it is the connection between and among the constituent parts that is the basis for the structure. The fourth principle is that of a signifying rupture. In effect, a rhizome cannot be destroyed; if a part or even some of its connections are destroyed, a rhizome can be reconstituted and regrow in two ways: existing lines or connections can lengthen, or new connections can be created. This regenerative property is part of the strength of the rhizome structure.

The last two principles, according to Deleuze and Guattari (2004), are those of cartography and decalomania. They show that a rhizome can be mapped and traced. A tracing, or decal, indicates an underlying, unifying structure. A rhizome has deep roots that can be elucidated, but beyond this underlying structure, mapping also occurs. A rhizome, being also a

mapping, is infinitely variable, and when its connections are mapped, the map itself becomes a part of the rhizome, creating a connection within the rhizome. If one is to describe a rhizome, then one must first perform a tracing and determine the underlying structure; then, a mapping must be performed in an attempt to find all the connections within the rhizome and their relationships to one another.

A rhizome is performative. It does not describe a finished product so much as it is a cartography of the creative process in which agents are engaged. As Deleuze and Guattari (2004) propose,

Make a rhizome. But you don't know what you can make a rhizome with, you don't know which subterranean stem is effectively going to make a rhizome, or enter a becoming, people your desert. So experiment. (p. 251)

The implications of this statement are clear: a rhizome is the act of creation, and that creation involves experimentation. Within a classroom, therefore, it is necessary to create an environment in which students can engage in the act of rhizome-making. To describe what such an environment would look like, Gough (2006) argues that rhizome creation involves storytelling, as it is only through the creation of narratives that a true community develops. He demonstrates that these stories stand in opposition to “one true story,” which is the older, arboreal, non-rhizomatic conception of science.

Lee (2008) argues that one way to create the rhizome in the classroom is to create an agora of ideas. The agora is a Greek marketplace, but it is also a metaphor for the marketplace of competing ideas within Greek society. To create a rhizome in the OSCSS Innovation Project, therefore, those involved must first seek to create an agora in the classroom, a space in which students “feel” and “are” free to exchange ideas and follow paths wherever those paths may lead.

If the rhizome is to have a role in education, Lee (2008) suggests that it must oscillate between control and freedom. It is not a wholesale abandonment of control, for that would be chaos without form and, ultimately, without function. At the same time, it cannot superimpose or maintain control of a structure, or it would lose the essence of the accidental and serendipitous. Lee argues that Deleuze and Guattari (2004) are not utopian but, rather, are grounded realists with a clear understanding of the strength of the model they have proposed.

Hagood (2009) has used rhizoanalysis, a post-structuralist term for analysis using the rhizome, to examine language arts education. Using the work of Deleuze and Guattari (2004), Hagood demonstrates that language arts education is no longer based on a single definition of text as the written word. New media and new ways of communication have forged new connections among texts, and language arts education now has to acclimate and prepare students to work in a contextualized world of connections and multiplicities. It is these web-like linkages - these connections among these new forms of media and communication - that shape the rhizomes.

With a rhizome as the defining concept, teaching is about learning and becoming, not about mastering a prescribed curriculum. Dave Cormier (2010) points out that rhizomatic learning is not about expert interpretation of knowledge; it is not mediated through an instructor. Instead, it is constructed and negotiated in real time by the people participating in the learning. It is in the study of computer-supported collaborative learning (CSCL) (Suthers, 2006) that I have found in education an epistemology of the rhizome. Suthers uses the concept of inter-subjective meaning-making to explain the production of knowledge in collaborative work. In other words, the agents, or the students, involved in his CSCL project created meaning together and thus produced new knowledge.

Pfister (2005) introduces the concept of Common Ground, which provides a context for collaborative learning. Knowledge is not only gained by the meaning-maker herself, but it is also shared through platforms. He describes this process as going from unshared to shared information, which leads to knowledge acquisition. However, his thesis does not explain how knowledge that does not pre-date the collaboration can be created jointly among the members of the collaboration. For Pfister, knowledge can be constructed but not created within complex groups.

Inter-subjective learning, according to Suthers (2006), advances the concept of Common Ground in two significant ways. First, it posits that the learning is not only accomplished through the interactions of collaborative group members but consists of those interactions. This is learning as activity. Second, inter-subjectivity assumes that beliefs are enacted but not necessarily accepted. There does not have to be agreement among the members of the collaborative about the meaning-making and learning that are occurring.

Suthers (2006) points out that this is striking and important, for it distinguishes individual learning from socially accomplished learning. The latter, however, does not preclude the former. The individual is still making meaning for herself as an agent within the collaborative. This learning process is reflected in a rhizome. The tracing and mapping introduced by Deleuze and Guattari (2004) to represent a rhizome are both demonstrated through inter-subjective learning. The tracing, i.e., the deeply rooted structure, is the knowledge with which members of the group come to the OSCSS Innovation Project; the mapping should reflect the unexpected and chaotic “lines of flight” and connections of the rhizome they create. These “lines of flight” are the web-like linkages that are the structure of the rhizome.

Deleuze and Guattari (2004) introduce a new kind of science altogether, the idea of the nomad, which is reflected in Gough's (2008) work and in all conceptions of science as a rhizome. This new conception of science is opposed to "royal science," and Deleuze and Guattari argue that it is superior. Nomad science has a number of characteristics, but one is particularly salient for this discussion. Deleuze and Guattari write, "The model in question is one of becoming and heterogeneity, as opposed to the stable ..." (p. 361). Gough presents this property with respect to a textbook's discussion on Newton. He posits that the text presents a Newton divorced of context, with none of the connections of his person intact and without mutability. This is "royal science," and Newton's laws become sacrosanct as a result. Osborne (2010) refers to this as authoritative discourse and argues that this is the traditional classroom methodology. Heterogeneity in the classroom is important, in contradistinction to "royal science," because heterogeneity suggests that students learning science do not need to uncover facts but should, instead, create knowledge that represents their own understanding. This is nomad science, and it recognizes a model of knowledge creation rather than the memorization of facts, or knowledge transmission.

One can see, therefore, that the students partaking in the OSCSS Innovation Project form part of a complex system. This complexity results in emergence. The emergent form is a rhizome, and the creation of the rhizome defines and delineates the shape of the space in which the students are working. How then can we describe the rhizome the students create?

### Chapter III: Research Methodology

#### *3.1 Intended Methodology and Methodology Followed*

It was first necessary to choose a research methodology appropriate for the Innovation Project rhizoanalysis I intended to undertake. This methodology was the case study. Work by



Baxter and Jack (2008) indicates when it is appropriate to use a case study approach in qualitative research. There are four conditions within which the use of a case study approach is most appropriate,

(a) the focus of the study is to answer “how” and “why” questions; (b) you cannot manipulate the behaviour of those involved in the study; (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context (p. 545).

The rhizoanalysis undertaken in the current research clearly fulfills some of these conditions. In particular, the context of the research is intimately related to the rhizome created. The relationship between the students and the context in which they are working forms a fundamental part of the research.

Having determined that a case study approach was appropriate, it is necessary to determine what the case is for analysis, called the unit of analysis (Merriam, 2008). This unit was determined to be the rhizome itself, derived through data collected from the students through a variety of methods discussed below.

The case then must be bound in scope, and clear boundaries for the research have to be set. My research was bound by time, location, and activity. In time, it occurred over a single semester, was bound within the Ontario Science Centre Science School, and does not look at all of the activities of the school. Instead, it is further bound by the fact that it is related only to the Innovation Project.

The researcher must determine the type of case study, in this case exploratory (Baxter and Jack, 2008). An exploratory case study is appropriate when the explanations link program

implementation with program effects. In this case study, the Innovation Project was designed and implemented in a particular way to fulfill conditions of complex systems. The outcome is predicated on this implementation.

The hallmark of the case study approach is that it utilizes multiple data sources (Baxter & Jack, 2008). In this particular case study, data were collected through interviews, transcriptions of meetings, and through posted Facebook data. Baxter and Jack (2008) indicate that having multiple data sources increased credibility as deficits associated with a single source can be overcome.

The purpose of my research was to undertake a case study to determine and describe how students engage in knowledge creation and how their participation in the OSCSS Innovation Project results in rhizome construction. The aim was to perform a rhizoanalysis of the OSCSS Innovation Project work. The rhizoanalysis of the data collected during a single semester was used to construct an image of the rhizome that the students created while developing the Innovation Project. There are three steps in this case study: collection of the data, analysis of the data, and delineation of the rhizome.

### *3.2 Framework of the Methodology*

According to Blanche, Durrheim, and Painter (2006), there are basically three paradigms in which a researcher can work: positivist, interpretive, and constructionist. These differ in the ontology, epistemology, and the resulting methodologies that they suggest. This case study falls within the interpretive paradigm.

In the interpretive paradigm, I, as the researcher, strived to be empathetic, even though I also knew I would, at times, be subjective. There is a distinction and connection between these two roles. I am part of the OSCSS, in that I serve as principal of the school within my capacity as

Director of Education at the Ontario Science Centre. As such, I am also associated with the Innovation Project groups; however, I have no active role within the groups. I know the students and interact with them both in and outside of the classroom in situations unrelated to the Innovation Project. Clearly, my involvement differs from that of an external university practitioner conducting the research and from that of students or teacher members of the Innovation Project groups who might have undertaken the investigation themselves. The reality studied was the subjective experiences of the students and my own involvement in the creation of a rhizome. I worked with students with whom I had an established relationship, and I was familiar with the conditions in which they worked. However, I am not a member of any of the Innovation Project groups, which are each comprised of six students and one teacher.

I collected data from and about students with whom I have a relationship inside the Ontario Science Centre Science School. I used Fairclough's (1995) discourse analysis methodology to analyze the data collected from the students conducting the Innovation Project. Finally, I performed a rhizoanalysis of these data following Alvermann's (2000) procedure by going back to further analyze the data and asking questions suggested by Dimitriadis and Kamberelis (1997). This procedure is outlined in further detail below. Through discourse analysis, I looked for themes in the data and collected, coded, and interpreted the data through these themes. The rhizoanalysis asks for further reflection on the themes and looks for linkages among the data that might not have been clear.

As I worked within an interpretive paradigm, I followed the five steps that, according to Blanche et al. (2006), must be undertaken in data analysis. The first is familiarization with and immersion in the data. As the OSCSS Innovation Project had been undertaken for a number of years prior to this research, I felt immersed in the process already. Together, with a group of four

teachers, I had been responsible for designing and developing the Innovation Project. Upon reflection each year, we had made changes to the Project, both in scope and structure. As I had been responsible for the Project's development and implementation since its inception, I was embedded within the project.

Because I had been associated with the project for a number of semesters, I realized the possibility of initiating the research with a number of personal biases about what I expected as outcomes. It was essential for me to understand these expectations before beginning the project and articulate them so I would be able to demonstrate where my expectations might be imposed upon unbiased data collection. Stringer (2004) points out that these personal biases always exist in action research and that their identification and analysis are critical to success. This is precisely the reason for introducing Clarke and Robertson's (2001) meta-interview. It provided me with information about the process that helped me, as the researcher, to understand where I might have superimposed my expectations of the data.

Clarke and Robertson (2001) argue that meta-interviews allow us to examine both the content but also the context of what the data are showing. As has been argued from the beginning of this case study, the context is vital to the rhizomes produced. Through the meta-interview conducted as the final data collection tool, both the researcher and the students developed a greater understanding of the context of the OSCSS, and its relationship to the data collected. It was only through the meta-interview that a full understanding of the importance of Facebook and technology within this context was appreciated.

According to Blanche et al. (2006), as this research falls within the interpretive paradigm, the methodology chosen, the case study, had to be interactional, interpretive, and qualitative. It

was necessary to, first, collect the data to conduct Fairclough's (1992, 1995, 2003) discourse analysis and then perform the rhizoanalysis.

### *3.3 Collection of the Data*

The first step in collecting and analyzing the data for this case study was to determine the unit of analysis. Babbie (1989) distinguishes among four different units of analysis: individuals, groups, organizations, and social artifacts. In this particular research, rhizoanalysis determined that the unit of analysis was the group. Each group consisted of six students and a teacher. I collected data from two groups as they conducted the Innovation Project.

The rhizoanalysis that I performed posited a group function. I hypothesized that knowledge creation would occur within a social situation in the group, and that the knowledge gained would, in fact, be socially-situated. Individual students as agents within a complex structure contributed to this knowledge development, but it was their interaction and situation within the group that determined the knowledge the group created. The organization of the Ontario Science Centre School was too large to act as a single unit of analysis, so student groups were formed. It was not felt that all 30 students would share the knowledge created by a single group; instead, it was thought that knowledge would be shared among all the members of each particular group. In other words, each complex group would create its own rhizome. Finally, the products of the group work, which were exhibits and exhibitions for the Ontario Science Centre, were considered the social artifacts. In a science museum, an exhibit is an individual, interactive experience for the visitor; an exhibition is a group of exhibits assembled around a theme. The phenomenon of knowledge creation is demonstrated in the formation of the rhizome, not in the finished product of the group work.

Having multiple data sets is the hallmark of a case study (Merriam, 2008), I collected data through three primary methods: three interviews, video recordings of two group meetings, and Wiki posts made by members of the group. First, I conducted an open-ended, qualitative pre-project interview with each of the students involved in each of the two groups. Some sample interview questions are included in the Appendix. For details about the collection of data in open-ended qualitative interviews, I referenced the works of Appleton (1995) and DiCiccio-Bloom and Crabtree (2006). The process began with the acquisition of approval from four institutions to conduct research: York University, the two school boards, and the Ontario Science Centre.

Permission to conduct research from the Toronto District School Board and the Toronto Catholic District School Board took longer to secure than anticipated. Each board has a schedule and hierarchy for granting research approvals. The Ontario Science Centre would grant permission for the research only after the School Boards had done so. As a result, the first interview with students did not occur until after the Innovation Project had been initiated. Students were immersed in the process before I had a chance to conduct initial interviews. Following the interviews, I had intended to make a video recording of the initial interactions between faculty and students in the OSCSS as the teachers assigned the OSCSS Innovation Project to the students and as the students, as agents of a complex system, first began to develop their group approach. Research about using video recordings in the classroom comes from Pirie (1996) and Hennessy and Deaney (2009). It was necessary that all students be made aware that a video was on and was recording in the room; however, it was equally important that the camera not become the focus of the conversation. As much as possible, the video was to record the conversation as it would have occurred had the camera not been present. Even in this artificial

environment, where participants are aware of a recording for data collection, I was seeking candid, genuine responses.

During some prior semesters, the students had chosen their own groups, using affinity or knowledge of each other's skills to find groups with which they felt comfortable. In other semesters, students had asked to be assigned randomly to groups. By making a video recording of this opening exchange, I had hoped to be able to understand the students' rationale and social processes for choosing to communicate through Wiki posts, email conversations, or other texts. They were also offered a third selection process, having the teachers assign groups based on the teachers' knowledge of the students and the criteria of the projects. During some semesters, students had opted for each of these three selection methods, and each has had an impact on the execution and outcomes of the Innovation Project. Students were asked during the interviews why they made certain selections.

At the time of the video recording of the introduction to the whole class, students had not had an opportunity to consent to be part of the research. As a result, I discussed this video in my research only in terms of my presentation to the students, not the students' responses. After consenting to be a part of the research, students were asked about their responses during interviews. Group selections also occurred in this introductory meeting. In order to be able to discuss the selection process, which was an important step in the research, the first interview asked questions about group selection. Examples of such questions were, "What method of group selection do you prefer and why?", "Was your preferred method chosen?", and "Might this have had an impact on your relationships among your group's members?" The process by which they were first chosen was important to the formation of the groups and to deciding whether the groups were complex or not. During data analysis, I discussed whether the Innovation Project

groups met the criteria for being considered complex. The Innovation Project was designed to create complex groups, but the process by which groups were chosen, solely through affinity or teacher selection, might have prescribed roles for students, which precludes complexity. After some discussion, the students chose to be assigned randomly to their groups. This was a class decision, certainly not the individual decision of each student.

The third data collection technique was to make a video recording of a meeting of the two groups as they worked through the project. This continued the collection of data for use in Fairclough's (1995) discourse analysis. There were five groups of six students involved in the Innovation Project; however, data were collected only about two of these groups, both of which were intended to be chosen at random. This intention was not fulfilled; instead, the two groups with students who agreed to be part of the research were followed, as they presented the greatest amount of data. The researcher was not in attendance at the meeting that was recorded; however, the teacher assigned to that group was. Each group created a Wiki or similar online exchange site in order to communicate with others members within the group. The use of Wikis in educational research is recent, which limited the amount of information available about their effectiveness as a research tool. However, Cole (2009) offers insights into their use as a tool of engagement. The contents of this Wiki, with particular reference to the meeting that was analyzed, were also to be collected as data.

The two video recordings of group meetings provided insights into the teachers' roles within the groups. The groups to be studied had not been chosen at random as intended; instead, they were chosen when all six, or at least five of six, members of the group, and the appropriate teachers, had consented to be part of the research. When students were offered the opportunity to participate in the research, not all 30 agreed. In an attempt to create random groups, students



were assigned to Innovation Project groups without regard to whether they had consented to participate in the research. However, collecting data about groups in which fewer than five of the six members had agreed to be part of the research, or in which the teachers were unwilling to participate, would have resulted in insufficient data for this research project. As a result, only two groups met the qualifications to participate in the study, and it was from these two groups that the data were collected. Working with the others groups would have meant interviewing fewer students and collecting insufficient data to understand the rhizome created in the Innovation Project. In the final analysis, two groups were studied, as intended. Eleven students -- six in one group and five in the other -- were interviewed for this research, as were the teachers from these two groups, who had agreed to be part of the research.

The successful delineation of the rhizome meant collecting all of the data as outlined from each of the two groups. During the course of the first interview and the group meetings, it was determined that the students were not using the Wiki extensively for communication. Instead, because they all had access to smartphone technology and unlimited data plans, the students were communicating with each other much more on Facebook. The Ontario College of Teachers had asked educators in the province not to “friend” their students on Facebook. However, I sought and subsequently received permission from all participants to receive copies of each group’s Facebook threads related to the Innovation Project. These data were analyzed and included in the research and in the rhizome. The Facebook threads, like all the other data collected, were themed and coded through discourse analysis. However, because students were considered to be more candid if they did not know when they were contributing to the threads or that their comments would be analyzed, it was felt that these data would form the backbone of the actual rhizome delineation. This assumption was made clear in the data analysis. In addition

to contributions students made knowingly, their unsolicited comments, representing important unexpected data, were also included.

Each student in the group has undergone two additional interviews with the researcher. The exit interview complements the pre-project interview and examines knowledge creation within the project. The third of these three interviews is a meta-interview, proposed by Clarke and Robertson (2001), which explores the students' relationship to the research and the process the students have undergone to provide data for this research. The meta-interview asks questions of research subjects about the research process, seeks to identify biases, and helps to elucidate themes in the data collected. The meta-interview questions were determined by the students' reactions to the opening and exit interviews and to the video recordings and Facebook posts. The meta-interviews was conducted with all eleven student participants as a group.

These first of the two individual interviews were conducted in fall 2011 as the students began the semester-long Innovation Project. The second, or exit, interview was conducted individually with each student before exams in January 2012. The students were asked during the exit interview to reflect on the success of the project and of their own group's dynamics. The meta-interview was conducted as an extensive group interview, during which the interviewer allowed an opportunity for participants to respond to one another and not merely to the interviewer. This was important, as it led to a number of insights about the Science School as a whole and the relationship of the students to the teachers. It further highlighted differences in perceptions among the students. Another set of data collected were students' evaluations of each other's contributions to the group, which became important in the data analysis, as it often distinguished between what students had said to me as the interviewer, and what they had said to each other and to their teachers about how they truly felt about the dynamics within the group.

### *3.4 Theory of Data Analysis*

I have adopted the methodology used by Alvermann (2000), who performed a rhizoanalysis of data she collected in public libraries in the United States. Her data collection consisted of texts in a variety of media that contained written pieces, interviews, and videotaped group interactions.

Alvermann (2000) used Fairclough's (1992, 1995, 2003) discourse analysis to analyze the data she had collected. This discourse analysis forms the basis of the theoretical framework for Alvermann's and for my data analyses.

Alvermann (2000) realized that her initial data collection and analysis conformed to Deleuze and Guattari's (2004) conception of a tracing, a representation that showed only the outlines of a rhizome's structure. Along with the tracing, Alvermann needed to create a mapping in order to perform a complete rhizoanalysis. She returned to her data and performed a mapping, which looks for "middles" rather than beginnings or endings. These "middles" are Deleuze and Guattari's "lines of flight." Using as an analogy a satellite photo found online, the photo is a tracing; it shows detail, but the mapping comes when routes linking points in the photo are found. One might ask, for example, "In which direction does a river flow?" or "What are the speed limits on roadways?" In the rhizomes delineated in this research, each "line-of-flight" required a direction and a flavour. Each connection represented communication from and to someone, and each connection had a tone. One must move beyond the tracing to mapping in order to understand the rhizome that is created. Alvermann mapped her data by asking herself a series of questions described by Dimitriadis and Kamberelis (1997). These questions helped her return to her original texts and look for links that CDA does not find. The questions included

asking herself to analyze her relationships to the texts, whether these relationships were emotional, and, if so, why. I tried to do the same with my data analysis. In particular, when trying to move from a tracing to a mapping, I looked at how I had been involved with the students and how the students had engaged with their teachers. I was fortunate to have candid data from Facebook to compare to the less candid responses I had received in interviews and video meetings in which students knew that their comments were being recorded. The comparison of what might be termed expected to unexpected data was fundamental to my own rhizoanalysis.

My data collection included social media posts created by the students, and I was able to hypothesize about their mapping. Discourse analysis looks at the social media posting, describes it, determines its meaning, and examines why the students chose to make a posting. This discourse analysis must be done first, and it gives us the tracing. From this, we will know why the students have chosen social media as a method of communication for some of their work. Rhizoanalysis continues past the discourse analysis process and examines how the social media post is related to other posts that have been made or erased, observes how they are linked to each other, and determines the structure and importance of the links between posts. Erasures and changes are trackable on our Wiki postings; however, because the students used Facebook much more frequently for communication, information about changed and deleted posts was lost within the research. The Facebook postings were analyzed, but changes to the postings, deletions, and edits were not.

This discourse analysis constitutes a mapping rather than a tracing, according to Deleuze and Guattari (2004). Both mapping and tracing are necessary to perform a rhizoanalysis and to create an image of the rhizome.

Grosz (1993) explains that a text itself acts as a rhizome. It is not important what the text is about but, instead, what it does and to what it is related. To perform a rhizoanalysis, these relationships are traced and mapped. I collected a series of texts consisting of interviews, videotapes, and social media postings, and these texts were traced using discourse analysis and mapped using rhizoanalysis.

Alvermann's (2000) rhizoanalysis revealed silences in the data, topics that the students in her library research did not broach. By collecting candid data like Facebook postings and students' group evaluations of each other, I was able to identify some topics about which students had remained reticent during interviews but to which they were able to prepare a response. In her research, these silences were topics that Alvermann thought should have arisen in the text but did not. My search for silences led to a number of instances in which students refused to comment on other members of their group in a negative way; however, these comments could be mapped later in the candid data. The "middles," the links between intersections in the text, had not been visible to Alvermann until she superimposed on the tracing – which is the picture of the basic structure with the mapping and the product of CDA – the mapping, or the product of rhizoanalysis. Together these gave the amorphous shape of the rhizome that the students had created. To be able to see what Alvermann calls the "middles" and what Deleuze and Guattari (2004) call "lines of flight," it was clear that I needed to have a relationship with the students beyond the Innovation Project. Further, as Alvermann points out, close examination was necessary also to find the connections that the students were not making, that is, their silences.

Masny (2013) demonstrates that coding of the data is not sufficient, and that although the rhizome is a map of the data, it cannot be created through traditional methods. This again stresses the difference between the tracing and the mapping as described by Deleuze and Guattari (2004).

As mentioned above, an additional data source not initially anticipated was collected. In addition to the Facebook threads, which underwent discourse analysis and rhizoanalysis, teachers presented a group member evaluation to each student in the class. This evaluation was not intended to be reflected in a grade for the students, but, instead, allowed the students to reflect on their experience and learn what they considered to be their own contributions and those of others. These data consisted of a circle given to each participant, who was then asked to divide the circle into segments, the size of each segment representing the contribution by each of the members of the group to the overall project. Students were asked to comment briefly on their completed circles. Afterwards, they granted permission for these data to be analyzed. These candid data were used throughout to compare both types of students' answers to questions, those that they knew were going to be recorded for research and their reflections on group dynamics that they did not initially realize were going to form part of the data. This resulted in the discovery of a number of inconsistencies, which are identified in the data analysis section of this research, and in the identification of a number of silences, those issues about which students were more reluctant to speak. These data also gave insight into students' evaluation of their own participation, which often varied sharply from what other students or teachers had perceived.

### *3.5 Process of Data Analysis*

The first step of the data analysis was to code all of the data that had been collected, including interviews, video, Facebook postings, and evaluations. Each interview and video was transcribed verbatim. It was then possible to discern themes and patterns within the data. It was during this step that it was the most difficult for me to avoid introducing my own expectations as the researcher. I used the rhizome as a paradigm for describing the students' knowledge creation; however, I had to resist forming preconceived notions of the shape, scope, or boundaries of this structure, as Strauss and Corbin's (1990) research had cautioned. There are a number of countermeasures that can be taken to preclude the researcher from finding only what he or she expects to find. For my research, I labeled the categories using the vocabulary of the students rather than abstract theoretical language. The themes that arose emanated from and were shaped by the data, not from my preconceived ideas.

The second step was recoding of all of the data to see if different themes emerged from a reorganization of the data. I followed the procedure outlined by Auerbach and Silverstein (2003), whose analysis includes a number of software programs that can be used to code data. Barry's (1998) procedural document for choosing the most appropriate computer software for data coding was consulted. It resulted in the selection of AQUAD software to analyze my data. As Strauss and Corbin (1990) point out, coding entails organizing the collected data into the themes that the data have suggested. For example, if the theme of "research" arose, each time a student used language related to the topic of research, that text passage was labeled with the appropriate code. AQUAD allows for the coding of text, audio, and video data. It is important to recognize that the coding is fluid and that the coding process itself can lead to new and unexpected themes and to a recoding of the data. Barry suggests that use of a computer program does not easily

allow for this fluidity of approach. Hence, it was important to document any change of coding as the process unfolded.

The coding and the recoding of all of the recorded data, including interviews and Facebook posts, took several months from the time the data analysis began. I attempted to familiarize myself with the data as much as possible, and then I sought to find themes from the data that might only come to the fore after my extensive immersion into the various data sets. Two different computer programs were used to analyze the data, but with very limited success. AQUAD and the Coding Analysis Toolkit, a product of the Qualitative Data Analysis Program at the University of Pittsburgh, were both used. Unfortunately, it was found that both of these computer programs required the researcher to determine the themes in advance and to code every statement as falling into one of the themes. Thereafter, the software itself grouped the statements and counted contributions within each theme. In this way, the computer programs tried to make quantitative data out of the qualitative data that had been collected. This was determined not to be useful, and manual coding through multiple iterations seemed to yield the most favorable results. I used the individual sections determined by the computer programs, and I rearranged them in new ways as new themes suggested themselves.

Step three entailed continued analysis and elaboration. This occurred when I, as the researcher, moved from experiencing the data in chronological order, the way it had been collected, to examining the data in coded categories that no longer bore temporal relationships. It is important to note that one of the important contributions of social media to data collection is the temporal nature of the data. This temporal aspect became vital during the data analysis and the delineation of the rhizome. According to Dey (1993) and Bryman (1990), it is important at this stage to recode the data again in multiply different ways. Recoding occurs when new themes



are introduced and data are rearranged to conform to new patterns. By recoding, the researcher attempts to serendipitously discover relationships and meaning that might not comport with the researcher's preconceived biases (Blanche et al., 2006). The danger in coding data only once is that the themes and codes identified might merely serve to confirm the ideas the researcher had before initiating the research. It is important in the elaboration stage, then, to consider multiple approaches to coding the data to see if these result in new insights and new knowledge formation.

In my research, recoding occurred multiple times, and the chronological order of the data was disrupted a number of ways. First, after examining the data chronologically, all of the data were recoded when separated by student contributor rather than by date. Some of the results of this recoding were categorized in terms of students' success and roles that they had taken on within their groups. Second, the data were recoded again by the Innovation Project Group. These analyses allowed some new themes, for example, unhappiness with the contributions of others, to be revealed.

Finally, step four was the interpretation and checking of the data. This is the stage at which, I, as the researcher, had to re-examine my own biases and determine whether I had over-interpreted or misinterpreted the data in order to support my own hypotheses.

### *3.6 Delineation of the Rhizome*

After these steps had been completed, a meta-analysis consisting of a rhizoanalysis was conducted to, as Alvermann (2000) says, create a mapping of the web-like connections and openings for the cartography of the rhizome that the students had created. As Alvermann posited, it was also important to determine what the students had not talked about as they went through the process of knowledge creation in the OSCSS Innovation Project. These silences represent

“middles” that may not have been articulated but, nevertheless, formed links among themes and constitute an integral part of the emerging rhizome.

There was an additional unanticipated step added here. Although the data from the Facebook threads had been coded and analyzed, it was determined that this coding was not useful to the creation, or assemblage (Masny, 2013) that was to represent the data for analysis. All of the Facebook thread data, every single entry, was represented within a mapping, and this rhizomatic structure was then used for data analysis that depended as much on the resulting shapes as on the individual items inserted to create them.

## Chapter IV: The Research Context and the Students' Views of the OSCSS

### *4.1 An Introduction to the Researcher*

As the researcher, it is important that I reveal my relationship to the Ontario Science Centre and the Science School as part of any possible bias. I first was hired as a seconded faculty member to be part of the OSCSS in 1995 as the biology teacher. This was my first exposure to informal science education, although I was teaching a formal class. In 2006, after being Director of Education at the Dallas Museum of Nature and Science (now the Perot Museum of Nature and Science) I returned as the biology and chemistry teacher at the Science School.

In 2008, I was hired to be the Director of Education and Weston Family Chair of Innovative Education of the Ontario Science Centre. This role included responsibility for the Science School, and indeed the school at this point was in a crisis. The Toronto District School Board had withdrawn funding, and there was a fear at the OSC that the school would not continue to exist. I was hired explicitly to re-establish funding from the TDSB, and to articulate a justification for having a formal school in an informal science education setting.

Working together with the teachers in 2008, we created the Innovation Project as an opportunity to form a space of informal education within the formal education curriculum that the OSCSS followed in each of its classes. The creation of the project, and the articulation of the goals of the OSCSS were sufficient for the TDSB to once again fund the school and to ensure the school's continued existence into the future.

In January 2013, I became the Executive Director of SciWorks, the Science Centre in Winston-Salem, North Carolina. My tenure at this institution has been marked by my education background and with my experience in formal, informal, and intersectional environments. It is not common to move from an educational background to be the Director of a Science Centre,

and the Innovation Project informs my discussions in changing educational values in Winston-Salem.

#### *4.2 An Introduction to the Ontario Science Centre Science School (OSCSS) Innovation Project*

In the semester under examination, the students were given access to smartphone technology through a generous donation from *Telus*. *Telus* is a cellular service provider across Canada with an interest in informal education in science, technology, engineering, and mathematics. Several science centres across Canada, including the Ontario Science Centre (OSC), receive funding from *Telus*, and many informal education providers in Toronto were approached about educational uses of smartphone technology. The OSC determined that providing the OSCSS with smartphones was an interesting application for exploration. The research was designed before the researcher was aware that each student would have a smartphone, and so the results of the research changed in fundamental aspects. Data collection included Facebook threads that, without smartphone technology, the students might not have created or used as extensively. Each student and teacher in the OSCSS was provided with a smartphone. There was, therefore, no digital divide, i.e., no difference in access to technology among the participants in this research. The phones had an unlimited data and voice plan, with the bill paid by *Telus*. In this way, students and teachers were encouraged to explore the educational use of smartphone technology.

Because all 30 students had access to smartphone technology, this semester's Innovation Project had an added dimension. Students were asked to incorporate into the design of their exhibit some way for visitors with smartphone technology to engage with the exhibit using this technology. This was a difficult challenge for the students, as they had not had prior experience with the technology. They were asked to stay away from application design, and instead consider

ways in which the functions of the smartphone itself could lend themselves to demonstrate engagement. In this way, any visitor to a student-designed exhibit could engage with the exhibit either with or without a smartphone and without the need to download an application.

Each semester, the students are given the opportunity to present their project to the exhibit research and development team at the OSC. Several project ideas suggested by students in the past have gone into development to make actual exhibits on the floor, for example Face Time. The idea for this exhibit came from students who designed the exhibit in order to provide an opportunity for visitors to the OSC to practice collaboration. The basis for the exhibit was Charles Darwin's research into facial expression of emotion. The students ask the question, "How much of her face do you need to be able to see in order to determine the emotion experienced by an individual?" The exhibit allows visitors to photograph themselves and add one trait (eye, nose, mouth) to an amalgam of traits from other visitors already saved in the exhibit's database. In this way, visitors collaborate to create new faces with seemingly unreadable emotional expressions. The resulting amalgam faces challenge visitors to recognize emotion in small facial characteristics, and to begin to identify which characteristics are dominant in communicating emotion. Students whose projects have been selected to be part of the Weston Family Innovation Centre maintain contact with the research and development team to work on the on-floor working models of their Innovation Project exhibits.

Students in the OSCSS are asked to meet on a regular basis to work on the Innovation Project; the meeting time, duration, and structure are all determined by the students. Throughout the Innovation Project, each student member of the group is responsible to see that a group journal is maintained, and the students are encouraged to maintain this journal in a Wiki format. The evaluation of the project is based not on the exhibit designed but on an interview with the

students. This interview is conducted by the entire teaching staff of the OSCSS and takes place at the end of the semester after the Innovation Project has been completed. Each student is interviewed separately, and an individual mark for the Innovation Project is determined from this interview alone. To promote risk-taking, this interview mark is generally 100%, and the students are aware of this before embarking on the Innovation Project.

#### *4.3 An Introduction to the Students*

This section introduces the students involved in the Innovation Projects that were being followed in 2011/2012. The ethnicities and social backgrounds of each student are described, with a review of their home school environment.

Arthur, born in China, moved to Canada as a young child. He attends a public (non-Catholic) academic high school in the north end of Toronto. He consistently received excellent marks through his high school career, struggling only with Mandarin in school. His school offers both Mandarin and Cantonese, thus reflecting the ethnic diversity of the student population.

Bernadette was born in Canada and is of Chinese ancestry. She attends a public high school in Pickering, a suburb east of Toronto. Bernadette's marks are in the 80s (As) in sciences and 70s (Bs) in mathematics. Her marks were noticeably lower than those of many of the students who apply to the OSCSS.

Carter is white, and English is his first language. Born in Canada, he lives and attends school in Shelburne, a town about one-and-one-half hours north of Toronto. Carter's marks in science and math are outstanding. As part of all applications to the OSCSS, students submit recommendations from two teachers. In general, these are excellent and rarely include any negative comments. In Carter's case, both teachers noted awkward classroom behaviour and engagement with other students.

Christine was born in Canada of Chinese ancestry. She attends a publicly-funded Catholic high school in Markham, a suburb north of Toronto. Christine participated in a “laptop” education program at her home school and consistently received excellent marks. She struggled only with learning Cantonese, which she suggested that her community expects her to speak outside of school and work. Mother-language courses are offered in her school but only in Mandarin and Cantonese.

Catherine is of South Asian and Caribbean ancestry and was born in Canada. She attends a Catholic high school (be consistent) in Scarborough, an inner suburb east of Toronto. Catherine’s marks were very good, though her highest marks were in the visual arts and music and not in science and math. This makes her different from many applicants to the OSCSS. When choosing students, the school often looks for this type of diversity in subject areas in which students excel.

Elizabeth is English-speaking and white. She was born in Canada and attends an all-girls Catholic high school in Toronto. Elizabeth was in her fifth year of high school, meaning that she had returned for an extra year, not to repeat any courses but to take a greater variety of courses. Elizabeth had not taken any of the science courses at grade 12 before attending the OSCSS. At her home school, she studied mostly English and history. Elizabeth had excellent marks in all of her subjects.

Kirk was born in Canada and is of Chinese ancestry. He attends the same Catholic high school and is part of the same “laptop” program as Christine. His marks were exceptional, except in Mandarin, which was lower. Kirk, like Christine, feels that his community expects him to speak his native language (Cantonese) outside of school and work. Kirk’s teachers noted that he was extremely gregarious and that he had participated in Shad Valley, a pan-Canadian program

run in the summers on university campuses that allows students to experience entrepreneurship. Kirk had, therefore, already engaged in some of the ideas of the Innovation Project through his Shad Valley experience.

Mark is French Canadian, though English is the primary language at home. He attends a public high school in Grimsby, a small community on the Niagara Peninsula about one hour southwest of Toronto. Mark's grades were mediocre, especially by the standards of the Science School. He was chosen largely through his essay, in which he expressed an interest in exploring science further due to his curiosity. He professed to be bored by school and said he hoped that the OSCSS would provide a different environment and a new experience that could improve his work ethic.

Mary was born in Zambia and moved to Canada during elementary school. She attends a Catholic secondary school in Brampton, a suburb northwest of Toronto. Mary's marks varied greatly in school, from a 63 (C) in grade 11 mathematics to an 83 (A) in grade 11 chemistry. Mary's English and French marks were consistently her lowest.

Michelle is white and was born to English-speaking parents. She attends Mary Ward Catholic High School in Toronto, which has a special program for independent learning. This means that during high school, Michelle had no classes and was responsible for the timing and progress of her education. She reported to a teacher assigned for each course and was able to complete courses at her own pace.

Peter was born in the Gulf States and is of South Asian heritage. He moved to Canada as an elementary school student. Peter lived in Brampton and attended a public (non-Catholic) high school. Peter's parents moved to Toronto for him to be able to take part in the OSCSS, and he



spent the second semester at Don Mills Collegiate, OSCSS' partner school in the Toronto District School Board. Peter's marks were consistently very high.

There were also two teachers involved in this research, with each assigned to an Innovation Project group. Martha is seconded to the Science Centre from the Toronto Catholic District School Board and has been teaching for almost 30 years. She is a department head in science and was previously department head in music. Judy is seconded from the Toronto District School Board and has ten years of experience. She is also a department head of science at her home school. Both of the teachers are white and native English speakers.

#### *4.4 Students' View of Context of the OSCSS*

The Ontario Science Centre Science School presents an environment different from the "home-school" experiences that the students have had up until their semester in grade 12 here. The students were aware of this contextual difference and expressed it during interviews by invoking the theme of the "real world" versus regular education experiences. Some students saw the OSCSS as more like the "real world" than their home schools. Others saw the Innovation Project as more like the "real world" than regular OSCSS classes. All of them saw this mimicry of the "real world" as an essential experience in school and one they had been lacking up until now.

When thinking about the informal learning going on in the Science Centre, Bernadette described it as

Kind of sneaky learning, because, like, you don't really know what you're learning until afterwards, you're kind of, like, 'Oh,' like, when you think about it. It's sneaky learning because in class, like, you go in and you're, like, 'Oh, I'm going to learn a lesson today.' At the Science Centre, you're kind of, like, 'Let's go kind of have fun,' and then in the

background it's, like, 'and do some learning' (Bernadette, personal communication, January, 2012).

The students hoped that the OSCSS would provide them some opportunity for this “sneaky learning” as well. They chose the Science School because they thought that it was cool to have a school inside the Science Centre.

This is part of the difficulty facing the OSCSS. Students come believing that they are going to engage in an informal science education experience because the courses are being held within a Science Centre. However, the classes are extremely formal. Only the Innovation Project allows the students an opportunity to experience the informal, free choice education that they believed they would be engaging in at the OSCSS. This has proven to be a problem, and students have complained that the school is not what they expected it to be.

Part of the context noted by the students in this research is the size of the school. There are only 30 students each semester, and they are each registered in three or four classes. Peter thought that this made the school special:

Here, we, like, almost all of us share the same classes, and we, like, sort of have to work on the same thing, whereas in high school, you have different teachers, they want different things, and they have different styles, like, they want; like, lab reports might be different and varied from one teacher to another” (Peter, personal communication, January, 2012).

Notice the distinction that Peter draws between the Science School and high school (by which he means his home school). It is clear that the students consider the context sufficiently different to warrant comment, even when the classes cover the Ontario curriculum and are entirely formal.

Carter also thought that the small size of the school was important to its context and feel. He noted that the school's size allowed students to make cross-postings in social media, meaning that discussions were not limited to the Innovation Project, for example, because other members of the group would have the same test or questions for the next day if they shared courses. In other words, social media postings could be about multiple subjects and still be of importance to all the other students. The students' use of social media will be discussed in detail later in this dissertation.

The students understood it was central to the quality of the program that the school chose 30 qualified students for the school, 30 students who want to be at the Science School for any given semester. One of the big differences of the OSCSS from other schools is that students must apply to attend. With this arrangement, the school hopes to ensure that all 30 students are highly motivated. The students understood their own and their fellow-students' high motivation within the program as crucial to the program's attractiveness and success. Generally, the students commented on the number of laboratories and opportunities at the OSC as reasons to come to the school and to tell their friends about it. The school's process of choosing students is not always successful. Students have been chosen who were less motivated and who did not live away from home successfully. Also, the school has chosen students who did not get along well with their peers and were unable to work successfully in a group-project environment. This discrepancy points to flaws in the application procedures. The students have, on occasion, expressed a preference for a system in which the school would randomly select students from among qualified applicants. This way, questions about suitability are not left to the teaching staff, and compatibility is not a personal decision by a teacher.

It is unusual within the Science School environment that the teachers are part of the application process, as they are responsible for actually choosing the students they are going to teach in the coming year. Bernadette thought that this worked in the school's favour.

You know, they're going to do their homework; they're going to try and give their effort in their projects and stuff, where sometimes at home school, like, you have some kids in a class who, like, they're just taking the class because it's required (Bernadette, personal communication, January, 2012).

The fact that the school is optional for students and that they must undergo a selection process was paramount to the students' understanding of the context of the school.

The students' use of technology in the classrooms was intriguing. Whereas I believed that the students would be indiscriminate users of technology, it was clear that they took conscious and discriminating advantage of the available technology. Carter, for example, explained, "But I mean, I think a lot of us like actual books and resources. Like, I hate looking at textbooks on a computer; it's just so less convenient than [to] actually have it, like, physically in front of you." I thought this surprising. In particular, I asked if the students would have preferred to have a tablet computer to the smartphones with which they had been supplied. In general, the students found tablets to be too big and bulky; Bernadette actually called them "nasty." However, they were looking for WiFi access and were surprised that the Science Centre would not be able to provide them with WiFi. As an agency of the Government of Ontario, the Ontario Science Centre is not allowed to offer WiFi access to the general public or to the staff and students of the Centre. All of the Internet access provided is from Ethernet ports. Fortunately, their cell phones came with unlimited data access, so the students were able to take advantage of consistent

Internet access without WiFi by using their phones as Internet hubs for their computers and others’.

Returning to their home school after attending the Science School was difficult for the students. Carter stressed how different the experience had been, and that somehow he had seen behind the “curtain” of education. The Science School gave students unprecedented, at least for them, access to staff. That access provides insights into the workings of the education system in formal school settings. Carter expressed it by saying, “I see high school and, like, the education system so different; like, high school, like, will never, ever be the same.” In other words, he believed that the Science School had provided him with insight that a traditional formal school could not provide. This was an opportunity to view education and schooling from a new perspective.

This does not mean that returning to their home school is a bad experience; many of them have been homesick for that situation. Bernadette, in particular, expressed a longing for her friends and for the sports activities that she engages in at her home school. In fact, many more students choose first semester than second semester because they hope to return and go through the final semester of high school with their friends. Being away from friends in the last year of high school at any time can be traumatic, and that trauma is an important part of the context of the Science School. The students feel a certain camaraderie in adversity; they also expressed that they were missing events and friends at their home schools. This is particularly true in the last year of high school, when many time-honoured high school rituals take place. The students often lament the events that they miss in their home schools.

Not every student is happy with his or her experience at the Science School. Although making sure that students enjoy the experience is a priority for the school, it is not always

achieved successfully. For example, Mary was surprised by how the semester had divided students into small friendship groups. There was no feeling of community, she thought, whereas that is particularly what staff are trying to create. Mary's assessment of the school atmosphere must count as one of our failures to create a coherent community. The staff's inability to create a welcoming atmosphere may have contributed to the groups' success or lack of success in the Innovation Project. Mary says, "Our group, it's kind of like, yeah, that person's kind of annoying, I don't want to be with them [sic] or whatever." What she is saying is that there was strife and dissension within her Innovation Project group, something the school tries to avoid within the school, and particularly within groups. However, the school cannot create an environment in which every student is happy and successful.

## Chapter V: Data Analysis – The Innovation Project Groups at Work

### *5.1 Coding and Theme Development*

The first step in discourse analysis is to code the data, a task that I undertook using a computer program. The program asks the user to select themes in advance, then brings up each sentence in sequence, and asks the user to select the theme into which the sentence falls. The program quickly gives relative frequency of themes arising and maintains the data in the separate themes identified. This would be an extremely effective approach if one were looking to turn the qualitative data into quantitative data.

After applying the computer program to the first set of interviews with the students, I decided that this approach would not be helpful. A major factor in this decision was its difficulty in discovering a new theme part-way through the coding and returning to the items that had already been coded. The computer program, although able to sort through the same information multiple times, was unable to collate the data with previous sorts. If, for example, a certain phrase was part of Theme A in the first sorting, it could be made part of Theme B in a second sort; however, the program could not relate the two themes to one another.

Going through the data with different coloured highlighters and scissors proved much more effective. Using this process, coded data could be sorted by theme in accordance with the colours and then resorted, but the colours were maintained, and relationships among recoded themes became clearer.

The first attempt to sort through the data yielded several themes by which the data were coded. Themes included, for example, the environment of the Science School, group dynamics within the Innovation Project groups, and the selection of roles and responsibilities. A second sorting of the data yielded underlying discussions of the appropriate use of technology and the

scientific nature of the Innovation Project itself. It became clear that many of the students' comments could be coded as parts of a multiplicity of these themes.

Within particular themes were sub-themes as well. Under the theme of group dynamics, the students discussed hierarchies within groups, both inside and outside the Innovation Project. They also discussed workload and work ethic independent of an established hierarchy.

One theme that was of particular interest to me were comments that I felt students had made in an attempt to fulfill what they perceived were my expectations. I discovered through the interviews that students who had already been interviewed were discussing with subsequent interviewees the questions I had asked. A case in point is Michelle, who had prepared her answers in advance. This created a problem regarding whether students were being candid and truthful, or if they were responding after having had time to consider the question and modify their responses. For this reason, the Facebook data became very important, since students seemed uninhibited in commenting on social media and were, at least in my opinion, more likely to respond openly and honestly.

In previous semesters, students had access to computers in the Science School and at home, and we made certain that there was always a computer and Internet access available to all students when they were away from school. However, during this semester, students gained access to smartphone technology for the first time. Through smartphone use, the teachers in the Science School discovered that students were more comfortable communicating on Facebook than on the Wiki that we believed initially each group would create and utilize for asynchronous communication throughout the Innovation Project.

When this research began, I intended to examine the Wikis that each Innovation Group -- the Haptic Touch group and the Driving While Distracted group -- had created and use this



information to track the group's progress. I discovered that the Wikis were not being used for communication among the members of a group but only for their communication with the teacher and only inclusive of those topics that the teacher insisted in advance be posted to the Wiki.

Candid communication, which seemed to me to be much more representative of the students, was actually occurring on Facebook. This phenomenon is discussed later in an analysis of the students' use of social media. The students provided me with access to their Facebook postings, which appeared in the form of threads. These data were particularly interesting because the thread is maintained chronologically and was not intended to be shared with teachers. The use of Facebook and other social media had profound implications for the Innovation Projects and, therefore, for this research, but these methods of communication also changed dramatically the dynamics of the formal classes in which the students were enrolled. The impact of the use of social media outside of the Innovation Project is also discussed.

The data collected from Facebook, with the students' permission, was also coded and analyzed. However, I returned to these raw data directly when preparing the diagrams of the rhizomes themselves. This occurred for three reasons. First, the Facebook data had temporal integrity, as each posting was date-stamped and time-stamped. Students were not being asked in an interview to remember the sequence of events, as that chronological memory was maintained intact in Facebook. Second, the Facebook posts are candid. The Ontario College of Teachers has asked teachers in the Province not to "friend" students on Facebook. The result was that Facebook became a teacher-free zone, where more freedom of expression, and perhaps more honesty, was facilitated. Finally, as all students were provided with equal access through their

smartphones, participation in Facebook conversations, or of lack of participation, carried its own significance in the creation of the resulting rhizome.

### *5.2 Outline of Data Presentation*

The data are presented in three different ways in the following data analysis section. Some data, from the student interviews for example, are sorted by name of the student. This was important so as to be able to differentiate each student's contribution and render a judgment concerning the contribution of others in the group. Also, this method of sorting facilitated the discussion of how each student had changed in his or her responses from the first interview to the second.

The second technique of presenting the data was to group all of the data from a particular meeting. This was done for both student groups in their interviews with teachers. It is critical as students establish relationships with their teachers, and in considering how teachers impact each of the groups, that their conversations be examined intact. Each of the teacher's involvement is problematic based on the complexity of her group but in a different manner. To highlight this situation, it was necessary to examine these events separately from the analyses of the students' responses.

Finally, some themes were of such great importance that they are discussed separately as a theme rather than within each student section. In particular, the students' use of social media is delineated as a separate section, which allowed me an opportunity to explore and learn about an unanticipated aspect of the research: the Innovation Project and the formal classroom.

### *5.3 Classroom Introduction of the Innovation Project*

The data from the introduction of the project to the students were not coded. Although the meeting with staff and students was filmed, it was not possible to secure the participants'

permission to be subjects of the research prior to their introduction to the Innovation Project. Without their consent, their comments could not be included. Nevertheless, I have outlined my contribution and the process by which students first learned about the Innovation Project.

I work as part of the team at the Ontario Science Centre Science School. There are four educators, a coordinator, and myself. I am the Director of Education and Weston Family Chair of Innovative Education. My role includes oversight of the Ontario Science Centre Science School, and I am nominally “principal.” I am responsible for all aspects of the school, but the position is not official within either of the two school boards to which these schools report. Although I lead the team, I am not in control of every aspect of the team’s work, and classroom teachers are given tremendous autonomy. The Innovation Project was first introduced so that students would learn about the skills of innovation and how to introduce those skills through exhibits to visitors to the Ontario Science Centre’s Weston Family Innovation Centre. Teachers, who are seconded for only a few years to the school, are sometimes new to the Innovation Project, and often they have their own ideas about the extent to which the students’ final marks should be influenced by a project such as this.

Each Thursday afternoon, students have an Innovation period. This is scheduled class time designed to give the students an opportunity to explore beyond the Ontario Curriculum. For an hour during one of the sessions in October 2011, I presented the Innovation Project to the students. We began by looking at the skills of innovation, and we asked the students to think about these skills as they designed their exhibit but to also understand that the Innovation Project was designed to give them the opportunity to practice these skills on their own.

The Ontario Science Centre delineated these skills of innovation in the design of the Weston Family Innovation Centre. I selected four skills to introduce to the students: creativity,

risk-taking, collaboration, and perseverance. These skills were chosen because they are traditionally difficult to introduce through the Ontario science curriculum. Students are not often given the opportunity to be creative. Taking a risk often involves a student risking his or her grade. Genuine collaboration can be difficult in a classroom, especially in university preparation courses where students are competing for grades. Generally, the curriculum does not allow time for long-term engagement with a single project. The Innovation Project develops these skills in two distinct ways. The project was designed especially to allow the students to explore these skills as they developed the exhibit, and the exhibit incorporated these skills as demonstrations for the visitors. I discussed with the students how the Innovation Project has been designed to promote each skill and how their exhibit must allow visitors to explore these skills as well.

It is our contention at the Ontario Science Centre Science School that creativity and risk-taking are not supported in the regular Ontario classroom. In order to allow students a genuine opportunity to be creative and to take risks, it was necessary to remove grading from the equation. If a teacher were to grade the Innovation Project, students would likely ask the teacher, “What exactly would you like me to do?” In other words, the students are almost singularly focused on how they can achieve the highest possible mark, not on applying their creativity to the project. By removing grading from the equation, we hoped to get students to ask themselves, “What would I like to do?” This distinction between asking the teacher and asking oneself is very important to the ethos of informal science education, and it marks a fundamental difference between informal and formal education. We eliminated grading within the Innovation Project by guaranteeing each student a grade of 100 percent. This grade makes up one third of each student’s summative evaluation, and therefore counts for 10 percent of their overall final mark in each course in which they are registered. Some teachers within the school find this formula very

frustrating. It was important, however, for students to have some motivation other than grades to ensure their full engagement in the project.

Csikszentmihalyi and Hermanson (1995) discuss intrinsic and extrinsic motivation among museum patrons and the extent to which they are motivated by such factors as grades or approval. They argue that free-choice, learning-based, informal museums, including science centres, allow visitors to explore only those exhibits for which they hold an interest. Visitors are not looking for an external, extrinsic reward but only to move from one exhibit to another in which they are personally engaged.

It is my belief that by relying on extrinsic rewards in formal education, for example, grades in the classroom, teachers suppress the creativity and risk-taking that their students could express. By removing grading as an issue, we allowed students to identify their own intrinsic motivations for participating in the Innovation Project and to choose exhibit topics in which they were truly interested. This is one of the fundamental differences between the Science School and other high school experiences; indeed, it aptly answers the question, “Why have a school inside a science centre?”

Creativity and risk-taking being the first two, the other two skills of innovation are collaboration and perseverance. The students were presented with the idea that their collaboration would come not only from the group nature of the project, but that the exhibit they designed must also allow visitors an opportunity to collaborate when they engage with the exhibit. Finally, we tried in the OSCSS to allow the students an opportunity to practice and demonstrate perseverance by giving them an extended timeline for the project, over two-and-a-half months in total. At the same time, we asked them to record their progress along the way, which was an effort to help curb a very natural tendency toward procrastination.

The four skills of innovation, and their relation to the curriculum, were outlined to the students in our initial meeting about the Innovation Project. The participants of this meeting were all 30 students and myself; the teachers generally do not attend. During the meeting, I reviewed Allen's (2004) article concerning the learning purposes of science museum exhibits, in which she outlines a philosophy of exhibit design. I asked the students to consider the particular role for their own exhibit as they create their design during in the Innovation Project. Allen outlines four characteristics of a well-designed science centre exhibit that are crucial to its success. First, it must have immediate apprehendability. This means that any visitor approaching the exhibit should immediately be able to determine its subject matter and goal. It is impossible to engage someone's initial curiosity and intrinsic motivation if he or she is unclear about an exhibit's purpose.

The second attribute of an excellent exhibit is user-centred design. In my experience at the OSCSS, this aspect of exhibit design had caused students in previous semesters to experience difficulty. User-centred design is the idea that there are natural characteristics within the visitor's world of experience that should be mimicked within the exhibit. Two examples of such natural characteristics might include colour coding dials according to the aspects of the exhibit that they control, or making certain that an exhibit is adjustable for visitors of different heights.

The third attribute an exhibit requires is a coherent challenge, or what Allen (2004) refers to as conceptual coherence. In other words, there must be a puzzle that is solvable either through interaction with or observation of the exhibit. If there is no satisfactory puzzle, then a visitor's curiosity cannot be engaged. If the puzzle's solution proves to be too difficult, then the results are frustration and a shutdown of the visitor's intrinsic motivation. It is a very difficult balance to design an exhibit that is both a sufficient but not excessive challenge to the visitor. In the same

way, the Innovation Project was designed to be a significant but not insurmountable challenge to the students engaged with it.

Finally, an excellent exhibit is multimodal. This means that visitors with different learning styles and different levels of background knowledge will be successful in finding entry points to engaging with the exhibit. This is particularly important as one of our priority audience segments at the Ontario Science Centre is families with children. Clearly, parents and children may come with different learning styles, and they all come with wildly different knowledge levels about the subject of the exhibits. It is these different entry points that often determine whether an exhibit on display in the science centre is a success or not.

At the end of this introductory session, students were told that those enrolled in previous semesters had successfully designed exhibits that had subsequently become part of both the Weston Family Innovation Centre and a travelling exhibition called *Imagine* that was built by the OSC. In particular, there is an exhibit called “Face Time” that allows visitors to take a photo of their face, upload it into a database, and then exchange their eyes, ears, nose, and mouth with the photos that other visitors would have uploaded earlier. The initial conception and design of this exhibit was produced by an Innovation Project group. I provided this information as an extrinsic motivation for the participants. It was the belief of those in the science school that seeing an exhibit actually built by the Science Centre would be as strong a motivator in this instance as a teacher’s control of grading might be under other circumstances. In other words, we acknowledged that some extrinsic motivation was required in the Innovation Project in order to ensure that the students performed their best. We chose not to make this project one that would result in a grade because grades are under the control of the teacher. Whether a student-designed exhibit becomes permanent within the science centre is a choice made by the exhibit

development staff who have no other relationship to the students. This extrinsic motivation, then, is professional and external to the school. We felt though that this made for a stronger motivation for the students to participate.

The final segment of this initial meeting was group selection, where students determined the methodology they preferred to follow in determining the members of each Innovation Project group. Each group was constituted immediately.

#### *5.4 Innovation Project Group Selection*

When the project was presented to the students early in the semester, one of the first questions put forward was how the groups would be selected. Students were given three options for group selection. The first was teacher selection. As the teachers knew the students after having interacted with them approximately one month during the semester, it was felt that the students could decide whether they wanted the teachers to pick the members of the groups. The second possible method was student selection. The students were offered the choice to select their own groups; however, no method of selection was specified. The third option was random selection, in which students' names were to be picked from a hat.

The majority of students in the class voted for random selection. However, only the students involved in this research were asked which type of group selection they had preferred and why. This question was posed only after the selections had been made.

Of the 30 students in the class, 11 students in two groups were part of this research. These 11 were asked about their preferences for group selection. Arthur said he would normally like to choose his own groups, largely because he was afraid that if the teachers chose, then people of different abilities would get paired together. "Some people, they do more work than the other people," he reasoned. However, when it came to voting, he abstained because "We're



all alike in our abilities at the Science School.” It is true that among the teachers, there is a preference for mixed-ability groups. Martha said,

So, usually when I choose groups at the beginning of a class or at the beginning of a semester, I often let the kids choose their own groups just to see how they’ll group, and they often choose their friends, right? But as the semester goes on and I get to know the kids better, I will often pair weak with strong (Martha, personal communication, January, 2012).

Arthur, it would seem, was right then to worry that weak and strong students would be intentionally linked if teachers chose the groups.

Two of the students used Martha’s logic to explain why they liked teacher-selected groups. Catherine said, “I’d probably prefer the teachers selecting because they know us on a, I guess they kind of know us on a, personal level so they can put us together ...” Michelle too saw this as a strength, preferring it when teachers selected based on what they observed about students’ behaviour: “So students who are better leaders go with students who are quieter and they kind of make the groups based on people’s strengths.” Michelle actually voted for the teachers to pick the groups; Catherine did not. Catherine voted for random selection because she believed that everyone in the Science School would be willing to do his or her share of the work.

The students were universal in condemning the idea of students choosing their own groups. Only Mark voted for this option at the time, and in the interview he expressed his choice this way,

Sometimes I like choosing the groups, but other times you end up with like a, like when you end up with a group of friends you end up with people who [maybe “you”] may get

along with better but may not be as good workers (Mark, personal communication, January, 2012).

Mark saw himself falling into this category. “So, with random lottery it was kind of nice because I knew that I wouldn’t have any misconceptions about people, I guess.” At the end of the Innovation Project, Mark said that he would have chosen the lottery or random selection because he was happy with his group and they worked well together.

The students’ primary reason for not approving the student-selected groups seems to have been a worry over some students feeling ostracized by the groups. Mary thought, in retrospect, that random selection was the most appropriate selection technique because of her worries about students being cliquy and choosing only their own friends, and that this would be awkward. Mary felt that, although not everyone in her group worked hard, that this was still the right way to choose a group.

Carter initially thought that he would prefer to work with students he knew well beforehand. Carter was boarding with a family near the Ontario Science Centre, and nearby were many other students staying in similar circumstances. These students, all of whom have short commutes each day, initially considered working together. Although he acknowledged this would have worked well for him, he quickly realized that this would not work for students commuting from Brampton and Pickering, and so he voted for random selection.

Most of the research subjects agreed with Mary, however. Bernadette said, I thought it was a better idea to just randomly pick them out of a hat because they, you, can have, like if there are clumps of friends then no one’s like left out and then just kind of put into a group (Bernadette, personal communication, January, 2012).

Peter expressed this as, “If the students chose them, friends would get together and then some people would get left out if nobody mentions them.”

Carter said it this way, “I know Sarah, Taylor and Ally, and they were talking, you know, about people living close to one another and that they should work together.” Ally did not live close to this group, though Carter and Mark did. Mark actually voted for student-selection because he lived near Carter, Taylor, and Natasha. Although Mark and Carter are both part of this research, they worked in separate groups and not together.

Kirk was an outlier in the interview. He preferred to choose his groups because he likes to choose people with whom he meshes. Or, if he wants to challenge himself, he will intentionally choose people with whom he does not get along. None of the others expressed this kind of opinion. Kirk had participated in the past in the Shad Valley program that offered students a business-oriented summer program with a project similar to the Innovation Project. He was the only one to come to the Science Centre School this semester having had that experience. This may have influenced his decisions about choosing a group.

I was surprised by these data, primarily for two reasons. First, I did not realize that the students would harbour resentment toward groups assigned by teachers. The teachers admitted themselves that they like to mix students with different abilities within groups, hoping to thereby ensure learning among all of the students. However, the students in the Science School saw this as an infringement. Many of the students expressed difficulty with the idea of taking on the work of other students. For some of them, this was expressed straightforwardly as worry over a grade. They felt it was unfair that projects generally give all students the same grade, when usually one student is responsible for the majority of the work. Teacher-selected groups often end this way intentionally, as the teacher makes groups of mixed ability to improve the grade of students who

are not performing well. The OSCSS students felt this was unfair. Arthur saw himself as the guy who is always asked to pitch in and get things done when others do not do their part. Referring to grades, he added, “Well, at the end of the day, I don’t really care what the other person gets, it’s just, it’s all about, you know, what I get, you know?”

Second, I was surprised that the interviewees felt that the students in their semester had formed cliques and were not ready to select their own groups without reference to these cliques. It was fear of this outcome that had driven many students to choose random selection as the methodology of group selection. I was worried that the students would come to resent the group work because the groups were not comprised of their friends, but this did not seem to have been the outcome.

### *5.5 Are the Innovation Project Groups Complex?*

Davis and Simmt (2003) assert that a mathematics classroom or a group of mathematics teachers can be considered a complex system. They outline five attributes of complex systems and demonstrate how a purposefully-designed classroom might display each of these attributes: internal differences, redundancy, decentralized control, organized chaos, and feedback.

The Innovation Project at the OSCSS was designed intentionally for each group, which was assumed to be complex, to possess these five attributes. It was assumed also that the product of the groups could be considered emergent. The hypothesis of this research was that the product of the Innovation Project groups was emergent; however, for this to be true, the Innovation Project groups would have to be complex. In reviewing the Innovation Project groups with respect to the five attributes of complex systems, I found, to the contrary, some areas in which the groups did not exhibit complex characteristics.

The first attribute demonstrated by complex systems is internal differences within the groups. The students participating in the project come from different schools and different areas of the province. Some of the students attended Catholic schools; others are enrolled in public schools. The educational philosophy in one of those schools, Mary Ward, a Catholic high school in Toronto, was fundamentally different from the philosophy of the others. Michelle attended Mary Ward, a school that has no discrete classes. Instead, students are asked to proceed through prepared lessons at their own pace and to check in with their teachers throughout their progression. They may choose to work on any course at any time, but they are expected to demonstrate timely progress in all of their courses. This arrangement gives them the opportunity to be independent and responsible.

Given the variation relative only to this school's education philosophy, the remaining ten students who were a part of this study attended schools that had very similar educational backgrounds. These backgrounds include an emphasis on standardized testing through EQAO (Education and Quality Accountability Office of Ontario). The course syllabi, teaching methods, lab performance, and many of the evaluations throughout their school years were identical for all of the students. In fact, the success of the OSCSS is possible only when every school in Ontario is assumed to follow the same curriculum. This helps ensure that students from across the province will come to the Ontario Science Centre having had similar educational experiences.

Only one student, Kirk, through his participation in Shad Valley, had previously experienced a similar open-ended educational environment. Shad Valley is a business-oriented summer program that gives groups of students the opportunity to design a product and then consider how that product could be brought to market.

As has been stipulated, there were differences among the students in terms of gender, ethnicity, and home environment. Coupled with a variety of temperament that was obvious through the interviews, I believe there is sufficient difference within the groups to demonstrate that they meet the first attribute of complex systems, internal difference.

Redundancy, the second attribute of complex systems, is also necessary, according to Davis and Simmt (2003), so that the groups can form a sense of “we.” In other words, too much difference precludes the formation of a collective identity, and chaos tends to thwart complexity. Through the similarity of curricula and school experiences, there is redundancy within each of the Innovation Project groups. Before coming to the OSCSS, all students undertook the same Ontario Curriculum, which specifies not only objectives but also laboratory activities and standardized testing. Given that all the students would have completed the required grade 11 prerequisite courses, it may be assumed that the students’ knowledge and skills coming into the program should also be the same. This similarity of experiences makes a specialized grade 12 school possible.

By saying that the groups must be diverse and redundant in order to be complex, there was a corresponding tendency for me to look for these attributes within the group; i.e., as the researcher, I was tempted to find that for which I was looking. I did not know whether, in fact, there was sufficient difference or redundancy within the Innovation Project for a complex system to form. However, this inability to determine difference or redundancy was not the major impediment to these groups being considered complex.

The third attribute of complex systems is decentralized control. There should be no hierarchy within the groups if they are complex systems. It is this attribute that I believe the Innovation Project groups failed to demonstrate despite the design’s best intentions. It seems to

me that in order to achieve decentralized control, there had to be trust among the members of the group that every agent would perform his or her share of the work. Unfortunately, it was found that the students did not trust one another to complete their work, and that often they took on the work of other members. Hierarchies were determined almost immediately within the groups and were often encouraged by the teachers, who asked the students to define roles and report back on these roles. Finally, the teachers themselves were involved in the projects and, before analysis of the data made this clear to me, took on much more of a directing role than I had assumed they would.

For all these reasons, I do not believe that decentralized control of the groups occurred, and, without it, I am not certain that the groups could be considered truly complex. I still believed, however, that the product of the group's efforts might be emergent.

The fourth attribute of complex systems is organized chaos; this is the difference between designing the Innovation Project to be proscriptive rather than prescriptive. At the beginning of the project, the students were given an outline that discussed only the scope of the project and its overall intention: to design an exhibit for the Weston Family Innovation Centre. The students were given very few parameters and no indications of what a final product might look like. Again, however, it was believed that teacher involvement in the Innovation Project groups might detract from this organized chaos. Working with traditional classroom teachers meant that certain conventions of the traditional classroom would be maintained in the group.

It is at this point that a description of the students' relationship with their teachers is necessary. In the group meta-interview at the end of data collection, students were asked about their relationship to their teachers both inside and outside the setting of the Innovation Project groups. Their responses revealed that the students were using Facebook much more than the

Wiki as a location for communication and exchange of ideas. When asked, “Would it be OK for teachers to be in your Facebook groups?”, students gave mixed reactions; however, in general, they expressed that they felt allowing teachers access to their Facebook would result in considerably more filtering of their conversations and collaboration on Facebook. The students used Facebook socially as well as for school, and they were afraid that the social aspects of their conversations, such as jokes, videos, and other interactions unrelated to their classes or Innovation Project, would be lost.

The students also believed that referring to their teachers by first names made a difference in the relationship they forged with teachers in the school. Nevertheless, when asked about their relationship to the teachers, Kirk said, “It’s kind of intimidating; it’s kind of just like fear of judgment, I guess.” It was this intimidation and fear of judgment that I was concerned would somehow restrict the openness of the group meetings of the Innovation Project. Yet, it was clear that the teachers did not trust the students to be able to fulfill the necessary parts of the Innovation Project without the input of a staff member. For both teachers and students, then, staff involvement in Innovation Project groups created a level of control that is antithetical to complexity theory.

The other students agreed with Kirk, and Carter went even further to describe his relationship to his teachers. Carter considered the situation of a student approaching a teacher at her desk to ask a question. It is important to note that in the Science Centre, the Education Branch desks for those who are not in management are arranged in pods, with each educator being assigned to a cubicle. This pod structure is an open-office arrangement, and all educators are able to stand and see the cubicles of all other educators within the Science School and beyond. The cubicles of the four Science School teachers are located together, in a crude circle,



with an open space in the middle and the desks facing outward. Carter says, “Yeah, I found that the cubicles, actually since all four teachers are there and they all see you asking the questions, were intimidating ...” This arrangement led students to prefer asking each other questions on Facebook rather than approach the teachers outside of class. These student-to-student questions were posed on Facebook first to see if a student knew the answer before a teacher was approached. If no satisfactory answer were obtained, the best student in the class, as perceived by the class as a whole, was asked to approach the teacher for an answer. Carter was considered the best student in class and, therefore, was generally delegated to ask questions for the group. In this way, a student with a question would remain anonymous without fear of intimidation or judgment. Questions were forwarded to Carter, and teachers answered them; however, because he was considered to be the best student in the class, teachers were often surprised that he had asked. Teachers did not realize that the questions were actually coming from other students. This method used by students to remain anonymous was made clear only during the meta-interview. It revealed significant information about the students’ relationship with their teachers, and, as a result, it was clear that the teachers’ roles in the Innovation Project groups could not be simply as observers.

Clearly, the students were conscious of a significant power differential between themselves and the teachers. Yet, later in the meta-interview, the students implied that, at the very least, the OSCSS had had some success in diminishing this power difference. Use of the teachers’ first names, in particular, came up as an advantage of participating in the project, even though this took some “getting used to,” according to Bernadette. She continued, “At first, I felt, like, really disrespectful.” For those of us working in the school, this feeling of being disrespectful when referring to teachers by first names seems ironic, as we had thought that the

use of first names would make the students feel more comfortable rather than less so. Peter, however, expressed the viewpoint for which the teachers had been searching:

After the first meeting, I mean, I noticed that, like, I felt like we were all equals, instead of, like, you know, the almighty.... You felt level with them, and you could interact better, like they were more of your friends (Peter, personal communication, January, 2012).

This is precisely the engagement that we had sought by implementing this practice in the school and in the Innovation Project.

What resulted were two situations, one in which the teachers were seen as intimidating, and the other in which they appeared almost as equals, as friends, to the students. The students were able to maintain a clear distinction between these two situations. Bernadette commented, “Like, when you’re asking them questions, you feel as though there’s, like, that difference -- student to teacher, but I mean if, like, I mean yesterday at sushi, we sat inside and we were just having a normal conversation.” The students make a distinction between “normal conversation” and “classroom conversation,” as Kirk pointed out clearly, “I think there’s a distinction between when we go to them for, like, educational related stuff and just, like, general personal interaction; there’s a different orientation there.”

This means that in order to avoid having a hierarchy, the students would have to consider the Innovation Project as part of their ordinary conversation with a teacher and not as part of their educational relationship. The desire to remove the hierarchy was explicit in the attempt to eliminate grading within the project. Students were told that they would receive a perfect mark from the moment the project started, which, therefore, should have made it unnecessary for them to see the need to work toward pleasing the teachers assigned to the Innovation Project groups.

Nevertheless, the evidence from the students' engagement with the teachers demonstrates quite clearly that the students deferred to the teachers, and that the teachers expected to be deferred to throughout the project.

The fifth attribute for a group to be considered complex is feedback. Clearly, the students had opportunities to provide each other with feedback through their Facebook groups. The functioning of these groups is discussed subsequently in the chapter on data analysis.

### *5.6 Students' Roles and Contributions*

On two separate occasions, the students were interviewed individually about their contribution to the Innovation Project group in which they were engaged. In the first interview, which occurred at the outset of the project, students were asked what their usual role was within a group and to speculate on their role within the Innovation Project. After the project was complete, students were again interviewed individually, but before the meta-interview, to determine what they thought their role had been and to evaluate others in their Innovation Project group.

The students' evaluation of one another during the year of the research was a new step to the Innovation Project. It had been suggested by Judy, one of the teachers involved in this research. To conduct the peer evaluations, Judy gave each student a circle on a sheet of paper and asked the students to divide the circle into segments, where each segment was to be proportional in size to the contribution of each member of the group. Each student was asked to write a brief explanation for the segment sizes that they had assigned to each of the other members of the group. This evaluation of other team members and their contributions remained anonymous within the group.

All interviews were conducted between October 2011 and January 2012 at the Ontario Science Centre. Students were assured of anonymity, and their names have been changed to protect their identity. To facilitate narrative flow, individual references will not be made each time a personal communication entry is included. The students' names are sufficient to identify the source of the communication, and the dates for all communication occurred between the dates mentioned above

### *5.7 Group 1: Haptic Touch*

In order to examine the students' roles in the Innovation Project groups, following is a discussion of the individual members of each group. The first Innovation Project team, comprised of Arthur, Catherine, Kirk, Mark, Mary, and Rebecca, designed the "Haptic Touch" exhibit, although Rebecca chose not to be part of this research project. The teacher associated with this group was Judy.

Arthur described himself as the type of person who pitches in and gets the work done, especially when others are not getting their work done. In reference to grading, Arthur said, "Well, at the end of the day, I don't really care what the other person gets, it's just, it's all about, you know, what I get, you know?" Arthur sees it as necessary to pitch in to do work in order to make certain that the grade he receives is adequate, regardless of the grades that others receive. This might be seen as selfish, but Arthur made it clear that he did not care what others in the group received as a grade, even if they got the same mark as he. However, he also made it clear that in any situation where a group is dysfunctional, he will ensure that the work of the group is completed.

Arthur said that he only takes on the leadership role when the group is without a leader or when the other members of the group are not as competent as he is. Only in these situations did

he say he would consider himself the leader. In the first interview, Arthur had said that there was no leader within this group because he considered all of the students in the group to be equally competent.

In his interview at the end of the Innovation Project, Arthur described himself as the “design correspondent,” saying, “Basically I worked out the technical aspects of the exhibit, like what it was going to, yeah, include and what not.” He referred to Kirk as the leader of the group, calling himself (Arthur) an “employee.” He said of Kirk, “I just basically followed what he said.” This is interesting because, initially, Arthur had said he did not believe that the group had a leader, and he had suggested that a leader might not be necessary because each member of the group had come from the same background. Later, however, it appears that Arthur recognized differences in group members’ skill sets, dedication, and perseverance and accepted Kirk as a leader and himself with less power. At the first meeting, Kirk had been made the “chairman,” and, in effect, the rest of the members of the group ceded to Kirk their ability to forge the agenda. From what Arthur and other group members indicated, it appeared that Kirk actually did less actual work than other members of the group. However, Arthur, described Kirk’s participation this way: “Like, when we were practicing for the presentation, he actually called, like, each one of us to, like, rehearse our individual parts, and he was pretty engaged with that.”

Arthur believed that the group had a successful dynamic because everyone had to take on a separate task, otherwise, there would be, in his words, “mob rule.” He did acknowledge, nevertheless, that some members of the group had worked harder than others.

When it came to evaluating the effort of each of the members of the group, Arthur scored Mark and Rebecca at half what each of the other four members received. It is clear that Arthur considered Kirk’s contribution as leader to be valid and equal to that of the other hard-working

members of the group. On his circle evaluation, he had written the contributions of each of the four members he considered had done their share; he did not write a comment for Mark's or Rebecca's contribution. At no time did he credit Mark with having had the idea for Haptic Touch, the group's Innovation Project. It appeared, then, that Arthur portrayed a bias against creativity, which Mark had demonstrated in suggesting the idea for the group project, and favoritism toward traditional hard work. In his scoring of each student's effort within the group, Arthur acknowledged writing, research, and leadership as equal contributions. However, Mark's contribution of the subject matter for the Innovation Project, which demonstrates creativity, was not acknowledged as being equal in value to others' contributions.

During the first interview, Catherine, another member of the group, initially indicated that she saw no conflicts within her group. "No one really, like, everyone's really open to each other's idea so there weren't really conflicts," she suggested, adding that there was an advantage to having a large group (six is the largest group within which she has worked) because, in her opinion, this generates more ideas, helps to gain different perspectives, and provides more group support.

Later in the same interview, Catherine said she believed that the group was not working well because everyone in the group had different ideas. She noted, "We haven't really narrowed it down to, like, I guess, one type of science or, like, one type of idea that we can expand on or work on." Catherine was worried that the group was comprised of many different personalities and that this might have made it difficult for them to choose a topic for their Innovation Project.

This conflict, suggesting at one point that having more people leads to a greater diversity of ideas and later that this diversity of ideas might be a problem, is not as contradictory as it might have appeared at first. The most difficult aspect of the Innovation Project in the initial

stages was developing a single good idea. Catherine had never done anything as open-ended as this project, and she suggested that,

Once we come up with one idea, my group members tend to stick to it and not want to, I guess, expand or think of new ideas, so we get stuck in a web kind of that one idea that they just want to use because they came up with it (Catherine, personal communication, January, 2012).

This was a theme that was repeated through many of the students' interviews. Individuals expressed ideas about what they wanted to do but were unable to change their minds or convince others. Rather than trying to reach consensus, or brainstorming to find new ideas, groups simply voted on students' ideas until a single one was chosen. The student whose idea was chosen felt victorious; others were disappointed. Once an idea became the topic for the Innovation Project, as Catherine noted repeatedly, there was little new information added, and work continued toward the goal that had been determined at the beginning; there was little scope for adaptation of ideas through the process of the project.

Catherine elaborated on this theme:

... Like when me [sic] and Kirk tried to, like, push people to, like, come up with ideas, like, we were trying to come up with, like, as many ideas as possible ... but it didn't work very well. People were set on the particular ideas that they had ... Arthur liked the multitasking idea that was then axed by Judy ..., and he kept pushing for that (Catherine, personal communication, January, 2012).

Although she was a member of Kirk's group, Catherine said in her second interview, "I was the one who ended up organizing everything, just making sure everyone stayed on top of things because our group was pretty disorganized." This could be seen as a rebuke to the various

members of the group who saw themselves as leader, including Catherine herself. In particular, Catherine had been annoyed that some members of the group had not taken advantage of the Facebook page that the group organized for the exchange of information and research, “I had to stay on top of it,” Catherine said, adding that she felt as if she had taken on a greater role than other people in the group. “Sometimes, communication doesn’t work and it’s just easier if I end up doing it myself.” Leadership, in this context, is not far from Arthur’s definition of his “employee” role, just getting things done that needed doing.

Arthur saw Kirk as the leader, but Catherine did not think that Kirk was sufficiently reliable to become a good leader, and, in fact, she said she believed that Kirk would have been the leader only if she had not been present. Catherine said she believed that the project was successful and that everything went well.

When it came to scoring the members of their group, Catherine depicted the contributions of each member approximately equal, with the exceptions of Mark and Rebecca. She credited Kirk with being the “chairman,” but, clearly, she did not see him as the leader he had been described as earlier. In particular, Catherine made note of how much she believed that each member had contributed to meetings within the group. She did not feel that Rebecca had contributed significantly and made a special point of Rebecca having missed a deadline. She “didn’t email [her] proposal, her responsibility.” There was extensive discussion of this delay in the Facebook page thread.

For Catherine, the contribution to discussions and the organization of members determined their score. Catherine was aware that Mark’s idea was the one chosen, and yet there was no reflection of this in her evaluation of his contribution. Further, Rebecca’s assigned role was to take minutes of all of the meetings, as others had noted, but Catherine did not mention



this in her evaluation of Rebecca. Like Arthur, Catherine seemed to judge certain types of work as being more valuable.

Kirk had experienced this type of open-ended project before. The previous summer, he had participated in Shad Valley, a summer institute that asked students to take on the design and development of an invention of their choice. They were then asked to create a business model and a marketing plan for bringing their invention to the larger public. It was my belief that Kirk's business training at Shad Valley had generated some of the terminology present in various students' interviews. For instance, Catherine referred to Kirk as the chairman, and Arthur referred to himself as an "employee" in relation to Kirk.

Kirk's first interview was enlightening. He said that when he was younger, group work meant that he would take on the role of a follower or perform some assigned role. However, because of some of the experiences at his home school and at Shad Valley, Kirk said he felt as if he had been working on his leadership skills during the past two to three years:

I typically enjoy working with other people, but, again, I do recognize the times where, for certain tasks, it would be better to work alone for things like studying because sometimes extroversion gets in the way when studying and you get off task. I guess it would depend on how I deem, like, which way would be more respective in the situation (Kirk, personal communication, January, 2012).

At the end of the Innovation Project, Kirk acknowledged that he was the leader of the group, noting that "... otherwise we wouldn't get anywhere." He found that other members needed a push and that his own workload within the project became much more intense as time went on. Although Kirk did not believe that everyone had made an equal effort, he felt that the group had been successful and that everyone had made some kind of contribution.

In a discussion of the group's brainstorming session, Kirk brought forward a theme that was repeated throughout the interviews. Kirk said, "A lot of us did our own research, and brainstorming, and we would have meetings where we would discuss them all, and that part of it went really well, I think." Before the beginning of the Innovation Project, all 30 students had been given a lesson in brainstorming by Aylin Doyle, an employee in the design department at the Science Centre. Doyle encouraged the students to use brainstorming in the group as a way to generate ideas, and she gave them a number of approaches to accomplishing this goal. However, it is clear that the students had learned something different in the past. Kirk said that the members of his group "did their own brainstorming" and then brought their ideas back to the group. It is these ideas, the products of individual versus group brainstorming, that Catherine found so difficult because she discovered that group members were unwilling to relinquish their own idea in favour of someone else's. It was clear that once an idea was set, there was no further brainstorming. This was a significant problem for the group and for the success of the Innovation Project. The students demonstrated that they could not be creative within a group, an insight that is reflected further in the conclusions of this research.

Kirk worried a bit about procrastination, but he also saw approaching deadlines as a strong motivator. He pointed out that the success of brainstorming lay in the generation of a whole group of ideas, but he noted that the only way they could move forward with a single idea to complete the project was to wait until the deadline was approaching and then choose the best idea they had.

Kirk evaluated the members of his Innovation Project group in an idiosyncratic way. He gave himself the largest segment of the evaluation circle, but he did not mention leadership or chairmanship. Instead, he talked about working with the other group members to practice their

parts of the presentation. He assigned Catherine, Mary, and Arthur the same score, but he gave Rebecca somewhat less and Mark significantly less. He credited Rebecca with taking the minutes of meetings but did not credit Mark with having had the idea for the Innovation Project exhibit.

For the first time, Mark encountered group work with defined roles at the Science School. This happened in Martha's physics class. He was comfortable, therefore, during his first interview describing his role in the Innovation Project group. Before the project began, he saw himself as the group leader:

I try to take more leadership activities now because I'm in cadets, right, and I've been put into a position of authority, and so I'm trying to step up and do that job, and I'm thinking it's going to carry over into school as well. But other than that, no, I've never really been the leader (Mark, personal communication, January, 2012).

Mark did not believe that the students in the Science School were 30 individual leaders joined together. He posited that at the beginning of the semester, people were very unsure of one another, and that this had prevented them from taking on a leadership role within groups. Up until this project, Mark said that his experience with groups had been "iffy" because he had developed a "well-deserved" reputation for having a poor work ethic. It is possible that his group tried to help him overcome his poor work ethic by choosing his Innovation Project idea. They may have believed that this would lead to greater engagement from Mark.

In the interview conducted at the end of the project, Mark said he did not believe that he had had much of a role within the group. He described this as awkward because he did not feel as if he was contributing, while others had their own "little things" to do. He said he felt that the selection of roles had gone awry because group members did not know what the available roles

might be. In fact, group members constructed their roles as the Innovation Project moved along. Mark had the idea for a robotic arm and took on the role of liaising with the design team in the Ontario Science Centre. This led him to the discovery of Haptic Touch, the fundamental basis for the exhibit his group developed. In the end, in conversation with Mark, he described his role thus: “I hunted down a visual aid for our presentation.” However, he was also responsible for helping to build the robotic arm.

Mark did feel that his contribution was fundamental to the group simply because “I came up with the idea.” Mark thought that the students worked fairly well together as a group but that the delays they experienced had been the result of the members not being able to decide on an idea. This has been echoed by both Catherine and Kirk. Mark added, “It’s too many people. I was surprised actually how well we worked together.” Mark thought that the leaders of the group were Catherine and Arthur. When asked whether Kirk had also been a leader, Mark replied, “Yeah, Kirk was .... I just figured saying three people out of a group of six would be excessive.” In describing the group’s efforts, Mark said he felt the work was excessive.

We had meetings, like, daily; it was a nightmare, every single lunch or after school. It’s all right, we’re here, we’re arguing about what’s going into the exhibit and we’re presenting new ideas. It took up a lot of time, particularly toward crunch time (Mark, personal communication, January, 2012).

Mark’s evaluation of the other group members was curious. He gave himself and Arthur the lowest scores, with the explanation that each had completed his tasks, but that they had very few tasks assigned to them. Though he did not mention Kirk as the group leader until prompted to do so, he acknowledged in the evaluation that Kirk had taken charge of the presentation and kept the group organized. He scored Rebecca as highly as the others for having taken notes of

“*everything*” [emphasis provided by Mark], and he acknowledged Mary’s research. He made no note of Catherine or Arthur as being leaders in the group. As will be shown later in the Facebook thread data, Mark had not been an active participant in the group, and it may be that he was unaware of the contributions of other members.

In the second interview, Mary said she saw herself as the group researcher and organizer. It would seem, therefore, that everyone would have acknowledged Mary’s contribution to the research of Haptic Touch. Mary also saw herself as having kept track of everyone else, which was curious because Catherine and Kirk also viewed keeping track of others as part of their jobs; all three believed that the project could not have been completed easily without their organizational contributions. Mary viewed Rebecca as the secretary and said she thought that Catherine performed the same role – posting minutes to the Wiki and Facebook pages. Arthur and Mark were considered the design team, and Kirk was seen as the chairman. Mary did not think that she had been given sufficient work, and she did not find the project arduous.

According to Mary, the most difficult aspect of group work was getting people together for face-to-face meetings. Whereas Mark acknowledged that these meetings had been difficult and too frequent, Mary was worried that Mark had not attended a significant number of them. She acknowledged her own contribution, “I kept them on track,” echoing Catherine’s thought, “I had to stay on top of it.” Mary says that Catherine would have taken on even more of this role had Mary had not been part of the group, though she felt that Catherine was too easily stressed.

Mary pointed out that she liked working in a group where the members were responsible. When asked if the members of her Innovation Project group had been responsible, she replied, “... Some of them,” and suggested that the number of responsible members would have been

equally as high at her home school. For Mary, group work at the Science Centre School had not, therefore, created a special context.

Mary's evaluation of the group members was similar to a number of the others' evaluations. She gave Rebecca the smallest segment of the evaluation circle and Catherine and herself the largest. She thought that Mark had not done enough, had procrastinated too often, and had been late to the presentation.

### *5.8 Group 2: Driving While Distracted*

The members of the second group, Driving While Distracted, were Bernadette, Carter, Christine, Elizabeth, Michelle, and Peter. The teacher working with this group was Martha. This group's Innovation Project involved developing an exhibit in which members of the public could simulate driving an automobile while trying to talk on a phone or text a friend simultaneously.

In her first interview, Bernadette said that in a group, she is the one who comes up with ideas, pitching them to the others. She also described herself as a skeptic, often being able to spot problems before they arise. Bernadette voiced the same difficulty arising in her group as had arisen in the first group, Haptic Touch. Members of the Driving While Distracted group had also become fixated on their own ideas and were not able to objectively consider others' suggestions or ideas, feeling that theirs were the only valuable ones. Bernadette reported, "I try to be open-minded but, like, sometimes you're just biased against certain opinions or certain ideas, but I definitely feel that sometimes I'll just sit." She felt that the clashes arose within the group because, "We're all in that leadership role, so we're all like, 'Oh, but what if, we do this' – so the ideas aren't really coming together." Bernadette found that the discord within the group resulted in her becoming the worker of the group, and this role also elevated her in the minds of the other members when it came time for them to record their ideas of her contributions.

In her interview at the end of the project, Bernadette said she felt that she had had to chivvy other members of the group along, making sure that they were present for group meetings, other group activities, and so on. In the end, she was not convinced that members of the group would complete all of the work just because they were in the Science School. When students were asked about selecting groups, they indicated that it did not matter who was in the group because all of the students were hard-working. It was only after going through the Innovation Project with other students in the class that they realized they did not all share the same work ethic. To keep her group on track, Bernadette used both face-to-face reminders and social media to prompt the other group members.

Bernadette felt that becoming the liaison with the development and design team at the OSC was her main role within the Innovation Project group. She assumed this role when Aylin Doyle, who had led the brainstorming session for the Science Centre, gave her business card to Bernadette. This role as the design-team liaison, therefore, had come to Bernadette serendipitously. Teachers giving business cards to students was a new phenomenon to the students, as teachers did not generally share them with their students. Being given Doyle's business card caused Bernadette to feel she had a connection with Doyle that the other students did not share. Of course, Doyle did not realize that she was creating a special relationship with Bernadette simply by sharing a single business card.

As was the case in the first interview, Bernadette again indicated that she had seen a "fight for power" in her group, wherein it seemed that only one person's opinion mattered, and each member was convinced that he or she was completely right. She commented, "They would sometimes trump other people's suggestions or just like, you know, like if we were brainstorming for something, or people throwing out ideas, it would just be, like, immediately

not a factor.” Bernadette said she did not herself vie for power; instead, she said she just wanted to make the presentation as successful as possible.

When it came to scoring the members of her group by dividing their contributions into segments on a circle, Bernadette gave everyone an approximately equal share, except for Peter, whom she gave somewhat less, noting that his attendance at meetings had been sporadic. She also noted as important that Michelle had had the original idea for this project but had remained considerate of others’ ideas. Bernadette, unlike members of the Haptic Touch group, was able to see creativity in idea-generation as a genuine contribution and as a real effort on Michelle’s behalf. The students in Haptic Touch had not seen Mark’s contribution of the central idea in their group the same way as Bernadette had perceived Michelle’s contribution within hers.

During his first interview, Carter said that he thought his group had been successful until the point of generating the idea for the project. He was disappointed that his idea had not been chosen for the group’s Innovation Project, but he said he was willing to work to make the project successful. He thought the idea chosen by the group was insufficiently inventive. Carter usually liked being the leader in groups, and he worried that all other members of the group were also used to being the leaders in group-work situations. Nevertheless, he was looking forward to the Innovation Project because he believed that working in groups would result in more work getting accomplished. His role, as he outlined it in the first interview just as the project was starting, was to keep people on task.

Later in the same interview, Carter said, “I’ve never craved group work; I always like to work on my own, and I never tended towards group work.” However, in this context, he was able to convince himself and others that group work in the Innovation Project was going to lead to efficiencies. Carter did not think that Doyle’s brainstorming session had been particularly



useful, and his group selected a different technique, making a mind map, which had not been covered in Doyle's session. However, for all the talk of brainstorming, the individuals within the group came up with ideas independently, and it was these ideas that were debated and, ultimately, from which one idea was chosen. This process mirrored the one followed by the Haptic Touch group exactly.

In the interview at the end of the project, Carter said he felt that his role had been being in charge of the written material and being responsible for time management. He kept track of the various deadlines along the way. He was also in charge of the Wiki, with the help of Christine and Bernadette. They tended to just copy and paste to the Wiki, probably from Facebook. I was not aware until after data collection how important Facebook had been as a communication tool. "There were a couple of really strong leaders in the group, like Michelle," Carter said, which meant that he had not seen his being in charge of time management or the written material as a leadership role. Carter believed that if he had not been a part of the group, everything would still have been completed. Although he saw himself as a perfectionist, he did not believe that the final product was different as a result of his participation. "I said that we had to stick with one idea," he said, although people were "constantly" suggesting other ideas.

In the second interview, Carter pointed out that one group member had been inconsistent in his work and that the others had to make up for the slack, although he acknowledged that this was a common outcome of group work. He said, "You know, it was nothing. But I mean it was still kind of a little irritating."

The student that Carter referred to as having been inconsistent was Peter. However, when it came time for Carter's evaluation of each member's contribution, he actually credited Peter with a contribution almost equal to those of the others. He cited a number of shortfalls in Peter's

work -- “late for presentations, missed meetings” -- but then added, “Note, these are just major criticisms for his work through the process. I was *really impressed* [emphasis is Carter’s] with him for the presentation; he came through.” This evaluation demonstrates Carter’s understanding that different group members might have very different kinds of contributions that are still vital to the group as a whole.

Christine said she likes working in groups because, as she stated during her first interview, it inspires her to generate more ideas to discuss with others. “Like, sometimes I would have to take on, like, the leader role if the other people in the group are, like, I guess, more passive in a way,” she said. This indicated that in Christine’s mind, the difference between a leader and other group members is the level of their activity, or their ability to direct the activity. When asked what the role of the leader is, Christine stated, “Making sure that everyone’s on task and, I guess, organizing everything together.” This was a fascinating discovery because in both groups, Haptic Touch and Driving While Distracted, it was clear that others made a distinction between leading and organizing more generally. Members of Haptic Touch had seen themselves as organizing but had seen Kirk as the leader. Here, Christine clearly saw the organizing function as that of the leader.

In Driving While Distracted, Christine said that, “I’m more of the, I don’t know, the follower because there are some really strong people in the group.” She had initially thought she might become the recorder in this group or hold a similar role. She viewed herself as the chameleon of group work, able to take on any role that was necessary. In actuality, Christine did not always prefer group work, and sometimes she avoided it. However, for the Innovation Project, she thought that group work had been the correct approach because, fundamentally, she

saw the project as a creative one and felt that creativity required input from many different people.

By the time of the first interview, Christine had seen no conflicts in her group: “No, no one really, like, everyone’s really open to each other’s idea, so there weren’t really conflicts.” She thought that the large group size was an advantage because, in her opinion, more people would help the group gain different perspectives and gain more group support. Although Christine had several examples of brainstorming from Doyle’s presentation that she thought might work, the group had not yet used them because what they were doing was considered to be more “verbal.” Working with their teacher, Martha, they tried to evaluate their ideas based on the four skills of innovation that had been presented to them at the beginning of the project.

Christine believed that the project had gone well and that everybody had completed his or her part. In the second interview, Christine expressed that she had seen her role as being in charge of the presentation, and she asked if that was, in fact, a role. “It was like a slideshow presentation,” she said. In fact, Christine had made a complex movie that featured a visitor engaging with her exhibit, *Driving While Distracted*. This exhibit had given the visitor the opportunity to imagine herself driving in a number of tricky scenarios and then trying to text or telephone simultaneously. Christine also collated the information provided by other members of the group.

It is noted that Christine had not had the original idea. Everyone in the group commented at one time or another that the idea was Michelle’s, but Christine remembered that there was a vote,

. . . sort of. Well, it’s because, like, in the end everyone, like, agreed on it, so it was more like a consensus than a vote. So, like, we basically had, like, a

discussion or discussions until we could agree on one idea (Christine, personal communication, January, 2012).

This was the first mention of consensus in any of the groups. Up until this point, all the interviews had indicated that there was some acrimony in idea-generation and selection. It was clear that not every member of Driving While Distracted had viewed the process of idea-generation in the same manner. Christine expressed it this way:

Well, I learned that I like to sit down and have discussions, but the truth is, yeah, before, when I worked in other groups, we usually, usually, it's we split up the parts and then each person, like, goes home and does their own part, and then we meet, like, once or twice to put everything together. But, like, this time there was a lot more discussions, like, I guess that was new to me (Christine, personal communication, January, 2012).

When evaluating the group member's contributions, Christine indicated that every member had done his or her share of the work. Further, she was able to articulate what each member had done, and she designated research and recording functions as contributions worthy of mention. Interestingly, Christine did not designate anyone as the leader of the group, though in her division of labour, she mentioned that Carter had kept the group "on task."

In some ways, Elizabeth was different from some of the other students at the OSCSS. For example, she was the only student who initially said that she was not interested in having one of the smartphones provided by *Telus*, but she took the phone anyway. She said at the initial interview,

I just, like, use screens enough in my life, like, I'm on the computer a lot at home, so, like, I don't know. I find that you get really hooked and, like, it can be more of

a distraction than an asset for me (Elizabeth, personal communication, January, 2012).

This lack of interest in the computer world, at least at school, was very different from that shared by Elizabeth's fellow students.

Elizabeth was sometimes the leader and sometimes "more supportive" in situations in which there was a natural leader. Clearly, Elizabeth made a distinction between someone who leads and someone who supports; for Elizabeth, leading was from the front. Because at the OSCSS, "everyone is strong," Elizabeth felt that she might not become the leader in this group, which she thought would be good. "It definitely helps because everyone's really enthusiastic, and you can just kind of . . . , they're more, like, dynamic to work with . . . and stuff." Elizabeth was of the opinion that she could rely on people in this group more than she might have otherwise.

The situation had been different at Elizabeth's home school, an all-girls Roman Catholic school in the Toronto Catholic District School Board. "Well, mostly, like, at my home school . . . and stuff, just like when other people don't care as much, you just kind of, like, do it." What this meant was that at her home school, Elizabeth typically did the work of group members who were not fulfilling their roles. "Yeah, like, I don't like to do people's work for them, like, I just like to be, like, 'You do this, you do this a little bit,' yeah." Knowing this, it was obvious that Elizabeth was comfortable in the role of delegator. Here, Elizabeth pointed out that some tasks were actually better done alone than in groups, especially those tasks that required computers. As one computer could not be used simultaneously by two students, Elizabeth felt that computer tasks should not have been assigned in group work. However, as was evident in subsequent activities, Elizabeth was a participant in social media conversations among students.

At the time of her first interview, Elizabeth believed that the project was going well; however, she recognized that there were three different project ideas “in the air.” While Christine believed that the decision to pursue Driving While Distracted had been a consensus decision, Elizabeth noted that reaching consensus had taken some time. She said of these ideas, “I think the people who came up with the three different ones are kind of leaning towards their own. But, like, a lot of people are really kind of supportive of all three and impartial, which is nice. Yeah.” Of the three ideas proposed, one is Elizabeth’s; however, hers was not the one chosen as the project moved forward, a decision about which she later expressed some disappointment.

In her second interview, at the end of the project, Elizabeth saw her role in the group as helping to develop the idea: “I helped to give it more dimension.” She generally helped every member of the team and worked collaboratively. Elizabeth believed that if she had not been a member of the group, “Maybe we just wouldn’t have had as strong an idea of what our exhibit would look like and how the simulations would be.” Group meetings were always conducted in person, but Elizabeth, who initially expressed some reluctance to using computers, outlined that part of her learning occurred when using Google Docs with Christine. This observation is important for two reasons. First, Elizabeth demonstrated the same facility as her classmates with learning a new program on the computer in a very short period of time, though her attitude toward computers was significantly different. Second, Elizabeth had stressed in her first interview that she thought computer-based applications lent themselves to individual rather than group work. However, since Google Docs is an application specifically designed for both synchronous and asynchronous group work on a single product, it appears that working with this application may have changed Elizabeth’s mind. She says of Google Docs, “It’s pretty intuitive; like, she (Christine) just told me what link to go on, and I figured the rest out.”

Elizabeth thought that the group dynamic had been successful when she evaluated the outcome based on three criteria: they worked well together, they got everything done, and they felt good about it. Elizabeth said in the interview that she had thought everyone in the group would have commented that everyone contributed equally to the project. She particularly liked the opportunity to get to know people outside the classroom and to talk about topics that were separate from schoolwork.

When it came to evaluating the contribution of the other group members, Elizabeth indeed believed that everyone had contributed equally to the project. She was one of the few students whose evaluation submitted to the teachers matched what they had said during interviews. It became obvious that the students had been careful about what they communicated during interviews, not wishing to say anything negative about other students that they might have, alternatively, been willing to express in documentation that they did not know beforehand was going to be part of the research. This phenomenon is explored further in the Facebook data analysis.

Michelle is another student whose experience before coming to the OSCSS was different. She attended Mary Ward, a school in the TCDSB that does not have traditional classes. It is based on a philosophy of self-directed learning, and students move through the curriculum, each at his or her own pace, completing units within courses and performing tasks when they believe they can demonstrate mastery.

Michelle was not, therefore, as familiar with group work as other students attending the Science School. However, for the Innovation Project, she believed that group work was indeed the correct approach because of the sheer scope of the project; otherwise, she felt it might have proven overwhelming. Group work allowed for more and different ideas and for more support.

Michelle thought that the group dynamic had been successful up until the point of the first interview. In particular, she had been very focused on making sure that her idea was chosen by the group to move forward, and she had hoped that her group's teacher supervisor would also choose her idea. The interview was conducted the same day that Elizabeth's idea had been rejected, and the group was now left with two, Michelle's and Peter's. It is important to note that the students had expected the teacher, Martha, to choose the idea for the Project. Michelle described the group as follows:

Yes, we have a good group. We work together, we organize meeting times really well, but we have two main really good ideas, and then we're trying to decide. But, I don't know, I think I like to talk and get my ideas across, and I know it's, like, Christine, like, she listens. You can tell she's, like, really debating in her mind, and Elizabeth, too, is, like, really listening, but I think I like to talk, and I like to go away from it, come up with my ideas, and then bring them to the table at the meeting. That's how I like to work in a group (Michelle, personal communication, January, 2012).

Clearly, Michelle had thought about her response to the question about her role in the group. She was the last one interviewed, and the students had been discussing interview questions among themselves. She did not state whether she is a leader or follower, but, instead, she couched her role in terms of listening and talking. It was clear that she admired those who sit and listen and think about issues, but, at the same time, she acknowledged that she is a talker. It was also clear at this point that she had been hoping that her talking would convince the group to accept her idea.



Michelle described this individual idea-generation process and subsequent selection of the group's idea for the Innovation Project as brainstorming. This meant that the group had not generated ideas together. In her second interview, Michelle said, "I came up with the idea, and then it was that kind of like I really wanted it, like, a specific way. But then people started giving input and I kind of stepped back." It was clear that the generation of the idea, and the desire that it be her idea, were very important to Michelle. When asked her role within the group, Michelle says, "I kind of would regulate a lot of the meetings; like, on Facebook, I would be, 'OK, this is when we have our meeting' and then updating." This shows that Michelle was another leader among many in the group, even though, for her, group work was fairly new, having come from Mary Ward, whose focus was on self-directed learning. Michelle said she believed that there were people in her group who did not get along very well and that she had acted as moderator. "I was good at giving roles, that kind of thing," she said.

Michelle had thought that the group dynamic was successful; however, she said, "Peter was all over the place, but it was, like, good because it was, like, funny." Interestingly, Michelle was the only one who talked considerably in her interview about the other members of the group; no one else in the group mentioned Michelle at all when asked about the group dynamic. This may mean that Michelle was correct in her assessment of herself as a talker, but also that the others had not been listening, just as she had perceived. After contributing the initial idea for Driving While Distracted, Michelle felt that a large part of her contribution was complete. It has been made clear that the students in the Haptic Touch group did not consider idea-generation to have been a significant contribution to the work. This may also have been true for Driving While Distracted.

When it came to evaluating the members of her group and the size of their contributions to the Innovation Project, Michelle gave Christine a slightly larger portion but gave everyone else an equal size. This was because, as she described it, “Everyone did a great job.” It appears that Michelle, like all of the students during interviews, was careful never to say anything negative. Comments that showed how students really felt about others’ contributions would have to occur in more anonymous settings.

Peter’s assessment of brainstorming was similar to that of other members of the group. Everybody had their own ideas, and then the group selected from among the ideas presented. “We all just decided.” Peter saw his role in the group this way: “I sort of take on projects and then organize everything and then put my thoughts in and sort of adhere the group, but here, everybody’s sort of leading the group.” Peter noted that before he came to the Science School, he had been the student leading the group and the one assigning the work to others. “Here, everybody is great, so I don’t think it really matters; everybody is kick-ass and ready to do work.” However, the roles actually undertaken within the group would, in fact, depend on whose idea was eventually selected. Once an idea had been selected, that person would become the leader. By the time of this interview, the group had not yet chosen an idea.

“Each person has something they’re good at,” Peter expressed, while claiming that his own talents were in computers and 3-D design. He also articulated his strong belief in the division of labour within the group, an idea that probably created some conflict, since some students were keen to share work and others were more interested in dividing the work. It has been demonstrated in the group evaluations that these tendencies could potentially lead to tension within the group meetings.

Peter did not believe that the group had undertaken any brainstorming; instead, all six members of the group had presented their own ideas, and the final idea was selected from among these. Peter was initially very excited about the smartphones being incorporated within the project, but even at this early stage, he had realized that they were going to be an afterthought and not really well incorporated.

In his second interview, Peter expressed disappointment that his idea had not been chosen for the Innovation Project. Nevertheless, he thought that everyone had worked well together, as he describes here:

We sort of decided and made people, like, leaders of certain tasks, and they would ... people would be put in charge of various aspects; however, I was in charge of the visual model and SketchUP, and the smartphone application (Peter, personal communication, January, 2012).

When asked what the group would have been like without him, Peter said,

Like, even if we were one person short, I think we would have gone, like, haywire. Everybody sort of was together, and everybody's ideas were really important, and we sort of incorporated all of them into one, which made it what it was (Peter, personal communication, January, 2012).

However, during his interview, Peter had expressed worry that the other members of the group may not have thought his contribution was significant because, in his words, "it looked like they did more work." Also, Peter was certain that there had been no fighting within the group, not even once. People were respectful of ideas, and he added that of the approximately 20 meetings, he might have missed two.

Despite his suggestion during the first interview that he believed strongly in a division of labour, Peter felt that this was the first project that he worked on where there had been no division of labour. “Everyone worked on every part of the project.” This is very different from the circumstances described by others, though in answer to another question Peter said, “We divided that up too, so everything was divided up.” While it is difficult to resolve this contradiction, there are a number of possible explanations. First, this second interview occurred after the project had been completed; it is possible that Peter might have been remembering events differently than they had occurred or conflating separate meetings. Through Michelle’s interview, it became clear that students had discussed among themselves some of the questions I had been asking. It may also be that Peter believed that as researcher I wanted to hear that there was no division of labour. I was careful not to discuss with the students either complexity theory or the rationale behind the research for fear that they would try to provide answers to confirm my thesis.

In his evaluation of the members of his group, Peter gave everyone an equal share of the pie and commented that everybody had worked on every aspect of the Innovation Project.

### *5.9 Teacher Engagement with Project Groups*

#### *5.9.1 Judy*

Judy is a seconded teacher from the Toronto District School Board, where she taught chemistry, as she did within the OSCSS. She is the teacher associated with the Haptic Touch Group. A video and transcript of a meeting between Judy and the Haptic Touch group were analyzed, as I was not present at the meeting.

Judy had tried to get the group organized at the beginning of the meeting so the camera could see everyone. Judy is the kind of teacher who jokes with the students, though the jokes

always have an undertone of truth. For example, she said, “Can I see Catherine? Yes. Kirk, make sure, yeah, cozy on up. It’s going to be ... Yeah, there we go, pretend you like each other.” Judy then talked to them about their behaviour on the escalator and reminded them that this meeting is being recorded. Arthur said, “I wasn’t leaning, I was just standing.” Catherine responded, “He just doesn’t know how to stand,” to which Judy replied, “It’s a hard skill for Arthur,” referring to his standing on an escalator. Many teachers, I’m afraid, myself included, use this kind of sarcasm to pretend that we are close to the students and to control their ability to chat in class. This behavior on the part of teachers can be intimidating for students and may have changed the dynamic in the group.

Judy continued her efforts to begin the meeting by asking, “All right, who’s your meeting chair?” This is critical to note because in the other group, Driving While Distracted, it would not have been made clear that there was such a position. Further, by asking who in the group was fulfilling a certain position at a certain time, Judy both exerted control and prevented complexity by preventing fluid roles from forming. In this group, it would seem that the “meeting chair” would be a rotating position, or Judy would not have had to ask. However, there was some dispute between Kirk and Arthur, and with support from Catherine and Mark, Kirk is made chair. Arthur asked of Judy, “So, what’s your role in this again?” Judy replied, “Just as always. I’m your mentor, right?”

Judy’s next comment is fascinating, “So, just do anything. So, first of all, do we have some sort of an agenda? So, how about you start by giving me a progress report on where we are so far?” It is clear that although Judy has asked who the meeting chair is to be, she is actually fulfilling the role herself. Further, it is clear that she felt that it was her role to keep the group on track and working appropriately on the material that they were covering.

Kirk then took on the role of chair and reported the group's progress. Progress meant the extent to which the group was working toward the details of the project; at this point, they have chosen the idea. The agenda for the meeting, as Kirk outlined it, is, "So, for today, we're basically, we wanted to solidify a good name for the exhibit. We wanted to get an idea of what each person is going to write for their section and then we will go from there."

Mary interrupted in a way people often do and said, "I did my written part; I put it on the Wiki and on the Google Doc thing." In other words, it did not seem to matter what other members of the group had or had not done; she had completed her portion of the project.

Catherine outlined the introduction, and Arthur asked whether they were going to discuss the name. They continued to focus on the written report. Mary then read the paragraph that she had prepared for the written report. Arthur and Mark stated that they were working on the design aspect and, as a result, they had nothing written as yet. Their plan was for their Haptic Touch exhibit to have a robotic arm to test the visitors' dexterity with this kind of manipulation.

Concerning their design, Mark commented,

One thing we're still trying to do is iron out a choice of how they want the arms set up. I'm in favour of more, of like a system where the arm's actually on, like, a rail so they can slide side-to-side and have more mobility (Mark, personal communication, January, 2012).

Arthur responded, "And I'm more in favour of the arms being mounted like on a fixed station."

This conversation is crucial, as it shows a real difference in what the students consider as work. Many of the students, including Mark himself, complained that he was lazy and did not complete his share of the work. Nevertheless, it was clear that he had been thinking about the problem and was engaged with the project. To some, maybe especially Mary, work was defined

as the written performance and not the thought that went into developing an exhibit. It is significant to remember that in this case, it was Mark's original idea that was chosen by this group. In this meeting, it is obvious that Mark was engaged and that he contributed. However, in the evaluation of students' contributions, Mark and the other members of his group tended to suggest that Mark performed less work than others, which appears to reflect their judgment on the type of work Mark had done.

In order to resolve the choice between Arthur's and Mark's ideas, Judy suggested that they have a competition and vote within the group after Arthur and Mark had fleshed out their ideas further. They decide that if the group could not make a decision, a class poll would be taken using the Wiki. In particular, Judy pointed out that this was what the Wiki had been designed for – to provide access to others to be able to work together on a collaborative project. Mark and Arthur agreed to work on the pros and cons of each of their ideas for the next meeting.

There was a fair amount of group discussion on the building of a prototype of the robotic arm. There was no discussion however, of using this prototype on the floor to determine how the public would engage with it. Nevertheless, the group was keen to have a tangible demonstration ready for presentation to the design team. The students in the Science School conducted a number of school programs during their tenure. One such opportunity included a 45-minute program called "Inventor's Challenge: Build a Machine" (ICB), in which the students had to build a hydraulic arm. It was Judy who got them to see that this activity might engage visitors successfully. "So you can see that it does engage people," Judy remarked. This was similar to the Haptic Touch exhibit they were designing.

It was clear that, given the length of the ICB program, Judy was proposing a very simple prototype. However, when Arthur said that this type of prototype would work, Mark interrupted

and said, “I think I have the materials at home to build a fairly accurate example of an arm. I’m not sure how well I could get the controls to work out, but I’m pretty sure I can make something.” As it turned out, their prototype was a robotic arm toy that they had borrowed from the design department. Clearly, Mark was engaged during this meeting, so it is not clear when he became disengaged in the process, only that by the end, he was, in fact, disengaged.

Judy then went back to the simple idea proposed earlier, thus defying Mark’s interruption and demonstrating the plan for the entire group:

So, I mean, what do they build in Inventor’s Challenge? It’s just syringes, which we have around here that you could probably borrow, and some pieces of wood or whatever, instead of doing a hand that could pick up stuff for that one; the one in Inventor’s Challenge uses a magnet. So, it doesn’t have to be the electromagnet; you could just attach a permanent magnet, and then your materials could have a magnet, like a piece of metal or something, like, that’s magnetic. So, then there’s that challenge too, that they sort of have to manipulate them to pick them up. Just an idea, you don’t have to take it, but, again, then your presentation could be, you know, a brief intro and then you could call on people to do the challenge (Judy, personal communication, January, 2012).

For all her good intentions, I think that Judy was being disingenuous. She said that the students did not have to accept her idea, but, of course, they did. Arthur and Mark agreed to conduct the project the way Judy had suggested. In the end, as stated previously, whether due to time or energy, they adopted a much simpler model than even Judy’s suggestion. It was clear, however, that Judy believed that there was a right way, and that it was hers. If they knew this, it



could have stifled the students' creativity. This is the danger of having a teacher associated with the project.

When asked about the final presentation, Judy said, "We will be there to evaluate you in the process ... though you're pitching your idea to design a visitor experience, a department at the Ontario Science Centre." However, in reality the teachers were not going to evaluate the students at this stage, or ever, because, it was decided when the project was created that grades had to be removed in order to get the students to take real risks. Risk-taking is very difficult when grades are at stake. It appears that Judy was demonstrating that, at least for her, grades were the only incentive for hard work. Although Judy also believed that extrinsic motivation is important, she could not stop herself from communicating this threat of grades to the students.

Judy continued in this vein of assigning grades to students' work, "Here's the thing guys, we aren't going to, you know, evaluate; it's the process we're evaluating." This presented a real mixed message for the students, though they were quick to agree with Judy's description of the evaluation. Judy proceeded, "Your exhibit idea as well can be off the wall; it can be outside the box, take a risk." But, as noted previously, it would have been difficult for the students to take a risk if they felt they were being evaluated. Further, although Judy believed that the students' exhibit idea could be "outside the box," she had, in fact, already outlined for them an exhibit as she thought it should be.

To get the meeting back on track, Catherine asked if anyone else, after Mary, would like to read their contributions. Nobody else had written one, though Kirk tried to dismiss this, "Sure. What I'm looking into is how the brain, basically how a person learns." This off-handed comment was intended to deflect attention from his lack of preparation. Mary reminded everyone that their written presentation would be due on Monday. Judy reminded them to get everything in

on time because this is a group project and that they should be relying on one another. However, because Judy is present, they revert to the kinds of questions that the Innovation Project had been designed to avoid. For example, Arthur asked, “Like, how thorough does it have to be?” and Mark followed with, “How long is it approximately?” These questions were being asked despite the fact that the students did not have to prepare a written report at all; that was Judy’s interpretation of the requirements of the project. Again, it is clear that Judy, rather than the students, was in control of the project.

Judy went on to say, as Martha did later, that the project had to have a basis in science, since it was to be for the Ontario Science Centre. A new demand had been imposed this semester requiring every group to conduct scientific research into the area of their exhibit idea. So, when Arthur suggested that they provide their Google SketchUp as their progress report, Judy responded, “No, we don’t want your Google SketchUps.” This kind of reaction from the teacher potentially stifles the students’ creativity and their willingness to take a risk by presenting their project in a different way.

Judy’s subsequent comment made the likelihood of diminishing creativity and risk-taking even more explicit. “Here’s where you guys have to think about, you know, doing what’s asked for, because sometimes when you go over, you add stress. It’s not needed.” In other words, Judy suggested that the group perform in the manner the teachers expected, and that by doing so, they would experience less stress because they would know they had done it correctly. However, the Innovation Project was not meant to have a correct approach. Each time the members of the group, Catherine, Arthur and Mark, suggested alternatives, such as pictures, models, and the Google SketchUP, Judy retorted with the idea of a written report being less stressful, more of what is expected.

I was fascinated by these exchanges between Judy and the Haptic Touch group. I had previously outlined that fundamental to the Innovation Project was creating a proscriptive environment where students were encouraged to be creative and take risks. Upon hearing Judy's directions to her group, I realized that the students involved in Haptic Touch were not going to have the independence needed to truly experience creativity or risk-taking. The project subject matter and the manner of presentation were being decided for them, and the students were reverting to the formal teacher-student relationship of the classroom.

I had not considered in advance that I should have allowed opportunities for the Innovation Project groups to evaluate their teachers and their teachers' mentoring skills. During interviews, the students all seemed happy to be working with Judy, whom they liked and admired. I believed that some students found it an advantage to be given detailed instructions, as it made it easier for them to come to resolutions of problematic situations. It did, however, lead me to question yet again whether the Innovation Project groups could truly be considered complex. Clearly, extensive teacher training would be required in future semesters.

The group went on to discuss how the actual exhibit should look. As they tried to work out what the best method was, Kirk asked, "So, is there an alternate; do we have an option B?" This sounded like an opportunity to brainstorm a bit, particularly since it seemed that not everyone was happy with the arrangements thus far. However, Judy again intervened by saying, "Right now, you need to choose your idea and just go ... it's not time to do; we have five or six options." This implied that the exhibit could no longer evolve once the progress report had been presented to the staff.

As a final part of the meeting, Arthur suggested that they determine the name of the project, "OK, so I was just thinking of naming it The Challenge Dome." Immediately, Mark said,

“No. No, we’ve done this 100 times, Arthur. We are not calling it that.” However, when asked for the names he preferred, Mark could not remember them and began to wonder where his list was, asking Catherine if she had it. Judy then asked Mary if she had a name, to which Mary said, “No, I am just kind of skeptical because that’s my job.” Mary seemed to have shirked away from being creative throughout the process. She completed the scientific research into Haptic Touch, and she wrote her piece for the progress report, but after that, she was not interested in engaging with other parts of the project.

In the Ontario Science Centre is an enclosed area for educational and public programs called The Challenge Zone. The students’ confusion between “Dome” and “Zone” led to the following exchange:

Kirk: I have a problem with the idea as it sounds a lot like The Challenge Zone.

Arthur: No, but that’s what I was trying to get at is the ...

Mark: Yeah, but we don’t want that.

Judy: The Challenge Zone, many different challenges happen in the Challenge Zone.

Arthur. Yeah.

Judy: Your dome has one specific thing that they’re doing, right?

Arthur: Actually, there are going to be two; there can be, like, a freestyle option and there can be, like, ...

Judy: All right, so I’m going to give you all a task.

Arthur: OK.

You can almost hear the resignation in Arthur’s last “OK.” First, Mark has cut him off to say that they do not want to choose the name that Arthur has suggested. Then, Judy made it clear that she was not in favour, and, further, that she was going to give them a task. She continued,

“So you are all to, every single one of you, regardless of your title, your position, you are to come up with two possible names and post them on a page on the Wiki that says ‘Names’.” Judy took complete control, determining how the students were going to choose a name and usurping the students’ ability to decide their own roles and responsibilities within the group.

Judy ended the meeting with, “Meeting adjourned,” even though she had asked at the beginning of the meeting who was going to be the chair of the meeting.

### *5.9.2 Martha*

Martha is a seconded teacher from the Toronto Catholic District School Board. She is qualified to teach biology, physics, and music. When she came to the Ontario Science Centre, she was near retirement; currently she was a department head, a position she had held for over 20 years. Martha is the teacher associated with the Driving While Distracted group.

When the group session was recorded, it was clear from the beginning that Carter was the leader. He was the first to respond to questions from Martha, and he took control by asking the first question: “Is someone taking notes?” Carter himself was not expecting to do so. Elizabeth agreed to take the notes, and Carter took charge, saying, “Yeah, so we assigned, everybody got a paragraph” of the written report. He then outlined these assignments as follows:

So, Michelle is doing the introduction, I’m doing the science behind the exhibit, Christine and Elizabeth are doing the walkthrough of the exhibit, so from, like, the time you approach it to the time you get out, and then Peter’s doing the smartphone application, how it’s involved and used (Carter, personal communication, January, 2012).

Martha then asked who was in charge of putting the written report together, and Carter responded that he and Bernadette would. Martha mentioned timelines and tried to galvanize the

group into action. It was clear that Martha was trying to act as the motivator of the group without, at this point, stepping in to give the group a specific direction.

Carter outlined his position even further. “I was pushing everybody to do .... But I mean I might have already done mine, so ...” In other words, Carter was conscious of having completed the section that he had assigned to himself, the science behind the exhibit, and he was also aware of the need to push the others to complete their sections responsibly.

The students in Martha’s group, Driving While Distracted, had developed a proposal to build a prototype of their exhibit on the floor. This was an option that they could have pursued. However, they had some trepidation, which was expressed clearly by the manner in which they introduced the subject. Martha asked if they had made progress on a letter to the OSC design team whose permission was necessary to display the prototype in public. Carter responded by saying, “We were hoping to actually talk to you about it during this meeting. We weren’t sure if we should still go through with it.” Martha asked them to outline the purpose again for her. She considered her function as the teacher to remind the students to defend the decisions they had made so that they could continue to make them as a group. However, Martha often seemed to go further and give even more than advice, actually changing the intention of the group. When she established that the prototype might be fundamentally different from the exhibit that the group was designing, Martha instructed, “OK, so if you’re testing your exhibit in a prototype, it should be very similar to what the exhibit is so that you can get the kind of things out of it that you’re suggesting.” Eventually Martha led them to a decision not to create a prototype, for fear that they were not sufficiently organized and would not have time to create it and implement it before the final presentation.

Again, here is an example of a teacher controlling a group and preventing the group from coalescing in a complex fashion. The students, under Martha's guidance, were afraid to take a risk and approach the design team about placing a prototype of their exhibit on the floor. By explaining the purpose of a prototype, Martha had taken away their opportunity to try something and fail. This failure and its iteration until success, this perseverance, are fundamental to the innovation process and to the Innovation Project groups. By removing the opportunity for risk and failure, Martha had undermined the purpose of the Innovation Project.

The actual exhibit, as it had been described in the meeting, was the development of a driving challenge. The students wanted visitors to the Science Centre to enter a simulation of a car and drive to a supermarket following a route with which they were unfamiliar. At the same time, the driver would be receiving text messages. The idea of the exhibit was to familiarize visitors with the idea of distraction.

The group initially had three scenarios (driving, completing homework, and being in the car with friends) in which they wanted to examine the concept of distraction. However, Martha steered them toward using only one scenario. It was Bernadette who said, "I think we decided just to focus more on driving instead of, like, having one really good one and having like three pretty OK ones" (meaning three different scenarios). It was not until the seven-minute mark of the video of this meeting that Christine added her comment, which was to describe how the simulation of driving might work. It was Christine who later went on to actually film the scenario that they presented to the design and development team. Christine was a quiet member of the group who got her share of the work done.

Martha later introduced the idea that the exhibit would require some kind of scoring so that people could understand their level of distraction and how they compared to others. She

asked, “OK, so how are you going to identify how successful they were?” Elizabeth suggested that they had already thought of this, and that there would be pop-up tests with text on the screen along the way. In effect, while simulating driving, the distraction would be actual quizzes against which the visitor could compare his or her own score with those of others. This was interesting because there had been no prior discussion about what would constitute a good score. Would a good score indicate that someone was able to control the car despite distractions such as texts or music, or might such scoring send a confusing message? Or, would a good score represent someone who chose to pull over to deal with the text messages or someone who simply ignored the text messages until it was safe to read and respond? Many exhibits that the students designed involve scoring because they were aware that people would want to compare their own success with other visitors and because scoring would also engage those participating in the exhibit. However, there does not seem to have been a clear definition and discussion about what success might look like with this exhibit.

Martha, as the physics teacher, began talking to the students about making a comparison between driving the simulation course with and without distractions. She went as far as to say, “Because you know in an experiment, you need to have a control.” Her observation is a crucial one, as nowhere in the design of the Innovation Project or the resulting exhibit had there been a suggestion that the exhibit needed to be an experiment or that the data collected had to follow the scientific method. Many exhibits within the Science Centre do not follow correct experimental protocols. By introducing the concept of a control in the “experiment” rather than the exhibit, Martha had fundamentally changed the way the students thought about the Innovation Project. From the outset, the students had been instructed to develop and design their own exhibit, with as few parameters as possible placed on how this would work. Martha had created parameters for



them, turning the design of the exhibit into the design of an experiment. This prevented the students from exercising their full creativity and gave them a skewed view of what an exhibit in a science centre could be.

Martha articulated the need for a control this way: “Otherwise you have no way of saying a person ...” and her sentence is finished by Bernadette, “drives better or worse without it.” Bernadette was not thinking about the exhibit in a new way. Previously, the students’ design had asked people to consider whether they felt distracted by the text messages in the simulation; however, now they were actually part of an experiment in which data were being collected to see if the drivers were distracted.

This idea of the general public contributing to scientific research has been given the name Citizen Science. The students began, with Martha’s prodding, to consider their exhibit an example of Citizen Science. Carter said,

Or, like, let’s say they’d have to, like, for the results to be submitted, they have to go to the whole, they have to go for, like, a certain length and then click, like, “Do you want to submit this?” (Carter, personal communication, January, 2012).

In other words, visitors would be asked if they would like their score to be collected as data and submitted to become part of a Citizen Science experiment. Suddenly, not only did the members of this Innovation Project have to create a scoring system for their exhibit, now there existed the notion that the scores could be submitted and collected, with the idea that they might be used for genuine research if there were a control to the experiment. It is important to remember that this was Martha’s idea, not the students’.

The group has now begun to spend a considerable amount of time discussing how the scoring might actually occur. Martha immediately made this numerical by asking, “How are you

going to identify a three versus a two versus a zero?' Martha then suggested the problem of distinguishing good drivers, or good texters, from other participants:

So, maybe you'd be filming them as well and capturing the number of times [they are distracted]. You could. I mean you could count the number of times that they are looking down at their ..., you know, text. That could be counted through a visual thing (Martha, personal communication, January, 2012).

Again, Martha was shaping the thinking behind the exhibit. Further, the logic of her contribution was the same: how was the exhibit to be made scientifically accurate? This was one of the biggest challenges working with the teachers in the Science School. They were not confident that the students would learn enough science through designing an exhibit; and they worried about the contribution that this would make toward their course grades. As a result, as can be seen with Martha, the teachers exerted pressure on the students to consider the exhibit more of a science fair project and less an exhibit for the Ontario Science Centre. In Martha's and Judy's mind, this would have made the Innovation Project closer to the Ontario curriculum and, thereby, increased its legitimacy.

A typical exchange depicting this line of thinking occurred between Elizabeth and Martha. Elizabeth commented,

Yeah, well, we have actually written down, I'm just reading it. It has nothing to do with ..., like, whether they look at the text or whether they reply; it's just whether they stop, whether they stop and they're delayed, or whether they don't stop at all (Elizabeth, personal communication, January, 2012).

Elizabeth continued, "Which, I think, makes more sense, because you're right; they could be a good driver and not like ..." however Martha interrupted,

Or, they could be a bad driver and do that as well without ever looking at text, which goes back to my point of you need to set up something as a control and comparison with the text versus without the text through your.... It could be through your exhibit, like I said, first have no text, second have text (Martha, personal communication, January, 2012).

When the students agreed with Martha that a control situation was required, she said, “OK, so it sounds like your exhibit is pretty ironed out now.” It was Carter who spoke for the group and agreed. Martha then asked about how smartphones were going to be incorporated into the exhibit. Carter explained how the smartphone application would work: people downloading the application would have access to the simulation on their phones and be able to test themselves, compare with their friends, and then upload their results as part of a Citizen Science experiment. While Carter made this comment about the role of smartphones, it is important to note that at the beginning of the meeting, Carter had said that the smartphone application was part of Peter’s job. Here, it is apparent that Peter’s role is being usurped although it cannot be concluded at this point because it is unclear whether Peter is not doing his share of the work or if he is being sidelined. Peter contributed only one sentence to the last 15 minutes of the meeting about using the smartphone application: “And then can compare with their friends if their friends do it and they have the app, compare.” But Carter interrupted to elaborate the application further.

There is a striking and very interesting exchange that demonstrated just how much the teacher, Martha, remained in charge of the group throughout this meeting:

Carter: All right, and for our report I know you said, like, don’t bother changing it, but like ...

Martha: Carter

Carter: What?

Martha: Don't obsess.

Carter: No, but it's, like, we, it's like, we probably should redo our whole outline.

Martha: Absolutely not. You are providing what we've asked you to, absolutely.

Carter: All right.

Martha: Don't obsess. It will be fine.

Carter: All right.

Martha knows Carter from class, so this exchange was part of an ongoing conversation between the two of them. Still, it is important to see how much Martha was in control in the situation, making decisions for the group and taking those decisions away from the group leader.

Elizabeth did not accept this as being the end of the meeting and added, "Another thing I wanted to bring up was, weren't we saying we were going to actually style, like, a chair and but actually have, like, a car?" Elizabeth was suggesting that they should have been discussing the design of the actual exhibit, which was that this would be an actual car that a person could get into, with the windscreen serving as a projection of the road. The group liked this idea because they thought it would allow them to add a radio or other distractions and provide a more authentic feel. But, Martha squashed this idea quickly, "Remember, if you're doing an experiment, you change one variable." Martha liked the authenticity of the car suggestion but did not like it when the students introduced new complications in which they were interested.

Martha reverted to making sure that everything was on track as she attempted to wrap up the meeting. Carter made it clear that they would complete everything on time, but that they could not expect everyone to make it to every meeting, adding that those who did not make it to the meetings would have no right to contribute to a further conversation. They then made it clear

that they were talking again about Peter and his failure to present an idea for smartphone integration into the exhibit. Martha responded, “Yeah, you guys already talked about that,” but she then went on to suggest that they should create a new smartphone engagement because their original app idea would be similar to that of other groups. She added that they should come up with something creative, presenting the example of a group she had supervised in an earlier semester.

Interestingly, when there was a question of software being available on the computers in the student study area, it was Peter to whom Martha turned. In reference to Google SketchUp, Martha was talking to Carter, but she turned to Peter and asked, “Is it not up there, Peter? As this exchange continued, Martha stressed that the Google SketchUp of the exhibit be completed, commenting to Peter, “And that’s your job? OK. Have you got SketchUP at home that you can start working on?” Peter answered, “Yeah.”

Finally, Martha asked if they had consulted with the design team at all, and each member of the group answered, “No” in sequence. “Why not?” Martha countered. Then Bernadette, who claimed to be the design team liaison because she had been given Doyle’s card, as discussed earlier, responded, “The design team just never [came up].” But, Martha pressed Bernadette and stated, “Why don’t you?” Carter decided at this point that they should indeed consult with the design team.

The meeting finally ended, reverting to the idea of putting a prototype on the floor. Martha suggested that the students talk to me, as the researcher, about making that possible. She remarked, “Or, one of you can ask Paul about that. You want me to do it?” Carter responded “Yes.” Bernadette added, “Yes, please.” This suggested that perhaps they were more comfortable talking to Martha than coming to my office.

### *5.10 Students' Use of Social Media*

The students used social media throughout the Innovation Project and, indeed, throughout the entire semester. Each group had been asked to create a Wiki to share their information and to keep track of the group's progress. The school had already introduced the students to Wikispaces, the website that they were to use for this. However, from the beginning, the students were more comfortable using Facebook. In fact, many of the students in the semester had met each other on Facebook long before meeting each other in person at the Science Centre on the first day of school.

This migration of communication to Facebook from the Wikis was unexpected for us as a staff. Bernadette substantiated the importance of using Facebook instead of the Wikis: "I think it's multipurpose, because, I mean, we already are, normally ...we're all checking Facebook anyways, so if the message is right there, it's easier." The format that Facebook uses allows the users to determine quickly who has been involved in a discussion and the time at which a contribution was made. Hence, there was a sense of verification of communication among the students, which was not as readily available on the Wiki or in other formats. According to Michelle, the students were "always on Facebook."

It was very important to the students that everyone was on Facebook as often as possible, which meant that interactions on Facebook could be almost synchronous, although Facebook allows for asynchronous interactions as well. Many of the group's Facebook threads which I was provided showed that they were actually cajoling students deemed not to be regular enough users of social media to log on more often so they could keep up with occurrences within the group.

Another important distinction between the Wiki and Facebook was the presence of teachers. The Wiki, even though it was set up by the students, had assigned the teacher as a

member of each group. The Ontario College of Teachers, however, discouraged teachers from becoming Facebook friends with their students. As a result, students felt more assured that their Facebook conversations were private among themselves, away from the teachers. Bernadette pointed out that this notion of privacy allowed students to be “stupid” without a teacher having to know. Questions could be posed that a student would be embarrassed to ask the teacher directly. This made Facebook an even more important forum for the students. This idea of student anonymity in the classroom has been discussed, and was a surprise in the research.

Michelle liked that Facebook did not require the same input from everyone. She could read the updates on Facebook often, without having to comment or post an update. In this way, she could keep abreast of developments in the Innovation Project or in the class as a whole, without having to question anyone outright. However, this practice also proved contentious, as some students had to cajole others to make more frequent contributions. Michelle’s reading of Facebook posts were not obvious to other students, who would only be aware of her being on Facebook if she actually made her own contribution to the thread. Other group members might have mistaken Michelle’s silence for non-engagement.

Interestingly, the students appeared fully informed about the potential drawbacks of using social media as their primary method of communication. Bernadette noted, “I should watch what I say because, like, scholarships and jobs, like, those people can see and they can, like, check your Facebook, and then, on the other hand, like, incriminating stuff.” I did not ask about closed Facebook groups, but it appeared the students were not aware of an alternative and the groups being followed in this research had already been created by the students initially, without our knowledge. Bernadette’s awareness of this aspect of Facebook is, however, tempered in her next comment, “But I think after a while, you just kind of forget about it and it becomes like second

nature, and you don't really think about it." I don't know at what point students moved from being worried about the so-called "public" nature of their Facebook interactions and being able to "forget about it."

The second potential drawback of social media that students found was that, because it was not face-to-face but entirely verbal, it did not allow for visual clues. It was perhaps inevitable that the students would see this type of anonymity as a potential drawback to the use of social media, but they did not see it applying to themselves. "I'm very good at it," said Mark in reference to his ability to read and understand others' electronic communication.

There was a general feeling that the Facebook experience was enhanced by the students' access to smartphones. I was surprised to discover that the smartphones were being used for electronic communication beyond the Science School itself and with students' friends in the wider community, generally through text-messaging. The students thought that my lack of awareness of their expanded use of social media confirmed my *naivete*; after all, they pointed out, there was no need to have "contacts" listed with the names of students in class because they were able to communicate effectively through Facebook. Text message contacts were, therefore, completely unnecessary within the classroom setting; instead, contacts indicated people with whom texting or phone conversation were required because a Facebook friendship had generally not been established. This meant that students did not often contact each other by the phone functions of their smartphones, but they assumed that Facebook via Internet would be sufficient, even for work on the Innovation Project. Students working together in class used Facebook friendships as their medium of discussion. There is an important distinction therefore between a "friend" and a "contact", with the former being closer, and also connoting membership within a group rather than a one-to-one relationship of some formality.



This betrayed a confidence on the part of students that every member of a group had joined Facebook, and that every member had an equal understanding of its use. The first of these assumptions was true -- all 30 students in the class had Facebook accounts and access. As was seen from Michelle, the second assumption was not true. Michelle used Facebook differently, preferring to read others' posts but not to make posts herself. The other students may have misinterpreted this silence on Michelle's part, assuming that they all used Facebook in the same manner.

Carter pointed out, "What I actually noticed is when I was printing off the thread ... I was, like, I realized ... I was, like, this is actually not even half of what we did as a group on Facebook." This was because much of the discussion within Facebook was on the Semester 59 thread as a general listing, rather than specific to the Innovation Project. This meant that students in many groups were able to follow the progress of each of the Innovation Projects. I did not solicit, and I was not given access to, the general semester 59 thread. It must be remembered that one reason the students like using Facebook was that the teachers did not have access to it and, therefore, could not read their posts.

The students were maintaining multiple threads on Facebook, one for all 30 students in the semester that I have called in the previous paragraph "the general semester 59 thread," one for each formally taught subject, and one for each Innovation Project group. I was given access to the Innovation Project group threads, which were rich in detail and contained, I thought, all of the information necessary to create a time-stamped rhizome. However, it was clear from Carter's comment that much of the Innovation Project discussion also occurred in the general thread and in the subject-specific threads. I did not ask for access to these, as the majority of students

commenting on those threads had not agreed to be part of this research project, and their expectation that teachers were not aware of the content of those threads had to be maintained.

In order to collect sufficient data to create substantive rhizomes, therefore, I asked the students in the two groups that were part of the research to permit me to search through the threads for comments related to Haptic Touch and Driving While Distracted. This proved successful in gaining greater insight into online communication about these projects, while still allowing me to review only those data that I had permission to use. The collection of these data proves that Facebook groups and postings are fluid and not limited to a single thread. Students proved comfortable at sharing information through multiple threads, and with multiple groups. There seemed to be few privacy concerns among the students, at least within peer-group threads.

## Chapter VI: Data Analysis – Delineating the Rhizome

If the groups in which the students are working are indeed complex groups, then emergence can occur. It has been shown that the Innovation Project groups do not meet all of the conditions to be considered a complex system. Nevertheless, the students engaged in knowledge creation. I have argued that the knowledge created is rhizomatic, in the form of a rhizome, which depicts the linkages between and among elements in the group. The challenge in delineating the rhizome is to find the linkages among the students in a group and to trace and map these.

Delineating the rhizome required the creation of a number of rules. First, the data selected for inclusion had to be determined. I chose to use all of the Facebook data that had been shared with me. This had several advantages in the process of trying to trace and map the rhizomes of Innovation Project groups. The Facebook threads of project groups were all time- and date-stamped. This allowed for a temporal element to be added to the resulting rhizomes. Although the students' participation in the Facebook thread was asynchronous, it was possible to determine who had posted first and to follow the sequence of subsequent posts. In this way, it was possible to determine when an idea first emerged. During interviews with students, they were often vague about the sequence of events, or they misremembered either the sequence or which students were involved. This was not apparent in the interview but was evident only afterward through examination of the Facebook threads.

A second advantage of following Facebook was that the students were not initially aware that these data would become part of this research. As a result, the students were much more candid and much more likely to reveal antagonisms within the group. In interviews with the researcher, students were likely to respond in ways that would ensure that the research and the

Innovation Project would be successful. In some case, they prepared answers in advance, and they were less likely to criticize one another.

When the research began, I believed that I would be following the Innovation Project groups through their Wikis. Instead, the students and teachers involved quickly let me know that the Wiki was not being used. However, since the students were not meeting more often than scheduled, it was obvious to the staff that students must have been communicating through social media. In the interviews, the students revealed that this was true, and that, in fact, they had met each other on Facebook before coming to the Ontario Science Centre. This was a revelation, as their involvement in social media had not occurred in previous semesters. It is suspected that students' easy access to smartphone technology that allowed them to be connected to Facebook continuously made this method of communication preferable.

Students saw two other significant advantages to using Facebook. The first was that they were familiar with the format and with Facebook communication. This meant that there was no learning curve through which they had to pass in order to use this new technology. The Wikis on Wikispaces that had been recommended involved such a learning curve that students were not as likely to engage in them. The second significant advantage to the students was that they all had equal access to Facebook. Every student had a smartphone, and, as a result, all the students should have been able to participate in a Facebook conversation. In fact, some student threads related to the Science School as a whole and to the individual subjects had already been created on Facebook. It was not surprising in light of this information that the students would choose to use Facebook as their primary communication tool.

Having established that Facebook was to be the source of data for the rhizome, it was necessary to consider how to trace and map the data. While a rhizome not only demonstrates the

network of linkages among the students as they engaged with the Innovation Project, it must also delineate the direction of flow and the kinds of communication that the linkages represent. The researcher undertook the following steps to delineate the rhizome.

First, every Facebook communication among the students in the group had to be recorded in the rhizome, for each communication entry represented a linkage. Each of these linkages had to include the flavour of the communication as well as its tone and intent. It had to record the direction of the linkage, from whom the communication had originated, and for whom it had been intended. Each linkage also had to carry information about the content of the communication. I used a mixture of straight lines and curves to show linkages, though this aspect did not itself carry information. Figure 1 depicts the legend that explains the purpose of each line and linkage.

**Legend**

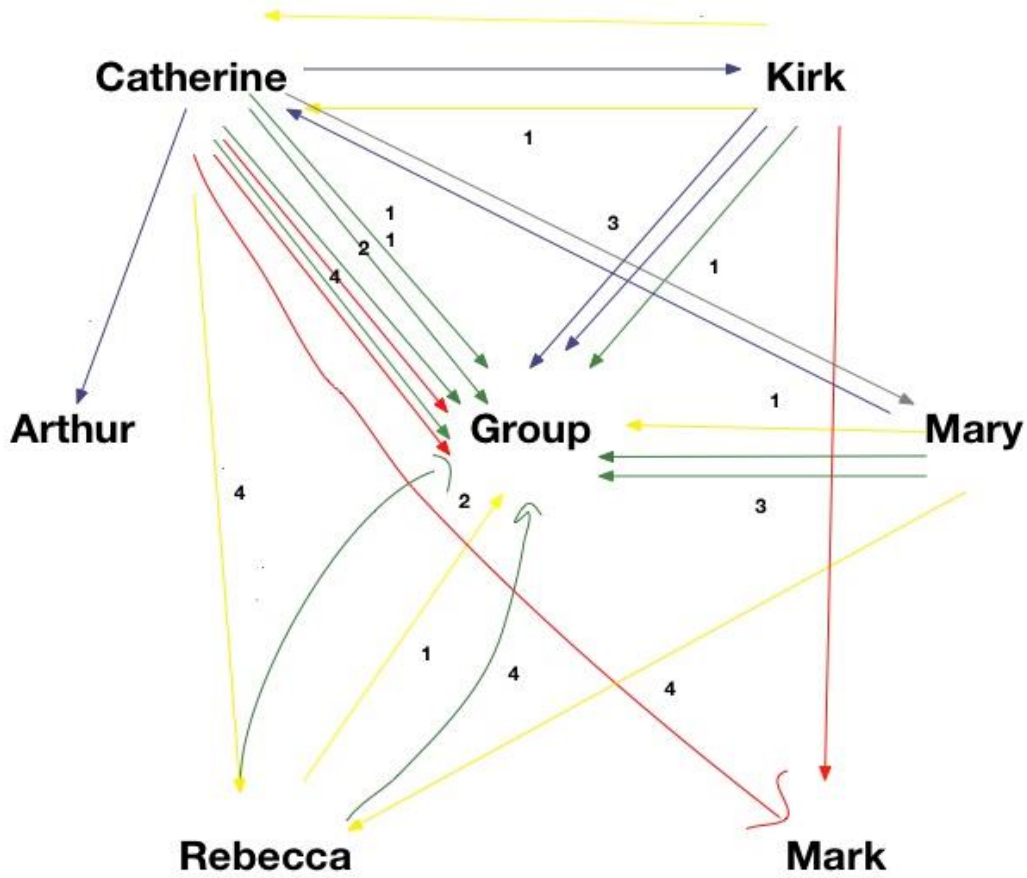
-  **New knowledge**
-  **Informational**
-  **Support for earlier comment**
-  **Negative feedback**
-  **Request for more information**

Figure 1

In each iteration of the rhizome, shown in Figure 2, the students' names were kept in the same location so as to maintain consistency of view. In this way, each iteration of the rhizome could be compared to the other iterations. Changes in frequency of linkages over time were easily recognized, and changes in the pattern became visible.

Figure 2 is the resulting rhizome for the Haptic Touch group for the period October 13, 2011 to October 26, 2011. The topics under discussion were as follows: Number 1 represents the group's consideration of a name for the group. Number 2 depicts the creation of the Wiki, for which the students at this point still felt responsible, although later in the project they let this Wiki lapse. Number 3 is a discussion about an article on exhibit design that was distributed to the students. Finally, in this figure, number 4 reflects the creation of the progress report that Judy, as the teacher of the Haptic Touch group, had requested.

**Haptic Touch Group**  
**10/13/11 -10/26/11**



1 represents the group’s consideration of a name for the group.  
 2 depicts the creation of the Wiki.  
 3 is a discussion about an article on exhibit design that was distributed to the students  
 4 reflects the creation of the progress report

**Legend**

- New knowledge
- Informational
- Support for earlier comment
- Negative feedback
- Request for more information

Figure 2



It was immediately apparent that four members of the Haptic Touch group, Catherine, Kirk, Mary, and Rebecca were the only participants thus far. By far, Catherine posted most often, and although her posts most often provided information and, therefore, built knowledge, she was also responsible for posting almost all of the negative feedback to the group. On Facebook, Catherine acted as the leader of the group, even though the student interviews suggested that Kirk was the group leader.

There was an important split within the group that was apparent in two different silences. Neither Arthur nor Mark had contributed to the rhizome during this period. Both Catherine and Kirk, in their roles as leader, made a comment directly to Mark in a shared Facebook thread about his silence. Facebook allows for direct communication between two parties, although this research did not examine that communication. However, both Catherine and Kirk were willing to make a public post, at least to the group, offering negative feedback to Mark. Interestingly, they were not willing to offer negative feedback to Arthur.

There are two possible explanations for this. First, negative feedback was offered to Arthur but through a different medium, either in conversation or through direct Facebook communication that was not part of this thread. Second, it is possible, and even likely, that the Haptic Touch group interpreted Arthur's and Mark's silences differently. Mark himself believed that he was not always good at group work, having described himself in his initial interview as a slacker. There is a strong likelihood that this was communicated to the other members of the Haptic Touch group, and the result was negative feedback directed toward Mark in a public forum. Arthur was assumed to have continued working through his silence.

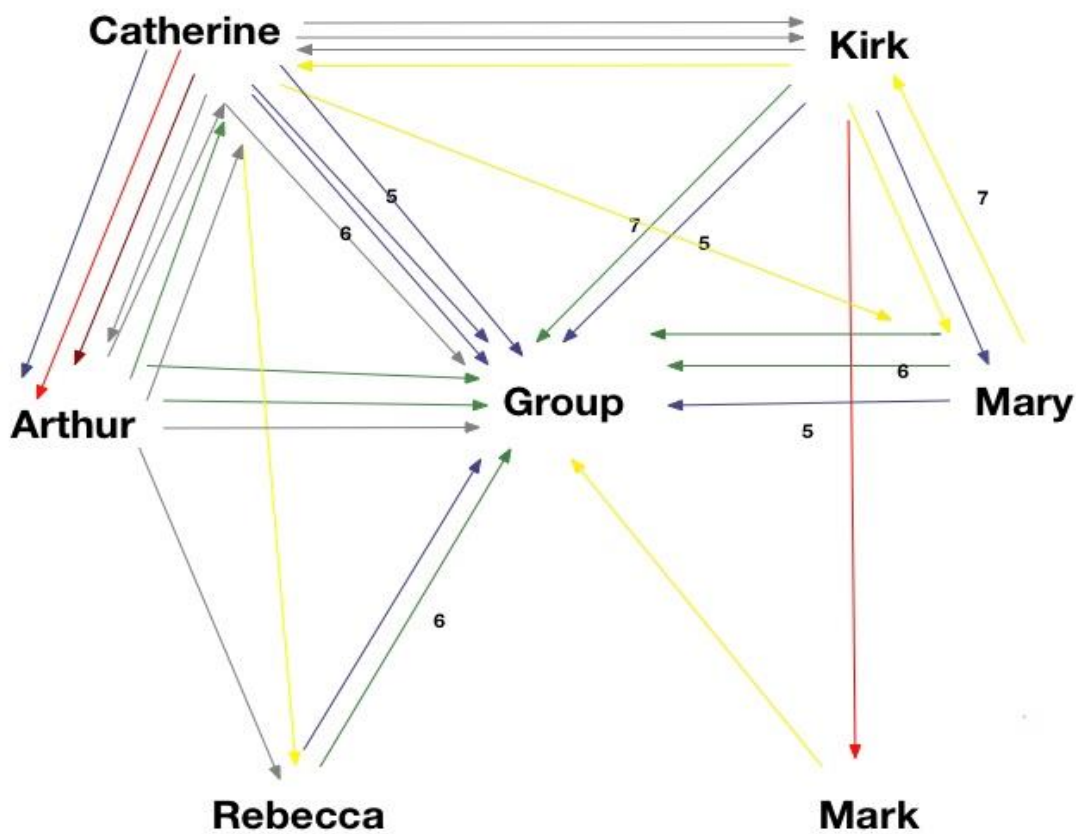
Among the four active participants during this time, there is a division of labour. Not all students commented on all of the different topics that arose. In fact, no single student had a

contribution on all four topics. There was also a curious and unexpected pattern emerging. The girls in this group, Catherine, Mary, and Rebecca, were much more likely to communicate with each other or with the group as a whole. The only exception was Catherine's communications. These involved informational linkages to Arthur and Kirk, which represented only the information they needed in order to participate in the Wiki and negative feedback to Mark. There is no apparent explanation for this, and there was no indication during the interviews that any member of the group was uncomfortable working with or communicating with any other member.

During this time, Catherine was the major participant in the Facebook thread. She both generated the highest number of individual postings and was the subject of the most direct communication within the public thread. However, in terms of volume within posts, most work had been done by Rebecca, who was not a participant in this research but whose contribution was recording minutes from meetings. Taking minutes was the role that others in the Haptic Touch group had said Rebecca had undertaken.

The students rated lowest the participation of Rebecca and Mark in the Haptic Touch group. It is not clear in this section of the rhizome that Rebecca was deserving of this rating. However, it is recognized that the type of work a student had undertaken became part of the rating. Despite being time-consuming, working on meeting minutes received positive feedback only from the other girls in the group. Kirk offered praise to Catherine for her organizational skills but none to Rebecca for the obvious work she had contributed.

**Haptic Touch Group**  
**10/25/11 - 11/07/11**



5 is a discussion of the name for the exhibit.  
 6 is a discussion of what the exhibit would consist of.  
 7 is the assignment of roles in the next stages of exhibit development.

**Legend**

- New knowledge
- Informational
- Support for earlier comment
- Negative feedback
- Request for more information

Figure 3

Three topics were discussed in the rhizome depicted in Figure 3, which represents the second iteration of the Haptic Touch rhizome. Topic number 5 is a discussion of the name for the exhibit, rather than a name for the group, which had been established earlier. Number 6 is a discussion of what the exhibit would consist of, and number 7 is the assignment of roles in the next stages of exhibit development. The meeting with Judy that was recorded and analyzed in this chapter occurred during this iteration, between topics 6 and 7.

A change in the shape of the rhizome is immediately apparent. The earlier iteration (Figure 2) showed a triangle connecting the girls in the group offering each other support. It was not clear who the leader was in that first iteration, as both Catherine and Kirk seemed to take on the leadership role. Over time, Arthur became a much more frequent participant in the Facebook thread, and so he has more linkages within the resulting rhizome (Figure 3). Rebecca's contribution of preparing minutes only got a supportive response from Catherine, demonstrating that the students no longer thought of submitting minutes as worthy of support.

Mark's contribution remains undetected, except for a single word. When the final proposal had been put together for presentation, after much discussion among Mary, Arthur, Catherine and Kirk, and after Rebecca had submitted her minutes of the meetings they had conducted, Mark posted the word "epic." His meaning was clear: he believed that work had been done by the other students, and he wished to acknowledge that work. Catherine no longer rebuked Mark for his lack of participation, and, instead, conducted an extended conversation with Arthur. The silence of most group members toward Mark demonstrated both their frustration with his lack of participation and their resignation to this situation.

Included within this iteration of the rhizome is a fascinating discussion about Mark, but one that does not include him. Catherine had asked Kirk to provide contact information for

Mark, since, in her estimation, he was clearly not following the Facebook thread and may not have been aware of changes that had taken place in the project. Up until this point, the students assumed that everyone was an active participant. Through his one word, “epic,” Mark demonstrated that he was, in fact, aware of the Facebook thread and at least followed it periodically. This awareness became a source of frustration for the others.

Mary’s participation in this iteration of the rhizome is also interesting. At no time did Mary ask her fellow group members for more information. Early in the project, she had been made responsible for conducting the research. She shared links to this research and provided information, but at no time did she concern herself with what the others were doing. Mary was the one student who during interviews expressed ambivalence about the experience and said that she thought the 30 students in the semester had separated into friendship groups. Here, her interaction with the others, even in the milieu of social media, demonstrated a marked difference from the others. She contributed but did not appear to pay attention to the contributions of the others.

Also of note, Catherine, who had the most postings and had the most postings directed toward her, did not contribute information to the group’s creation of knowledge. Her contributions either asked for information or provided logistical information; they do not contribute to knowledge creation. Yet, everyone else, with the exception of Mark, has contributed to this group’s knowledge creation. Importantly, Catherine and Mark were both aware of the knowledge the group was creating and were sharers, if not creators, of that knowledge.

**Haptic Touch Group**  
11/07/11 - 11/20/11

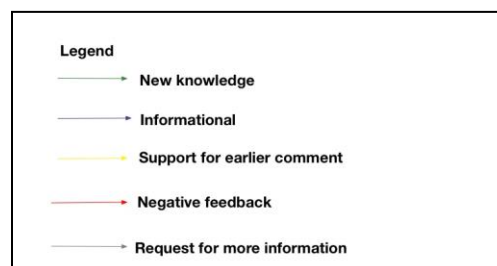
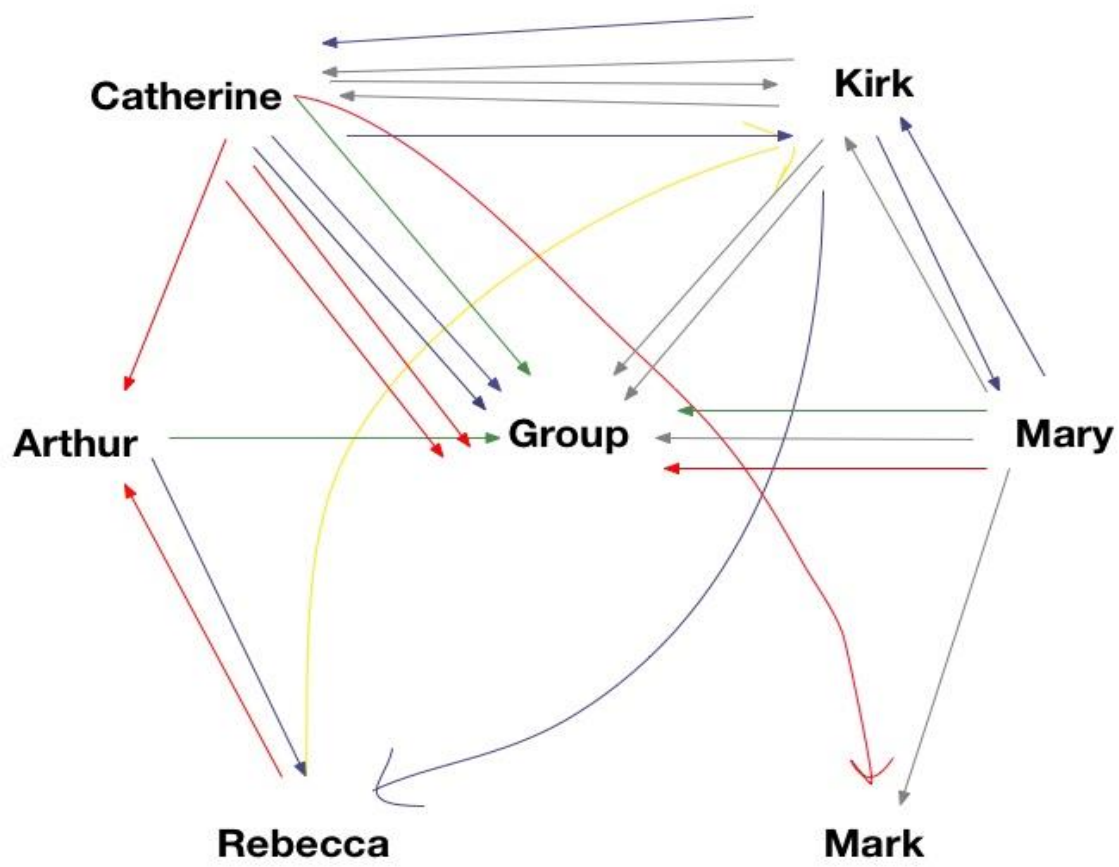


Figure 4

In the third iteration, shown in Figure 4, some new trends come to the fore. There was only one topic of discussion during this time frame: the production of a prototype exhibit, what would be included in the prototype, and how the students would present it to the staff of the Science School as they prepared for their presentation to the design and development team of the OSC. Here again, it is noted that the communication was largely among four members, and, again, Catherine had the largest share, although she exchanged numerous postings directly with Kirk.

During this iteration, Catherine, in her role as leader, had made many postings that consisted of negative feedback to others. Some of these were to the group as a whole, and some were to individuals. Kirk had abdicated this role entirely, perhaps not as leader but as provider of negative feedback. In fact, four of Kirk's six postings during this iteration concerned seeking further knowledge or clarification from individuals and from the group. It was Catherine who was left to worry about timelines and work being completed.

When the students were interviewed, they described Kirk as the leader, using a number of different terms, including "boss" and "employer." No one in the interviews identified Catherine as the leader of the group, except herself. Yet, Catherine took on the role of leader within this social media environment. This indicated fundamental differences between how the students perceived and presented themselves in an interview setting and how they presented online in an environment where they were free of teacher influence. Peer-group threads within Facebook allowed not only for varied communication but also a different conception of the individual. Students proved to present themselves differently in the several environments that they inhabited, and examining Facebook data gave access to a very different presentation of the students. The students were often unaware of this distinction.

Of note in this iteration is the change in Rebecca's contribution. Rebecca no longer added anything to group knowledge creation; instead, she had only two postings, one of which was negative feedback directed toward Arthur and the other a supportive post directed toward Kirk. Kirk had provided Rebecca with logistical information, as had Arthur. When the students evaluated each other's contribution to the project, the members of the group felt that Rebecca's and Mark's contributions were not as substantive as some of the others. It was clear that their perception was being driven, to some extent, by the students' participation in social media. Since Judy, the teacher for the Haptic Touch group, was present at meetings and all the staff were in attendance for presentations, there was some incentive for the students to appear to be making full contributions at those times. However, Facebook provided an opportunity to measure input in both quantity and quality of postings. Here, it became clear that Rebecca and Mark were not contributing in the same way as the others. Again, this could not have been due to unequal access to the social medium, as all of the students had smartphones, and they were all able to follow the thread at their convenience. Further, Mark's participation in an earlier iteration indicates he was aware of and was following the thread but was not participating.



**Haptic Touch Group**  
11/25/11 - 12/6/11

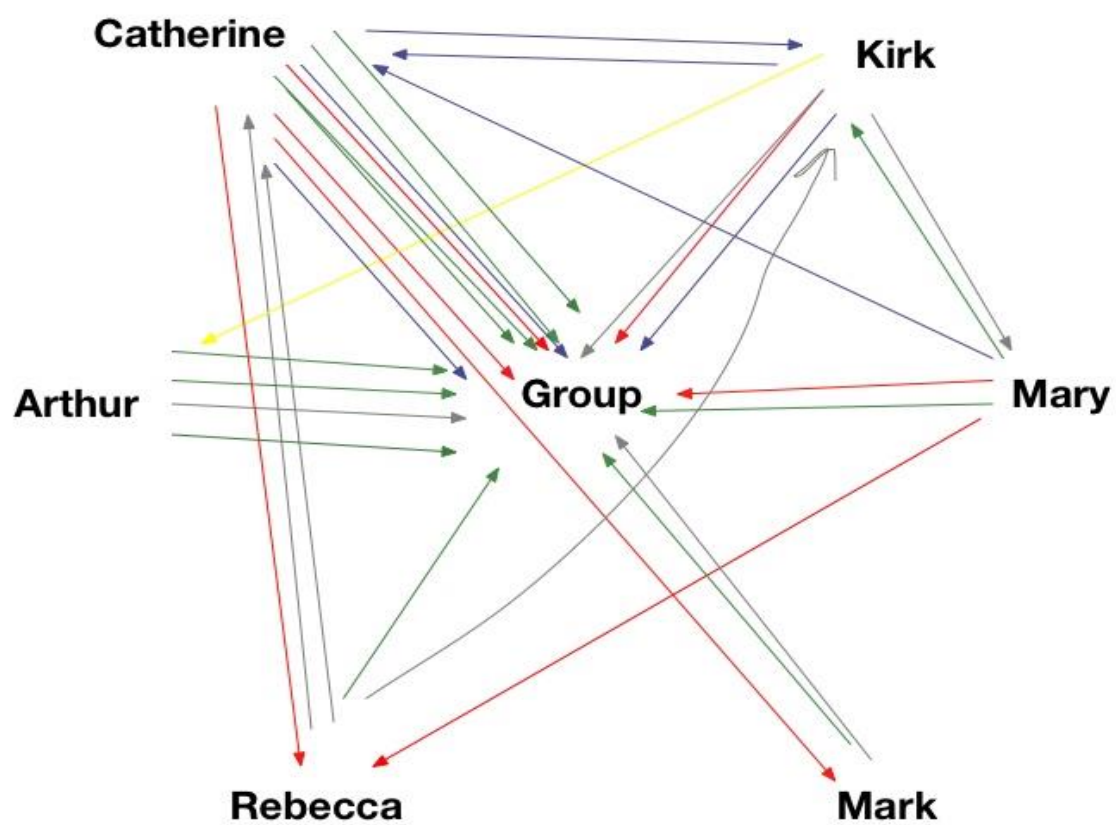
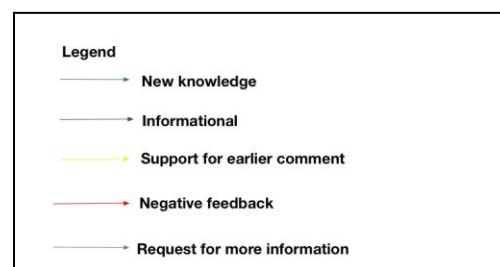


Figure 5



All of the discussion in this iteration, number 4 (Figure 5) from the Haptic Touch group, is again related to a single topic. This is the preparation of the final presentation to the exhibit design and development team at the OSC. The overall shape of the resulting rhizome is largely the same as earlier iterations; however, there are some important changes. During this iteration, every group member except Kirk had contributed to the group knowledge creation through research and exploration. There was also much more conflict and negative feedback during this iteration.

A new kind of conflict developed in the Facebook thread that might explain how students expressed themselves in interviews. It is important to remember that this conflict occurred in a Facebook thread that was visible to all of the members of the group. On November 25, Kirk posted to Mary, “Rebecca tells me she left that to you.” Mary responded, “I read it over at lunch and you said that Rebecca would finish it off.” Kirk posted, “LOL, I just messaged her and she was, like, ‘I left it to Mary.’” To this, Mary responded, “WHAT, she was there when I was reading it then she said she’d come back and then when I finished, you were like ‘Rebecca’s going to finish it’. Ok, so fine, I have to send it?” Mary was unhappy and understood that she was doing more work than had been outlined to her. Rebecca would have been able to see this conversation, but she made no reply.

Later, by December 4, there was a discussion among the group members concerning who would take on each part of the presentation. Mark asked for clarification here for the first time and said, “There are six people and four topics.” By this time, the four parts of the presentation had been divided, and Mark saw himself without a role to play. Catherine pointed out that there were, in fact, six topics, or parts of the presentation, for the six group members. Mark chose one

of the remaining parts, but later Catherine noted that only Mark and Arthur had submitted their parts for the final presentation.

During this iteration, Catherine had taken on the role of organizing the group and keeping everyone in line. Her frequent employment of negative feedback to the group and to individuals revolved around missed deadlines. Kirk, although a frequent participant on the Facebook thread, did not use his participation to organize outside of the discussion with Mary, which was discussed previously.

There are a number of silences and expected linkages that did not appear. First, Kirk did not contribute to the creation of knowledge in the group during this iteration. Most of his comments either asked for clarification or expressed humour at the frustration of others in the group. It was clear from his postings that Kirk considered himself the leader and organizer, and yet it was Catherine who had taken on this role herself and assumed the task of stimulating the others. Many of the linkages that represent postings to the group, especially those of knowledge creation, were in response to inquiries and negative feedback from Catherine.

Mark's silence continued, and yet because this silence was not absolute, it is clear that he was an active participant following the Facebook thread. It is interesting that when given specific direction on how he could contribute, Mark was one of the first to do so. There are, in all the iterations, some comments related to activities outside of the Innovation Project. The group members discussed birthdays and school assignments through this thread as well. Mark never contributed to these discussions. Despite direct negative feedback in this iteration, Mark never changed, and his silence remained conspicuous throughout.

The next two rhizomes represent the Facebook thread conversations of the Driving While Distracted Group. It is important to recognize that these conversations are fundamentally

different than the preceding ones and offer a new shape that was not visible in the earlier Haptic Touch rhizome.

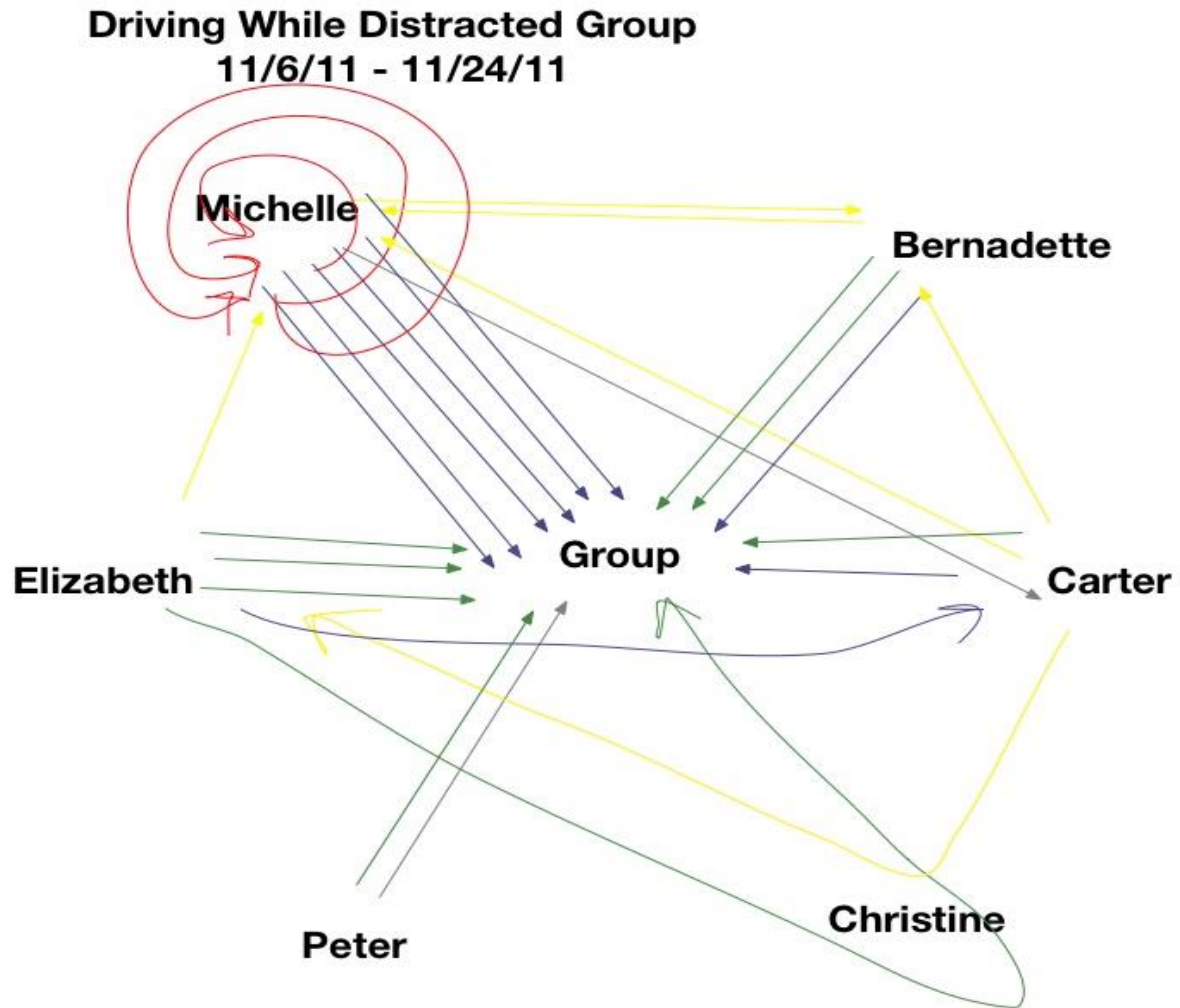


Figure 6

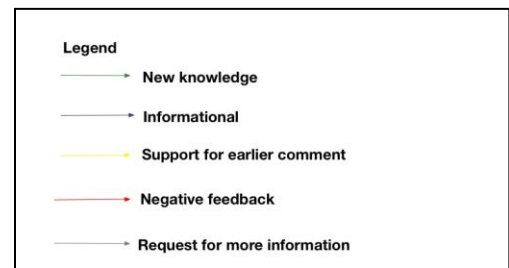


Figure 6 represents the first rhizome of the Driving While Distracted Group. There was only one topic of conversation, and that was the preparation and presentation of an oral report to the teaching staff of the OSCSS about the group's progress.

Around Michelle are many circles, a shape that appears for the first time in a rhizome. Also, these shapes are red, indicating that Michelle is offering criticism of herself on a public forum. This was different than any other posts and gave a definitive shape to the overall rhizome. Michelle's contributions are noteworthy for their logistical arrangement. She shared information with her peers, but at no time did she contribute to knowledge creation. It will be remembered from the earlier discussion that Michelle had provided the idea that the group followed for Driving While Distracted. Hence, Michelle believed that this made her the group leader.

Analysis of Michelle's contribution is instructive. On November 6, Michelle posts on Facebook,

Hey guys!! The oral report is due Wednesday so I'm thinking we should definitely meet tomorrow at lunch!! And unfortunately, I have to miss innovation this week *again* (emphasis by Michelle): I have an appointment and my mom is picking me up early, but ya we should definitely meet a lot this week! (Michelle, personal communication, January, 2012).

In this post, Michelle is critical of herself for having to miss this meeting, but she had also taken on the role of giving suggestions as to how the others should behave, which is considered a leadership role. There was nothing in this post that could have been construed as adding to the knowledge creation of the group.

Michelle's posts continued in this vein. She designated roles to the other members of the group and asked them all to post these to the Wiki so that they could be read by Martha, the

teacher associated with this group. However, Michelle herself was unable to do this and posted in Facebook on November 7, “Hey, the Wiki isn’t letting me edit it, do you think someone could post this?” The “this” that she had hoped to have posted was a list of defined roles and responsibilities for each group member. The phrasing “the Wiki isn’t letting me edit it” was familiar to all computer users and anthropomorphizes the technology that Michelle was using. It was clear that she was more comfortable with Facebook and that the students were using Facebook by choice, as she had posted to Facebook only to request that the information be transferred to the Wiki for Martha’s benefit, but not to communicate with her fellow group members. Facebook became the only tool for easy communication.

There is another new shape within this iteration of the Driving While Distracted rhizome and one that deserves extended consideration. The rhizome has knowledge creation coming from Elizabeth, encompassing Christine, and being delivered to the group as a whole. Elizabeth was initially not interested in the smartphone technology and indicated that she would have preferred not to spend her time in front of a screen. It might be extrapolated that Elizabeth was not interested in new technologies. However, Elizabeth and Christine had been working together on an extended part of the overall exhibit. They had done this using Google Docs, a program that allows multiple users to contribute to a single document. Neither Christine nor Elizabeth was familiar with Google Docs before the beginning of the Innovation Project, and Elizabeth had expressed a wish not to use computer technology. Yet, part of the group knowledge creation was learning this program together, and the two were utilizing the program to collaborate successfully asynchronously. This demonstrated the knowledge creation that had occurred within the Innovation Project and created an entirely new shape within the rhizome structure.

There is an interesting pattern observable around Carter as well, and this becomes clear when one considers the tone of his postings. Carter, by general admission of staff and students, is the brightest student in the class. He is aware of this status, and it has been shown that this characterization of Carter has led the students to take advantage of their smartphone technology by having Carter ask the questions in class. Their assumption is that Carter generating the questions would not change teachers' or students' opinions of him. Here, although Carter might be a natural leader, he clearly acted as the cheerleader of the group. He was careful to praise the other members of the group, and more than half of his postings were praise in nature. He shared this praise among all the members (including complimenting Elizabeth and Christine in a single post) except Peter. Again, like Mark in the previous rhizome of the Haptic Touch Group, Peter does not contribute in the same way as the others.

It was necessary to examine Peter's silence however, for, like Mark, the fact that his silence was not absolute indicated that it was by choice and not the result of a technological gap or inability to engage with the group through the medium of Facebook. During the preparation of the oral report, Peter contributed faithfully to group knowledge creation. He also provided logistical information. However, he did not contribute to any of the discussion underway, neither praising nor chiding other group members. It is important to remember that this group had chosen Michelle's idea for Driving While Distracted rather than Peter's idea, which was about astronomy. It is possible that Peter felt himself less a part of the group since his own idea had not been selected for further work by the group as a whole.

Peter's silence, then, was very different from Mark's, whose idea had been selected by the Haptic Touch group, whereas Peter's had not. Mark was disengaged and silent because that was his nature, something he had discussed from the very first interview, though he had hoped

that this experience might bring about change. Peter, on the other hand, seemed to be disengaged because he had not received positive feedback from the group early in the project. In the next iteration of the Driving While Distracted rhizome (Figure 7) Peter's disengagement, if anything, became stronger. This occurred despite the fact that during his interview, Peter had claimed to have become more engaged with the Innovation Project over time.



**Driving While Distracted Group**  
11/27/11 - 12/14/11

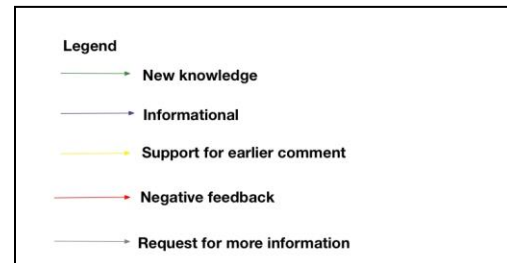
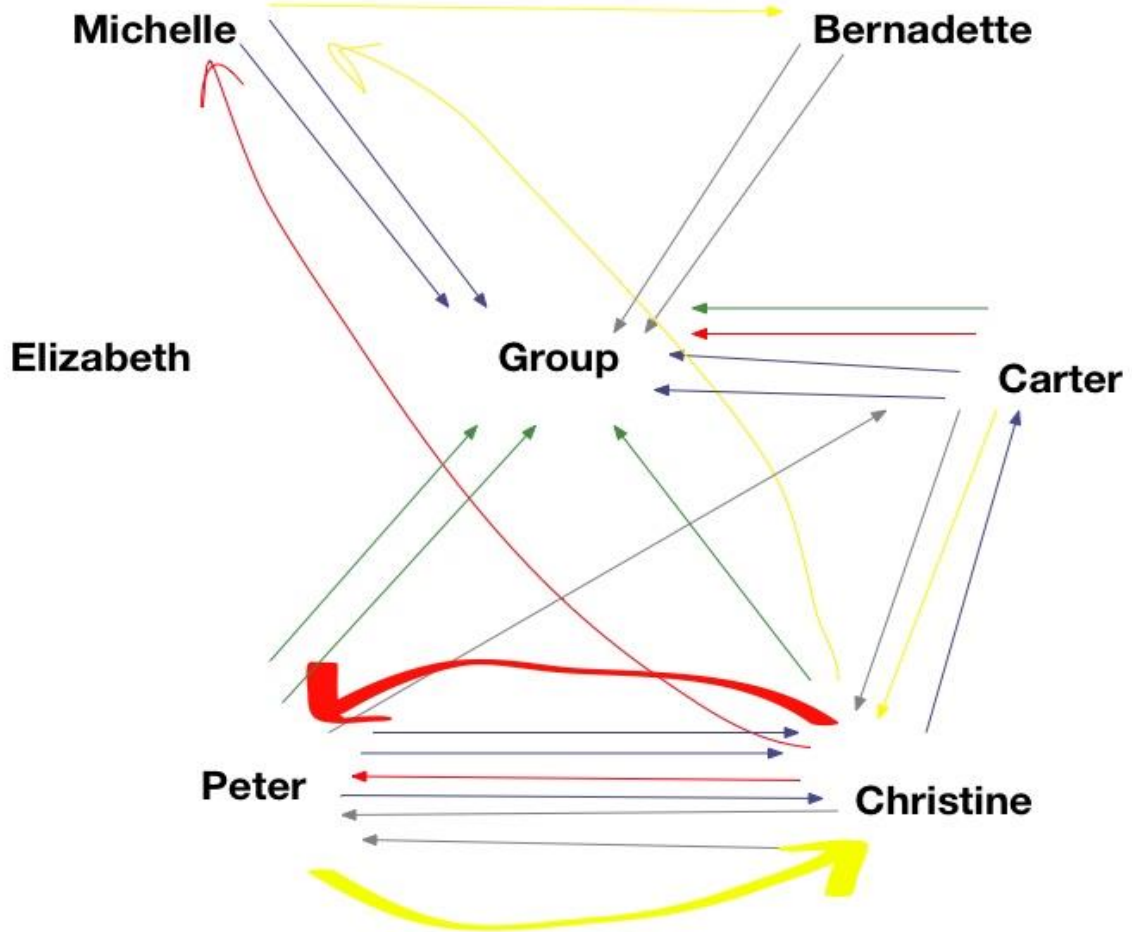


Figure 7

Figure 7 represents the second iteration of the Driving While Distracted Rhizome. Again, there was only a single topic of conversation during this period, and that was the preparation of the final presentation to be made to the exhibit design and development team at the OSC.

The second iteration of the Driving While Distracted rhizome is striking for a number of reasons. First is the extended conversation between Christine and Peter, which occurs in full view of the other group members, and clearly involves both negative and positive feedback. As these were expressed in the strongest possible terms, the “lines-of-flight” are represented on the rhizome by thicker lines to express that tone. Christine was responsible for putting together a PowerPoint slide show, and, therefore, required the contribution of each group member. She provided negative feedback to Michelle, who responded quite quickly, but Christine was clearly put out by Peter’s lack of contribution. Again, everyone in the group knew that Peter had access to the Facebook thread as needed and that his participation at other points meant that he was following. It may have been precisely the awareness of this fact that led Christine to her strongly worded negative feedback. On December 11, Christine posted in Facebook, “Yo, Peter, can u send me ur google sketchup please?” The “please” connoted the exact opposite of politeness, and the term had not been seen anywhere previously in Facebook or meeting transcripts. It actually conveyed a certain chill and formality that was new. On December 12, Christine posted, “PETER!” in all capitals. This was clearly negative feedback concerning his lack of response until this point. Capital letters, indicating strength of emotion, are reflected in the rhizome.

Peter subsequently provided the required information, and he praised Christine for her persistence in pursuing him to obtain the information. There was, however, in their conversation another post that is worthy of discussion. On December 14, Christine posted “Oh, and Peter we changed some of the sketchup,” a decision that could be viewed as devastating. At the end of the

project, when it was to be presented to the design and development team at the OSC, the group (“we”) had made changes without informing Peter. He was scheduled to present with the group the following day and was being given little time to prepare. This could only be considered a rebuke for Peter’s silence during early portions of this Facebook thread. Peter’s only response, was the post, “oh, ok.” He simply expressed his resignation to this change of circumstance.

Elizabeth’s complete silence during this iteration of the rhizome was exceptional. Throughout the project, and indeed throughout the semester, Elizabeth had had access to the smartphone and to Facebook. It is obvious from the earlier iteration that she was an active member of the Facebook thread and that she was willing to learn a new technology as part of her knowledge creation and her membership within the group. Her silence as the group prepared for its final presentation was notable. It is difficult to ascribe meaning to a complete silence, but it is noteworthy as well that none of the other group members had directed comments toward Elizabeth. It may be deduced, therefore, that Elizabeth had continued her participation with the group successfully but in a different format. She was not part of the Facebook thread anymore, but she must have submitted those parts for which she was responsible, as there was no negative feedback directed toward her from any of the group members. This is the only case in which the Facebook thread did not represent the entire conversation, and as for Elizabeth, it was necessary to rely on her interview contributions to understand her role within the group.

Michelle remains an enigma, contributing much less frequently through this iteration but continuing not to provide anything toward the knowledge creation of the group. Of note also is Carter’s contribution of negative feedback to the group as a whole. Until now, he had been entirely supportive and had indeed been conscientious about praising the other members. Carter’s opinion carried more value, as he was considered the star of the entire semester. His

negative feedback was mild compared to Christine's directed toward Peter. On December 11, Carter posted, "Everybody remember to send your slides to Christine!" This posting is notable for two reasons, other than it being a reminder that should not have been required. First, Carter, unlike any other Facebook user in either group, uses capital letters properly, writes in complete sentences, and uses full spelling. This is different from the majority of the students' posts, and his writing remained consistent over time, except in the creation of a nickname. Tellingly, this nickname was made for Peter and Michelle, whom Carter referred to by a "group designation" when he asked them for their submissions, again. Added to Carter's December 11 post is a connection to homework on the chemistry course Wiki. This entry demonstrated the cross postings that the students had alluded to that made Facebook attractive. Because the OSCSS includes only 30 students, posts for multiple subjects can be made in various threads with confidence that all of the desired viewers will have access to the posts.

Bernadette had not been a frequent contributor in either iteration. This was surprising, as in interviews Bernadette had been the most conversant with mobile technologies. Also, Bernadette had expressed a preference for the smartphone over the tablet computer as a means of posting to Facebook. However, Bernadette was the only one to express a longing for the friends from her home school, and it may be that her participation on Facebook was geared more toward maintaining contact with them than working with the Innovation Project group.

## Chapter VII: Conclusion, Future Directions and Implications

This case study relied on three nested hypotheses. First, it was hypothesized that the Innovation Project groups are complex in nature, though this complexity is contrived. The groups were not without objectives, nor did they flail in any way; however, they were created with the idea that the groups exist within a proscriptive environment that was intended to be without hierarchy. The second hypothesis was that these complex groups created knowledge which was emergent. Finally, the third hypothesis was that the emergent knowledge could be represented rhizomatically. This conclusion will evaluate these three hypotheses as it answers the questions posed in the introduction.

As qualitative research, this research conformed to Shenton's (2004) definition of trustworthiness and met the criteria of credibility, transferability, dependability and confirmability defined earlier.

This case study was based on a significant premise, that there is something special about the Ontario Science Centre Science School (OSCSS) by virtue of its location alone. The Innovation Project was designed to take advantage of the unique opportunity of a school being situated inside a functioning, public science centre.

There is a problematic, as has been stated, at the nexus of formal and informal science education that exists at the OSCSS. It is a formal school, employing teachers from the formal education system and following the standard Ontario curriculum. Classes occur in laboratories, and students are expected to complete assignments for evaluation. These assignments are determined by the curriculum, and the students' grades become part of their formal Ontario Educational Record.

Formal education is distinguished from informal science education as it occurs in the OSCSS. It was understood at the creation of the school in 1982 that its location alone should be sufficient to offer students an opportunity to consider science differently and to be able to approach problems in new and innovative ways. Findings from this research indicate that the premise about location may be incorrect, and that this problematic at the nexus of informal and formal learning is impacted by the teachers of the OSCSS, who have no training in informal science education.

A review of the teachers' engagement with the students shows that issues arise that change the fundamental idea about the goals of the OSCSS and the informal education process. The purpose of the Weston Family Innovation Centre, located within OSCSS, and the exhibits that the students designed for the centre is to give visitors the chance to practice the skills of innovation, which have been identified as creativity, collaboration, risk-taking, and perseverance. It is only with this last skill that the teachers in the OSCSS really allow the students to engage, even during the Innovation Project.

Risk-taking is one of the skills of innovation that students must learn and practice. In order for them to truly take risks, they must be willing to accept that the possibility of failure exists, and that this failure will not unduly affect their grade. In this instance, one of these risks was the Innovation Project group's participation in defining its own goals and determining the means by which these goals would be met by the group. It is obvious that both teachers, Judy and Martha, did not allow the students to determine their own goals. Instead, Judy provided deadlines and suggestions for how naming of the project should occur, and Martha steered her group to make certain that the project was a science experiment, not a science centre exhibit.

In the realm of creativity, which is another skill of innovation, similar interactions occurred. Phrases like, “We should check this with Martha,” or “What will Judy think about this change?” appear frequently in the data. The students lacked the confidence to override the teachers’ decisions or opinions or to challenge the premise, presented by the teachers, that the OSCSS and the Innovation Project were not inherently different from the formal classroom.

Another skill of innovation, collaboration, posed new challenges for the students as a result of their teachers’ involvement. According to Davis and Simmt (2004), static hierarchies cannot exist in complex groups. This notion was explained to the teaching staff, and, in fact, Martha was part of the teaching staff when the Innovation Project was first designed. It was understood that in order to create complexity, students’ roles would need to be fluid, and there could not be any hierarchy among or between teachers and students. Yet, in discussions with teachers and students, both Martha and Judy encouraged the students to designate particular roles, and students were encouraged to continue with the same role throughout the project. More damaging, for several students, their performance was valued differently by the teachers and the group. For instance, although Rebecca fulfilled the task assigned to her, her work was not considered to be of the same value as some of the others’ in her group. Not only was there a hierarchy imposed, but this hierarchy determined how the students perceived the value of each other’s contribution.

Finally, perseverance as a skill of innovation was imposed on students by the teachers, who insisted that the students continue working in directions that the students found fruitless. In fact, much of the discussion in Martha’s group centered on the frequency of meetings and the inability of the participants to move forward. However, this is precisely the type of perseverance that the OSCSS tries to dispel. The students had the same homework from their regular classes

that any high school student would receive. It was the intention of the Innovation Project to give students the opportunity to try something, fail, and be given sufficient time to try again, going through a process of iteration. Yet, in this research, both teachers use phrases like, “There is no time for that change” or “Let’s move on,” which prevented exactly the kind of failure students needed to experience in order to learn informally .

The conclusion is stark: the students were prohibited from participating in informal learning as intended, but the responsibility for this occurrence is less easy to discern. It is clear that the teachers assigned to these groups of students, and the students themselves, therefore, were unable to fully engage with the skills of innovation in the OSCSS setting. Hence, the sheer location of the OSCSS alone does not appear to fundamentally change the dynamic between teacher and student as was suggested at the outset. However, it is unclear whether this failure was the responsibility of the teachers, the students, or both, as the data are unable to assign relative responsibility.

What does seem clear is that the formal education system that the students and teachers had followed until their arrival at the OSCSS precludes experimentation of the type envisioned by OSCSS and its location. The students sought definitive answers from their Innovation Project group teachers. They looked for certainty that the Innovation Project was designed to circumvent. However, the teachers did not seem able to steer the students toward innovative practice; instead, they seemed to provide the students with the certainty that the students sought.

The premise, then, that the OSCSS is a special environment as a result of its location and philosophy does not seem to hold true. There is less of an intersection between formal and informal education than was assumed, and, in fact, there appears to be a formal school existing within, but oblivious to, the informal institution surrounding it. The OSCSS is a formal



secondary school, and its location does not in any way appear to change its operation. This formal school practice, despite being located within what was designed to be an informal setting, greatly impacted the Innovation Project's processes and outcomes, which, in the end, mirrored the formal classroom experience more than had been expected.

Surprisingly, this finding is not catastrophic to the current research. One of the intentions of the Innovation Project and this research was to explore the idea of introducing the Innovation Project in other schools. Although it is apparent that students did not engage as fully with the skills of innovation as had been expected, yet many of the circumstances and some of the student engagement actually made the Innovation Project creative and unique.

As Osborne (2010) points out, collaborative discourse in science education is a new area that requires further exploration. He differentiates collaborative discourse and argument from traditional science education that has teachers offering explanations rather than arguments. He contends that collaborative discourse and argumentation lead to improved learning. The Innovation Project was designed to capitalize on this insight.

The fact that the OSCSS operates like so many other classrooms in Ontario suggests that if the Innovation Project is worthy of replication, then it can be implemented more easily even if there is a change in venue. In other words, the Innovation Project, having occurred in what was virtually a formal classroom, could be replicated in other formal classrooms. This presumes that the Innovation Project is worthy of replication. However, although it is an example of collaborative discourse, the Innovation Project failed to take into account some of Osborne's (2010) strictures. In particular, Osborne (2010) stresses that students need to be taught the norms of social interaction and that the function of their discussion is to persuade others of the validity of their arguments. This clearly did not always happen in the Innovation Project. In the data, it

was clear that ideas were put forward, but arguments were not weighed, and rarely was any group member's mind changed.

Perhaps if, as a staff, we had reviewed collaborative discourse and effective argument with the students in advance of their undertaking the Innovation Project, then the results might have been very different. When the groups were designed to be complex, it was felt that any coaching of this type might interfere with the freedom we believed that the students required. If the Innovation Project were to be replicated in other classrooms, then Osborne's (2010) preparation of students in advance of group discussion would have to be implemented.

### *7.1 Research Questions Reviewed*

(1) *What knowledge do the students create together as they work in their group on the Innovation Project?* Attempting to answer this question revealed a challenging dichotomy that occurred within this case study. It was clear from discussions with the students and teachers that their respective expectations were different, and there were significant differences in their definitions of learning and knowledge creation. In particular, the teachers were interested only in scientific knowledge.

The Innovation Project was designed to meet the Ontario Curriculum; however, for the teachers involved, not all the objectives within this curriculum carry the same importance. Each unit within the curriculum is divided into three types of objectives: (1) relating science to society, technology, and the environment; (2) developing skills of investigation and communication; and (3) understanding basic concepts. Although the curriculum itself seems to follow these objectives in priority order, the teachers in the OSCSS, and, by extension, teachers throughout the province, place a special emphasis on the third set of objectives. Therefore, a unit, or a course, is said to be complete when all of the basic concept objectives, specifically number three, have been met. It

was this emphasis on basic concepts that created a difference in the idea of knowledge creation between teachers and the researcher in the Innovation Project.

The original design of the Innovation Project was specifically to examine the other objectives within the curriculum: relating science to society, technology, and the environment, and developing skills of investigation and communication. It can be argued further that students choose to attend the OSCSS precisely because they believe they will have a chance to engage with these other objectives in significant ways. A review of the students' views of the context of the OSCSS shows that they compared it favourably to their home-school experience and that they believe that OSCSS more closely resembles the real world. The difference the students expect, and, to some extent, enjoy is in emphasis. Through the Innovation Project, the OSCSS stresses the first two categories of objectives of the Ontario curriculum: relating science to society, technology, and the environment; and developing skills of investigation and communication; the formal classroom tends to stress the last, understanding basic concepts.

After the semester under examination, the teachers decided that the Innovation Project was not sufficiently rigorous. They wanted the students to be able to articulate not just what they had learned, but what they had learned in science particularly. In subsequent semesters, students were asked to complete a form describing the science that they had to research and master as they worked through the Innovation Project. The question specifically ignored objectives around values and attitudes and asked only about basic concepts with which the students had become engaged during the Project. This difference between the student and teacher expectations shows the very different possible answers to questions about the knowledge that students had created by participating in the Innovation Project.

If the knowledge created had to be basic concepts in science related to the grade 12 curriculum as the teachers suggested, then the Innovation Project was, for the most part, a failure. A review of the exhibits that the two groups created helps to explain this failure to engage with basic concepts in science.

The Haptic Touch group, working with Judy as their teacher, designed an exhibit in which a visitor to the museum would use a robotic arm to conduct a delicate operation, for example, assembling a structure. The group had learned about haptic touch, which is a form of feedback. The concept was that the robotic arm would carry information about its contact with objects back to the visitor performing the manipulation. This process would be similar to that of a surgeon performing an operation at a distance. Information can be visual, but there can also be information about the density, texture, and other characteristics of the material that would require physical contact in order to be determined. The process of carrying this information back to the surgeon through the blade is considered haptic touch, in which the individual located remotely receives the same physical sensation that the remotely manipulated robot would feel. This was an entirely new concept for the students, and one they were all able to articulate in the end.

However, haptic touch is not in the Ontario curriculum, and learning about it does not meet any of the objectives within the “understanding basic concepts” strand. For this reason, Judy, as the mentor teacher for this group, suggested that during the next semester, students should be required to articulate the basic concepts that they learned by going through the Innovation Project. Further, Judy thought that making certain that these basic concepts were a part of the Ontario curriculum would be an advantage.

Martha’s group, which worked on Driving While Distracted as its exhibit, encountered different criteria. This group’s exhibit was intended to imitate the experience of a person driving

a car through a city environment while distracted, perhaps due to texting. The design of the exhibit was to help visitors learn about changes in their own behaviour and their reaction time when distracted behind the wheel of a car. As in the previous discussion about a group meeting, however, Martha did not believe that this was science. In her opinion, the project would only be considered science if the students conducted the exhibit like a controlled experiment. Unlike Judy, Martha saw part of the science course as developing skills related to scientific investigation and not just about the basic concepts of the course. Like Judy, however, Martha believed in “royal science” mentioned earlier, and not in Deleuze and Guattari’s (2004) nomadic science. Martha, like Judy, found it difficult to allow the students space to make their own mistakes and to learn from them. This tendency is reflected in Osborne’s (2010) work, where he states, “Consequently science can appear to its students as a monolith of facts, an authoritative discourse ...” Osborne persuasively argues for a collaborative discourse instead, but this presumes that those in authority do not hold with the authoritative discourse.

In response to the question about knowledge creation, the students created knowledge about innovation and about the innovation process itself. They discovered their own ways to communicate as a group, eschewing the Wiki that had been set up for them and choosing, instead, to concentrate on Facebook, with which they were familiar. They developed a communal expertise in computer programs such as Google Docs, with which none of them had had experience with prior to the Innovation Project. The students navigated brainstorming and creativity within a group setting, and they created knowledge about setting parameters and consensus-building for use within the group. As mentioned, however, because this knowledge does not form part of the Ontario curriculum, teachers found it difficult to see it as worthy of a grade.

The conceptual basis for this research was that the knowledge the students created is rhizomatic. The Innovation Project groups were designed to be complex. When complex groups engage in knowledge creation, they create an emergent product, which is a rhizome.

*(2) How might the resulting rhizome be traced and mapped in order to be represented graphically and form an image of the knowledge created?* To answer this question, it must first be established that the conceptual basis of this research is true.

It has already been argued that in a number of significant ways, the Innovation Project groups were not complex. In particular, the groups had hierarchies, often imposed by the teachers associated with the groups, and, as a result, the interactions within the groups were not complex. It should follow, then, that knowledge creation within the group was not emergent; however, there is strong support that knowledge creation still occurred. This knowledge creation can be mapped and traced, as it is rhizomatic.

Was rhizoanalysis the correct approach to the analysis of data in this research? It is clear in the data analysis portion that much useful information could be gleaned from the communications among the students through Facebook that was not apparent through critical discourse analysis alone. The shape of the resulting maps, their density, and their flavour conveyed sense that could not be found otherwise. Again, as Masny (2013) says, sense emerges from the assemblage.

Delueze and Guattari (2004) argue that rhizomes are performative. The mapping and tracing of a rhizome represents the linkages within the rhizome, not the nodes, but the connections between the nodes. To use a metaphor, if one considers the Internet as a rhizome, mapping and tracing would delineate the linkages among computers, but they would not provide the information on the computers themselves. The students created a rhizome through their

communication with one another, and it was believed that these communications, these lines-of-flight and silences, could be successfully mapped and traced.

It has been argued that the Facebook threads of each of the two groups were the best source of data for mapping and tracing the resulting rhizomes. There were a number of reasons for this argument, but the two primary ones were the temporal nature of these data and the fact that there were no teachers involved in the discussions. It can also be seen that the Facebook thread is performative, that is, it was built by the students during their communication, or lack of communication, during the Innovation Project. Further, Facebook carries information about the flavour of the interactions, allowing not only for the researcher to perform the mapping and draw the linkages, but also to develop the tracing, which allows for a description of the nature of each link. These data would not have been suitable if any type of digital divide had existed among the students participating in each group. Due to the donation of smartphones, there was no such digital divide, and every student had an equal opportunity to participate. Every student involved in the project posted at least once.

In later research, as has been shown, Masny (2013) argues that the data used to map a rhizome cannot be coded in the traditional manner of critical discourse analysis. The rhizomes that were represented in this research were made from all of the Facebook data without distinction or coding. In this way, the research conforms to the mapping that Masny suggests.

*(3) Does this rhizome reflect the knowledge that the students have created through the Innovation Project?* It was discovered that the rhizomes accurately reflected the linkages among the students as they engaged in the Innovation Project. By ensuring that every individual Facebook communication was included in the analysis, the accuracy of the overall diagram could be assured. The flavour ascribed to each linkage was also reflective of the intent of the posts,

though here it was dependent on the students' recognition that this flavour attribution was accurate. The rhizome, then, reflects the knowledge that the students created.

A further inquiry is more difficult to answer and involves a personal bias. When this dissertation was proposed, the outcome of each of the Innovation Projects was assumed to be a rhizome, and, therefore, a method of mapping and tracing that rhizome had to be determined. It can be reasonably argued that if a different philosophical premise had been used, a different representation would have resulted. In essence, one is bound to see a rhizome if one is looking for a rhizome.

However, the students had not been given any information about Deleuze and Guattari (2004) and had not been told that a rhizoanalysis was being conducted from the data collected. In other words, if the students had recognized their knowledge creation through the rhizomes that had been mapped and traced by the researcher, then something fundamental might be concluded about their accuracy, for the students did not share my personal bias that their knowledge creation could be delineated as a rhizome.

I have since shared the resulting rhizomes with members of each of the groups. I did not have permission to share their responses beyond the following conclusions. Of the students asked, they recognized universally the honesty of the rhizome and its accuracy. They were also surprised sometimes by the flavour of the communications, not because the students thought the flavour false, but because they did not remember having participated in the way depicted. It must be remembered that many of the students' recollections about their roles were different than how those roles appeared in the rhizome. The students recognized their Innovation Project and their knowledge creation in the rhizome.



Critically, it has been demonstrated that there is knowledge to be gained from delineating the rhizome that could not have been gained in other ways. Through this visual display of the data collected from Facebook, I was able to draw conclusions about the students' engagement in the Innovation Project and the ways in which they had worked together that were not clear from interviews or from merely conducting a critical discourse analysis of the Facebook data.

This case study has several implications for future research. I have demonstrated that rhizoanalysis is an effective method of delineating and representing student group interactions. I was disappointed to discover that there was less of a distinction to the OSCSS than its location inside the Ontario Science Centre would imply. However, as noted, this means that the Innovation Project could well become part of the curriculum in other high schools, as its implementation did not require a special environment. I believe that these new incarnations of the Innovation Project in different environments would make fertile data sources for further analysis.

I have also demonstrated that teacher training around the implementation of the Innovation Project is needed. Although the groups had been created with knowledge of Davis and Simmt's (2004) ideas about complexity in the classroom, formal science teachers involved in this research found it impossible to allow a group to remain complex and without control. In their different ways, Judy and Martha managed to suppress complexity. I am confident that different results would have been obtained had it been possible to create an Innovation Project that would be assigned a grade but did not require the mentorship of a teacher.

It is also clear through the work of Osborne (2013) that education about collaborative discourse and effective argumentation would have improved student interaction. However, as

noted, teachers in the OSCSS require this education as much as the students do, if not more. The teachers appear to be firm believers in what Osborne (2013) calls authoritative discourse.

If I were to repeat this research, there are several steps that I would have conducted differently. First, I would have sought research permission from the students earlier. It would have been interesting to have discussed with the students the implications of the Innovation Project from the very beginning of the semester, when they were first learning about the OSCSS. Instead, their first interviews occurred after a month of the semester had passed. By this time, many of the students already had knowledge about the workings of the OSCSS and the Innovation Project. This delay may have changed the data in significant ways.

Had I known before the commencement of this semester that smartphone technology would play such a critical role in the overall design of the Innovation Project, it might have been possible to encourage the students' use of smartphones in different ways. In later semesters, the students were encouraged to engage with existing exhibits in the Ontario Science Centre, and they built smartphone applications to facilitate this engagement. This would have been an excellent and achievable added goal to the Innovation Project, and it would have presented a new realm of discovery, as the students created knowledge in development of the application.

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## Appendix: Pre-, Post, and Meta-Interview Questions

### *1. Pre-project Interview (Before commencement)*

#### Group Work:

What is your preferred model of group selection: random or chosen?

What role do you normally fill within a group? Is it the same every time?

Do you work well in groups, or do you prefer to work alone?

#### Knowledge Creation:

What does it mean to learn?

How do you know when you have learned something?

How do you usually share new knowledge you have with others?

#### Methodology of Project:

Are you familiar with brainstorming?

Have you used Wikis and other social media in your course work in the past?

### *2. Post Project Interview*

#### Group Work:

What role did you play in the Innovation Project group?

How would the Innovation Project group work have been different if you had not been a member?

How did you find the group dynamic?

#### Knowledge Creation:

What did you learn by doing the Innovation Project?

How much did you learn from group members? How much from yourself?

How did you share knowledge that you learned through the Project?

### Innovation Project Methodology:

Was group brainstorming a successful approach for the generation of ideas?

How did you use Wikis or social media through the project?

Did you find that electronic communication were as successful as face-to-face interactions, or more so?

### *3. Meta-interview*

These questions will be generated by responses to earlier interview questions and reflect the students' perception of the research process in the Innovation Project.