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**'I'm a consumer, I'm not a scientist': Cultivating Student Domain Identification,  
Agency, and Affect through Engagement in Scientific Practices**

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**Abstract**

‘I’m a consumer, I’m not a scientist’: Cultivating Student Domain Identification,  
Agency, and Affect through Engagement in Scientific Practices

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This study investigates the potential benefits of redesigning hands-on, commercial inquiry science kits for fifth grade that afford agency and the development of science identities by leveraging youth’s interests, personal or shared concerns, challenges or desires. Science identification is considered in relation to learning processes of being, becoming, knowing and doing. As identities are constructed dialogically through engagement, emotion, intentionality, innovation, and solidarity, students’ agency is mediated and conceptualized as it develops in practice. The study is introduced in Chapter 1 by acknowledging how agency and identity are

constructed from an ideological frame, thus problematizing the current neo-liberal policies undergirding educational reform. The conceptual argument in Chapter 2 outlines a theoretical synthesis of agency and learning. Subsequently, I leveraged a theory of semiosis to highlight how these perspectives on agency and identity contribute to the meaning-making processes of language, culture, and mind. Finally, conceptualizations of agency and identity are mapped to the sociology of scientific knowledge perspective. Chapter 3 situates the study context within a design-based implementation research model where the existing science curriculum units serve as comparisons (Inquiry group) to the experimental units (Agency group). The findings first demonstrate how student and teacher positioning are revealed during the turns of exchange by using functional grammar as a method to analyze how discourse works to construe experience and enact social relationships. Secondly, I analyze youth positioning across conditions highlighting the importance of raising student consciousness to the variegated ways scientists practice science and inducts students into how scientists intentionally and purposefully employ genres to engage in scientific ways of communicating. Student's perspectives, positioning, and emotional investments are then analyzed using appraisal analysis to show how students talking about their images of science yield different ways of knowing and dispositions in science. Thirdly, by tracing the inclination and obligation of doing science, I illustrate how subjectivity versus materiality/objectivity in science impact how students perceive science. Fourth, student images of science, ways of identifying with science and having agency in science are analyzed using a thematic analysis to identify patterns and emerging themes. Next, I assess students' developing understanding of scientific inquiry using HLM to determine whether the Agency units versus the Inquiry units predicted students' learning outcomes based on the inquiry assessment. Finally, I discuss the implications of these analyses. This study accounts for how

youth develop practice-linked identities in science entails the fleeting identity performances and language choices made for and by youth in the science classroom. Central to this notion of identity is agency where positionality as well as material and symbolic, interactional and situational resources constrain or enable identity development. In a learning context, these choices and values inherent in language use are relational to learner agency outside of language, but ensouled in performative curating where solidarity, intention, creativity, emotion, accountability, anticipation, cognition, and rewards enable the capacity to transform the self, others, and communities. This dissertation demonstrates how design features embedded in curriculum related to personal relevance and the societal context for science affords teachers to engage youth in agentic science learning in the classroom in ways that become more meaningful and supportive of science identification than traditional inquiry approaches to teaching science.

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## **DEDICATION**

To the spectacles of struggling

## Chapter 1 Introduction

We want students to develop a critical consciousness with respect to the context, where they have the capacity to transform their realities, and they are positioned as a growing member of a community with expanding and changing roles and responsibilities (Freire, 2005). To effectuate this perspective on agency and student's developing identities we need to firstly acknowledge how agency and identity are constructed from an ideological frame, thus problematizing the current neo-liberal policies undergirding educational reform. Secondly, I conjecture that if we wish to operate under a mode that supports learner identities and agency as mediating equitable science learning, we need to acknowledge our 'human condition'.

By means of an analogy, I refer to André Malraux's novel *La Condition Humaine* to unpack Freire's (2005) reformulations of human experience in the unfolding of modernization, where the emergence of the change agent engenders critical reflection, and so precipitating our "naïve consciousness" to a "critical consciousness". In other words, Malraux's 'human condition' is situated in a time of modernity where human agency is conditioned and contingent by the material relations of production through intentional action, which constitutes awareness for material contingency, one's rights and responsibilities stemming from our moral and ethical values, and self-reflection. Developing critical consciousness, in this view, entails practicing reflexivity. This dissertation investigates ways to cultivate student domain identification, agency, and affect through engagement in scientific practices.

My perspective, as a participant observer, within the classroom was critical and reflective for understanding learner agency, identity development, and sense-making. A critical stance yields possibilities for understanding the ontological relationship, which binds a students'

emergent critical consciousness - anchoring agency and identities - to knowing, emotion, and performativity in the context of the science classroom and beyond when it is made visible.

Correspondingly, I subscribe to Freire's central concern for people that, as Denis Goulet describes (Freire, 2005: xii), "rules out any policy, program, or project which does not become truly *theirs*." In another way, to know, as a researcher and community member, means to "problematize" in a manner that raises critical consciousness and engenders reflection.

Encouraging dialogue and reciprocity opens up the role of learning partners, which begins to address the part-whole issue by valuing, respecting, and meaningfully acting on student's repertoires of practice. The discourse of transformation, thus, "rules out" identifying attributes such as "recipients" or "consumer".

Freire's (2005: 80) lived experiences with educational reform, as described by Jacques Chonchol, led him to conclude, "all development is modernization, not all modernization is development." As an example, Vandebroek and Bouverne-De Bie (2006) argue that persuasion is construed as a highly valued skill in formal and informal contexts. Student's engaged in successful negotiations are positioned as authoritative because, as a coveted skill, it encompasses attributes of student agency such as autonomy and personal responsibility, critical thinking, active learning, social action, creativity (Vandebroek & Bouverne-De Bie, 2006). These attributes of power and control are, however, dominant socio-cultural constructions that emerge from white, western ways of thinking. Consequently, Tobin (1995 as cited in Vandebroek & Bouverne-De Bie, 2006) asserts that persuasion operates in a marginalizing manner where entitlements privilege an already privileged group of students. To this end, Vandebroek & Bouverne-De Bie contend it is a social reproduction of power and control where western values and norms are socially accepted forms of normative behavior and thus

expressed as benefits. From a political and social perspective, persuasion and student agency are perceived as distillations of democracy, globalization, and the state welfare. In most cases, socioeconomic interests and concerns become subject to education and personal consequence, underscoring as De Rijcke (2003 as cited in Vandebroek & Bouverne-De Bie, 2006) states, a preference for “individual autonomy over interdependency.” As a result, reform, viewed as mobilizing economic activity and international competitiveness comes with its own set of issues – of particular concern is that “we are wont to believe that education contributes to democracy.” (McGinn , 1996: 346 as cited in Welch).

From another perspective, Welch (2001) argues that as governments make structural adjustments there is an increased participation in education but a decline in social and political participation. The rapid development and deployment of communication technologies, such as the Internet and the use of iPhones to carry out everyday functions, restructures participation in ways that are isolating, which as Giddens (1999 as cited in Welch) suggests produces “action at a distance”. Stiegler (2014: 11) critically adds that these developing dispositions in society are a result of ‘technologies of control’ that operate as a “massification of behaviors of production and consumption.” Consequently, research is beginning to show that there is a decline in real-life social relationships among users spending more time online, which impacts emotional and social skills (cf. Engelberg & Sjöberg, 2004). Emerging research in neuroscience on the intersection of emotion and consciousness is highlighting the essential role brain structures have in regulating consciousness<sup>1</sup> and emotion<sup>2</sup>, and that there is a close association between consciousness and self-representation (cf. Tsuchiya and Adolphs (2007).

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<sup>1</sup> Consciousness is characterized as *level*, meaning coma, wakefulness, and *content* (what we are conscious of). (Tsuchiya & Adolphs, 2007)

It is apparent that these socioeconomic repercussions of “modernization” have a potentially deleterious effect on our emotions, agency, and identity. As an advocate for *true* transparency and for social justice, it is not my intention here to lambaste “modernization” and suggest a restructuring of structures. Moreover, as an adherent of existentialism, it is only a self-defeating act especially when we are operating under a system of “100 years of tradition unhampered by progress.” Similarly, Alice Goffman’s (2014: 196) ethnography illustrates this sense of sequestered agency by concluding “to be on the run is also to be at a standstill.” The implications drawn show that one’s agency is never separate from the structuring structures (cf. Giddens, 1979). Raising awareness of the role of consciousness and as it relates to our emotions, cognition, identities and agency needs to be considered from the perspective of transformation starting with the self.

Concomitantly, Thomas (1993) argues that features such as critical thinking, essential for evaluating how accepted ways of knowing modify consciousness into intellectual re-examination and social action is a neglected area of research. Moreover, science education research has underplayed the esthetics of science and learning, although scientists attest to the central role of an esthetic dimension in their work (e.g., Wechsler, 1977; Tauber, 1996); and the affective dimension of science, student agency, learning, and identity. For example, Traweek (1988: 82) evinces how novice physicists learn to “live and feel physics,” highlighting emotional qualities and esthetic judgments as essential for *doing* physics, for *becoming* a physicist.

Notions of affect, agency, identity and learning are situated in cognitive and cultural dimensions. Therefore, learning environments designed for agency foster practice-linked

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<sup>2</sup> Emotion, as an emotional state includes emotional response (Tsuchiya & Adolphs, 2007).

identities as students destabilize the disruptive negative cycles that are constraining to their *consciousness*, learning and emotion, their identities in science, and their capacity to be intentional and creative for critical interventions. Emotional investment opens up the space for playful experimentation and may affect how students align and self-identify with scientists. Consequently, I conjecture that student agency highlights the degree to which science excites, motivates, or changes the choices students make in their everyday lives in relation to a developing understanding of science knowledge, processes and practices.

## 1.1 Synopsis

This dissertation is situated under a broader research and development project for understanding how we can design inquiry-based curricula for teacher and student agency. Chapter 1, addresses agency, identity and sense-making from an ideological frame. In Chapter 2, I outline a conceptual argument focused on defining and selecting a view of agency that can be used to design for learner agency in classroom environments and interpret the actions of learners and teachers in that kind of setting. In Chapter 3, I address and demonstrate the potential benefits of designing learning environments for student agency and the development of science identities that leverages youth's interests, personal or shared concerns, challenges or desires. The analyses examine how systematic changes from our third iteration influenced learning, practice, agency and identity development in the redesigned curriculum materials that are guided by learning principles (the Agency condition), and comparing it to classrooms using the original commercial curriculum materials (the Inquiry condition). Consequently, using Halliday and Matthiessen's (2004) functional grammar as a method to analyze how teacher and student discourse works to construe experience and enact social relationships, the findings section reports on (a) the social

and material divisions of labor in teacher instructional framings; (b) youth positioning across conditions where I first present a case study showing the relation of the curriculum genre to science learning with agency, and then a representative episode of the inquiry condition; as well as students' affective engagement in science; (c) how students understand science where I analyzed student interview responses from an etic stance, focusing on students' perspectives on science at school and outside of school, their science experiences and how they related to their learning, the enterprise of science and their identification with science over the course of the intervention as well as a representative classroom episode from the Inquiry group to demonstrate how participation in science stems from students' emotional investments as they engage in scientific practices; tracing the inclination and obligation of doing science where I examine the functions of directives in teacher and student talk; (d) findings from an emic perspective using *T-Lab* version 9.2 (Lancia, 2012) to execute automated thematic analyses on students' perceptions of science in relation to their identities and agency; and (e) the results of students' learning outcomes based on scientific inquiry assessments by using Hierarchical Linear Modeling. The final section discusses the conclusions and implications from the findings.

## 1.2 References

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## **Chapter 2 Invoking Agency after 100 years of tradition unhampered by progress:**

### **Understanding Agency in elementary science classrooms**

Agency in general is concerned with what people say, do, or experience in the world. In every discipline, such as sociology, linguistics, anthropology, the conceptualization of agency remains variable (Ahearn, 2001; Emirbayer & Mische, 1998). Different views of agency as well as different modalities of agency (i.e., how it can be understood to manifest in the world) have their affordances and limitations when we want to design learning environments to support learner agency. Agency has been associated with selfhood, motivation, will, purposiveness, intentionality, choice, initiative, freedom, or creativity (Emirbayer & Mische, 1998). Given the broad range of associations to ‘agency,’ there is no distinct theoretical dimension. Emirbayer and Mische point out that these associations are often bound to structures, which in Giddens’ definition (Giddens, 1979, 1984) refers to rules and resources—that we cannot see how agency shapes social action.

Thus the notion of agency is not only “an elusive, albeit resonant, vagueness” (Emirbayer & Mische, 1998) in theory, but in practice it becomes a challenging act for the teacher when she treats learner agency as a way to think through her students’ capacities to take action and to think of the multiple ways they have been and “are actively involved in emergent, innovative, experimental, and substantive forms of solidarity and coexistence” (Oswell, 2013).

This paper is a conceptual argument focused on defining and selecting a view of agency that can be used to design for learner agency in classroom environments and interpret the actions of learners and teachers in that kind of setting. I begin outlining different, major theories that inform how one might design learning environments to support learner agency. Firstly, a sociological perspective provides an understanding of the relationship between structure and the

various modalities of agency. Emirbayer and Mische (1998) show how we can locate, compare, and predict the relationship between agentic differences. Next, I discuss agency from a socio-cognitive perspective as well as from a cultural anthropological approach. In the former, Damşa, Kirschner, Andriessen, Erkens & Sins (2010) explore agency from a collaborative perspective and define agency as epistemic and regulative. In the latter, Holland, Skinner, William, & Cain's (2001) notion of figured worlds, which takes a macroscopic semiotic lens, situates agency as a capacity and process that is shaped by human action by mediating behavior through reflection. These perspectives provide an understanding of agency from social, epistemic, and semiotic perspectives.

Next, the *Cultural Learning Pathways Model* (Bell, Tzou, Bricker & Baines, 2012) is used to show how agency is invoked in learning environments where agents “construct, leverage, repurpose, and transform social and material arrangements in order to provide meaningful, cross-setting connections related to their goals and concerns.”

The kinds of agencies I am advocating for draw on these various perspectives of agency. The way in which agency is operationalized in Action Theory and Practice Theory where it requires intention, motivation, responsibility, and or expectations of recognition or rewards is one aspect. In addition, as will be highlighted in the *Cultural Learning Pathways Model*, identity and learning across situated events and time are constitutive of learner agency. Engaging students in consequential, authentic scientific work where the content is resonant and transferable to their lives and relevant to choices involving social action (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2012), enables students to subject their own agentic orientations to imaginative transformations and critical judgments. Consequently, by repositioning and reframing their relationship to the enabling and constraining contexts, students develop *greater*

*capacity* for creative and critical intervention. Consequently, I conjecture that student agency highlights the degree to which science excites, motivates, or changes the choices learners make in their everyday lives in relation to a developing understanding of science knowledge and practices.

Building on these perspectives on agency, I take Ahearn's (2001) position where we need to examine the ways in which agency is constituted by the norms, practices, institutions, and discourses through which it is made available. I draw on social semiotics and a theory of meaning making to show how the various modalities of learner agency contribute to the meaning-making processes of language, culture, and mind. Peirce's notion of the sign, object, and interpretants are viewed as a series of integrative levels, which include the iconic, indexical, and symbolic modes of reference. I take Kockelman's (2013) theory of meaning approach to explain how these three dimensions of meaning-making conceptualize learner agency from a systemic functional linguistics perspective, drawing particularly on Halliday's functional grammar (cf. Halliday & Matthiessen, 2014). Thus agency in language is discussed in relation to social semiotics—as I outline at the end of this paper.

## **Part 1: Developing a Theoretical Synthesis of Agency and Learning**

### **2.1 Literature Review of Agency Across Disciplinary Perspectives**

#### *2.1.1 A Sociological View of Agency*

When identifying the conceptions of agency, we see how it is operationalized in different theories. For example, in Action Theory, where action is distinguished from an event, agency requires intention, motivation, responsibility, and or expectations of recognition or reward.

Holland et al. (1998) explain that active engagement in an activity occurs with meaningful intent with the environment. Ahearn (2001) points out that when agency is viewed as having intention-

in-action (Davidson, 1980 as cited in Ahearn, 2001), it often ignores the social nature of agency and the influence of culture on human intentions, beliefs, and actions.

Another way agency has been operationalized is through Giddens' (1979, 1984) structuration theory. Drawing from Garfinkel and Goffman (interactionist sociologists), where they highlight the ways in which social structures come into contact with human actions. Agency is linked to structure that are rules and resources related to actions. Giddens (1979, 1984) shows that people's actions are shaped (both in constraining and enabling ways) by the social structures that those actions then serve to reinforce or change. Giddens locates agency in the recursive implementation of structures by human actors (Emirbayer & Mische, 1998). Actions can be influenced by social structures and social structures are constantly recreated by actions (Ahearn, 2001). For example, in one of the Agency design units, *My Solution to Pollution*, which was implemented in the last trimester of the year, during one of the experiments students were expected to find out which of the three samples given to them from the teacher had the most concentration of pollutants. Students were provided with several materials (such as, scale, filters, weights) in which they selected in order to design a strategy for solving which sample had the most pollutants. During the experiment – an example of Pickering's (1995) notion of “reciprocal tuning”, a group of four students attempt to balance a scale as they use weight to measure their sample. During this “bridging” (Pickering, 1995) activity, which is instigated by the object – the scale – student's display “filling” (Pickering, 1995) moves as they attempt to balance the scale with weights. However, during these “filling” moves, one of the students touches the scale with her hand to reposition it. Another student tells her not to touch the scale with her hand because “it is cheating” (PolSol, PB\_130509\_G2). This example illustrates how the school science practice of not touching or tasting the materials during experiments disables

one from accommodating for the materials from one's frame of reference. Thus the structures of school science practices structure students' frames of reference when handling materials in a constraining way.

Finally, agency in Practice Theory draws on Bourdieu's (1977) notion of habitus. Habitus creates an infinite but bounded number of possible actions, thoughts, and perceptions, each having a culturally constructed meaning and value. These actions, thoughts, and perceptions then recreate and or challenge the culturally constructed meanings and values. Here, habitus is seen as a generative process yet the produced practices and representations are conditioned or bounded by the "structuring structures" from which they emerge. The practices and representations can be considered intended or unintended, which reproduce or change the habitus. For Bourdieu, our infinite thoughts, meanings, and practices, which are produced by the habitus, are constrained because we are predisposed to think and act in a manner that reproduces the existing system of inequalities. A shortcoming with Bourdieu's framework is that it makes no room for resistance or social change. However, it does explain the persistence of embedded relations of inequality. Giddens' structuration theory and Bourdieu's notion of the habitus in agency do not show how any habitus or structure can produce social change. Sewell (1992 as cited in Ahearn, 2001) argues that we cannot see how social reproduction becomes social transformation.

A sociological view of agency draws on Bourdieu's habitus and Giddens' social structures as well as tenants from Practice Theory. Emirbayer and Mische (1998: 964) provide a detailed account of how we can understand human agency. They focus particularly on how the structural environments of action are both dynamically sustained by and also altered through human agency. A sociological perspective examines changes in agentic orientations. Emirbayer

and Mische place emphasis on social actors and their relations to the constraining and enabling contexts of action. All forms of agency are temporally embedded in the flow of time, so by examining changes in agentic orientation, Emirbayer and Mische claim one can trace the variability in one's maneuverability, inventiveness, and reflective choice. Thus, they define agency as "the temporally constructed engagement by actors of different structural environments – which, through the interplay of habit, imagination, and judgment, both reproduces and transforms those structures in interactive response to the problems posed by changing historical situations" (1998:970).

When we unpack this definition of human agency, Emirbayer and Mische (1998:970) show three elements of agency embedded in the flow of time: (1) an iterational element, (2) a projective element, and (3) a practical-evaluative element. This chordal triad of agency occurs within a cultural context, a socio-structural context (social networks), and a social-psychological context (psychical structures related to emotional energy). As these elements come into play, actors are positioned in a temporal trajectory where there is a continual reconstruction of their orientations towards the past (iterational) and future (projectivity) in response to emergent events (practical evaluation). Thus, a science learner might draw on his/her previous experience and everyday, routinized ways of doing things across contexts to interpret and/or evaluate the current context. For example, the following utterance from a student in the Agency design group, *My Solution to Pollution*, illustrates how she orients towards her past experiences and future projections during a science experiment:

*Are we pretending cos I think I know which each one of them are. This is tap water. This is like umm mineral water and this is like salt water.*

This example of a proposition as an idea clause shows the Process is mental as it expresses meaning. The use of an indirect question, “Are we pretending”, shows that the student questions the status of the validity of the information. Halliday and Matthiessen (2004) state that indirect questions reveal an “undecided” state of mind, where in this instance, the student is doubtful about the authenticity of the samples (that is, real water samples from a local creek). Given this expressed doubt, from a semantic perspective the students’ experience of the in/accessible materials in her science class is rekeyed to mean something particular for her – perhaps that it is unlikely to obtain creek samples in school science. Meaning is thus dependent on mental processes. Subsequently, the student puts forward a claim, which she holds with asseveration by establishing a pretense.

So, returning to Emirbayer & Mische (1998) notion of a temporal trajectory in human agency, the use of the aspectual marker in “pretending” combined with the perfective tense indicates non-completion of the action that is in progress. The progressive aspect also conveys a particular or limited meaning where the student projects her subjective orientation, which is metaphorical as it represents an interpersonal assessment of modality and is expressed by the adjunct in the clause that expresses the preposition. Subsequently, the meaning potential of the proposition expands because of the relationship between modality and projection. Halliday and Matthiessen (2004) explain that modality and orientation expands when it is made explicit in wordings such as “I think”. As a result, they claim that modal assessments are interpreted as interpersonal projections. The student, as “projector”, expands on her proposition as indicated in “I think”, which, as a case of modalization, is made explicit because the subjective orientation of the student is “experientialized” and “neutralized as facts” (Halliday & Matthiessen, 2004: 629).

In sum, the interpersonal metafunction defines the environment because interpersonal metaphors are made explicit when a probability is expressed by a mental clause that projects the modalized proposition. Moreover, Halliday and Mattiessen state that interpersonal metaphors are supported and tested in the here-now. Therefore, the knowledge and experience the student has regarding access to authentic materials in her science class rests on past events, current circumstances, and projected imaginings. Each moment is marked with an orientation, a temporal perspective or “horizon” (Goffman, 1974:134).

The *iterational element* is akin to Bourdieu’s *habitus* where actors selectively reactivate past patterns of thought and action. These past and repetitive patterns of thought and action are routinely incorporated into everyday activity, thereby establishing stability and/or one’s *lifeworld*. This enables actors to sustain identities, interactions, and institutions over time (Emirbayer & Mische, 1998: 971). Agency lies in the recursive implementation of structures. Science time at school exemplifies the iterational element where at the beginning of science time, the teacher will review the activities from a previous science lesson, orient students to the goal of the science lesson, and establish ways of organizing and presenting information. For example:

*Teacher:       The next thing is this, listen Scientists. So, as a team you get to decide on a strategy...okay a method to do something. In order to figure out which solution is the most concentrated.... So, what I'm going to let you do is design the procedure to find out...*

Several aspects in this teacher set-up exemplify the iterational element. Classroom dialogue, for example, exposes the power relations that are embedded in teacher-student interactions where

the teacher has the authority to set-up the challenge for the students. Power relations are also embedded in the authority of science where there are particular ways of doing and talking science. Thus, the scientific enterprise can be viewed as a structuring structure and a structured structure. Students are navigating several structured structures simultaneously, such as the normative practices of school, the established scientific practices and those of school science, as well as the authority of the teacher. This example of the iterational element illustrates how science practices can be meaningful when students embody those practices. As students navigate several structured structures, they are concurrently structuring structures. Instead of the teacher setting-up the procedure, which is a common school science practice, students are given the capacity to “design the procedure”.

The *projective element* of agency is when actors imagine their possible future trajectories of action. Actors’ thoughts and actions are creatively reconfigured in relation to their hopes, fears, and desires for the future. Agency lies in the “hypothesization” of experience, meaning actors will reconfigure received schemas by generating alternative possible responses to the problematic situation (Emirbayer & Mische, 1998).

The *practical-evaluative* element of agency is when actors make practical and normative judgments among alternative possible trajectories of action, in response to the emerging demands, dilemmas, and ambiguities of presently evolving events. In other words, actors experience a problem where they need to deliberate before making a choice through consideration or planning. Then, actors are able to execute their choices to resolve the problem. The following example illustrates how a group of students plan to repurpose an object in light of the results from a previous experiment in science:

*Student: What we were thinking was we're going to take off the cup with the circle that we put one liter of water in, and we're going to put the one liter of water in a plastic baggie...we're going to poke holes, and then it's going to represent rain and it's going to be on site 1.*

Emirbayer and Mische explain that an actor's relationship to the past is based on characterization of a situation against past patterns of experience. Thus, the science learner found from previous experiments that using a 'water source'<sup>3</sup> in the stream-table creates a single stream. Being unsatisfied with the previous results, students decide to model rain using a plastic bag with holes poked in it so that water is dispersed evenly in the stream-table. An actor's relationship to the future is characterized by deliberation over possible trajectories of action. Deliberation may include emotional engagements. Actors may increase their ability to exercise agency when they practically evaluate a situation. In turn, Emirbayer and Mische contend that actors are able to pursue projects that may challenge and transform the situational contexts of action themselves.

These three elements of agency highlight differences in human action when we understand the relationship to the past, future, and present. Agency is also always a dialogical process by and through which actors immersed in temporal passage engage with others within collectively organized contexts of actions (Emirbayer & Mische, 1998). Giddens and Bourdieu do not show how schemas can be challenged, reconsidered, and reformulated; however, Emirbayer and Mische reveal how we can do so from a sociological perspective. From this

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<sup>3</sup> A water source is a container with a small hole on the underside. It is used during classroom experiments with stream tables to represent a flood or rain.

perspective, agency is never separate from structure and Emirbayer and Mische show how we can locate, compare, and predict the relationship between agentic differences.

In summary, a sociological perspective focuses on actors and their relations to the constraining and enabling contexts (structures) of action. While Damşa et al. (2010) also draw on Emirbayer and Mische notions of agency; they look at agency from an epistemic and regulative dimension, which I will elaborate on below. The difference between the two perspectives is that a sociological perspective looks at how the structural environments of action are changed or sustained through human agency. Since agency is never separate from structure, we can see from a sociological perspective how an actor in any context switches between their temporal orientations and is thus capable of changing their relationship to structure. Structuring structures establish practices dialectically and relationally. In the context of science learning, a socio-cognitive perspective of learner agency expands on the sociological perspective by addressing learner agency from an epistemic perspective and highlighting actions and processes involving knowledge and knowing, which is missing from a sociological perspective. An account of shared epistemic agency in science learning shows the stance a learner takes as he or she judges the validity of an assertion or proposal. Therefore shared epistemic agency becomes relevant as it shows how a learner gives prominence to their point of view or a fact.

### 2.1.2 *A Socio-Cognitive Perspective: Shared Epistemic Agency*

Damşa, Kirschner, Andriessen, Erkens & Sins (2010) take a learning sciences perspective when characterizing and operationalizing learner agency. Because there are different modalities of agency, Damşa et al. (2010: 149) draw on Scardamalia (2002) and Scardamalia and Bereiter (2003) knowledge-building communities and characterize agency as epistemic. The authors consider agency to be epistemic when students are engaged in intentional, goal-directed, and

sustained involvement in knowledge-driven, object-orientated, collaborative activities.

Students are primarily engaged in activities involving knowledge and knowing. Students are also viewed as responsible for what they themselves know and that knowledge arises from choices for which the student is responsible (Reed, 2001 as cited in Damşa et al, 2010). Damşa et al. (2010) highlight two types of actions and activities that are related to epistemic agency: knowledge-related actions and activities and process-related actions and activities. These actions and activities are mapped generally to a challenge-based science curriculum, *My Skokomish River Challenge (DRK-12) – an Earth Science unit*, which was designed for learner agency - as a way to illustrate how they may function in learning environments (Damşa et al. (2010) actions are italicized): The unit exhibits various dimensions of epistemic and regulative agency. As a result, I will briefly illustrate each action – as a dimension of epistemic or regulative agency - relevant to the sequence of the unit.

Throughout the unit many of the activities, as dimensions of epistemic agency, have *generative collaborative actions*. Learners are constantly producing, sharing, and revising their ideas either verbally or in their science journals by documenting evidence and the resultant decision. Initially, learners are introduced to a challenge by means of *creating awareness* and sparking interest to invite inquiry. Next, learners make informal and formal connections by exploring erosion and deposition – a knowledge-related activity where learners begin *gathering information and structuring new concepts*. Learner explorations in erosion and deposition then get situated in a local context, the Skokomish context. This type of knowledge-related activity establishes a *shared understanding* and newly acquired concepts and processes are *given meaning*. The next phase of the unit entails student-led investigations. The regulative dimension of agency during student-led investigations necessitates *projective actions* where learners *set*

*goals, plans, and engage proactively.* *Projective actions* orient agency towards future courses of action and they can be identified in practice when students show their intentions to actively engage in an activity, they set goals, make plans of actions, and display proactive attitudes. Projective actions can be characterized by the use of modals, such as “could”, “would”.

As learners conduct additional fair-test experiments during the investigation phase, they *coordinate* roles during experiment set-up and *monitor their materials* by observing how a manipulated variable, selected collaboratively by a group, will have an effect on erosion and/or deposition so that, based on all their gathered information, they can decide on which site to choose. These coordinating and monitoring group activities are called *regulative actions*, which also are characteristic of regulative agency. Students show responsibility for their learning through monitoring the advancement of collective activities and overcoming challenges emerging in the process. In the unit, the ‘Mitigation’ phase succeeds and is informed by the investigations. Consequently, learners design a strategy to mitigate for erosion. The culminating activity of the unit is the ‘Go Public’, meaning students put together a presentation that communicates their findings and final decision for site selection to an audience. The *social* aspects of the ‘Go Public’ encompass *relational actions*. Agency is located when students mediate problem-solving, create shared conceptual structures, or mutually construct knowledge.

Damşa et al. (2010) view of epistemic agency encompasses epistemic and regulative processes, as illustrated above. They elaborate on these processes by introducing the concept of *sharedness* to epistemic agency. Sharing generates certain collaborative strategies, happens in a community and with an interdependency of partners (Barron, 2000), and is triggered by actions that occur in collective settings (Matusov, 1996; Wertsch et al., 1995). Damşa et al. (2010) define this type of agency as *Shared Epistemic Agency*. It involves coordination of actions and

contribution to the joint venture (Akkerman et al., 2007; Matusov, 1996) driven both by common goals and by disagreements (Matusov, 1996).

Shared epistemic agency is regarded as “a capacity that enables groups to deliberately carry out collaborative, knowledge-driven activities with the aim of creating shared knowledge objects. It designates the epistemic work—including the productional, intentional, and intersubjective character of the collaborative activities taking place during knowledge object creation” (Damşa et al., 2010). The authors claim that groups displaying higher degrees of agency have a greater potential to engage in knowledge creation.

These views of agency may be exposing the limitations of students’ ideas; they may be limiting in reproducibility, that is, by keeping an abstract or conceptual focus and down-keying a rigorous, systematic approach to analysis when we want to examine how the redesigned curriculum units influenced learning, practice, and identity development. Finally, they highlight the dimensions of learner agency that help researchers understand how to conceptualize and operationalize various modalities of agency through time scales.

In my view, agency is related to notions of identity and learning as situated in cognitive and cultural dimensions. The learning environments we have been designing to support learner agency promote the development of practice-linked identities, which enables students to: destabilize the disruptive negative cycles that are constraining to their learning, cultivate their identities in science, and increase their capacity to be intentional and creative for critical interventions. Ahearn (2001) argues that we need to examine the ways in which agency is constituted by the norms, practices, institutions, and discourses through which it is made available. I draw on the Cultural Learning Pathways Theoretical Framework (Bell, Tzou,

Bricker & Baines, 2012) to make visible the ways in which agency is invoked in designed learning environments.

### 2.1.3 *Cultural Anthropological View of Agency*

Cultural anthropology also looks at agency from a social and transformative dimension, thereby partially sharing a sociological perspective on time, context and position; however, in addition to taking a social and transformative dimension, cultural anthropology focuses on the way roles of context, position, knowledge, and identity with agency intersect (Calabrese Barton & Tan, 2010). For this perspective I draw on Holland, Skinner, William, & Cain's (2001) notion of figured worlds. Holland et al. focus on the situatedness of identity in collectively formed activities. The "identities" of interest are ones that trace our participation, especially our agency, in socially produced, culturally constructed activities—what they call *figured worlds*.

For Holland et al. (2001: 4) identities in culturally constructed worlds (e.g. schools) are improvised during the flow of activity, they are possibilities for mediating agency, and they are conceptualized as they develop in practice. Agency is viewed as a capacity and process that is shaped by human action by mediating behavior through reflection. Taking stances that objectify, monitor, and evaluate mediate our behavior. As a result, we are subject to positioning by powerful discourses and their artifacts (e.g., science talk and experiments in the classroom). Holland et al. view semiotic mediation as a tool of agency and so agency can be traced through participation in figured worlds.

Figured worlds have socio-historical phenomena, they are socially instanced and located in time and place, they are socially organized and produced, and they are distributed. Holland et al. (2001: 41) maintain that identities developed in figured worlds are historical developments

that extend through continued participation in the positions defined by culturally constructed worlds.

In any social activity we are constantly positioned by others or things and by ourselves, and particular places define our scopes of possibility (Bell et al. 2012). As we participate in social activities, we bring perspective, what is known, to particular spaces, relationships, activities, and voice. However, personal activities occur in a social field of ordered and inter-related positions of possible activity. As a result, perspectives position one as an entitled or disentitled participant to particular spaces, relationships, activities, and voice (i.e., forms of expression). In turn, Holland et al. maintain that these positioning's are indexes of identity. When we are confronted with the unknown or unfamiliar in the flow of activity, we improvise. Improvisations mark a difference for the next performance—evoking agency and identity formation—dialectically and dialogically, thereby positioning one and mediating one's repositioning (Holland et al. 2001:45).

Improvisations gain impetus in ones' imaginary worlds or "as-if" realms by modeling possibilities that either inspire new actions or withdrawal from actions. Vygotsky's (1978) emphasis on play, in which the everyday meaning of objects is detached as new meanings are applied, enables one to enter a conceptual world and repurpose the objects and events of that world. Objects become stabilized through habitual use and function as resources as well as facilitate and embody thought, emotion, and behavior. Vygotsky's notion of a "pivot" enables one to shift to one's "as-if" realms. A pivot is regarded as a mediating or symbolic device that enables the shift (Holland et al., 2001: 50) and I argue it is a tool for invoking agency because it is in these worlds of possibilities that one's identity and agency is formed dialectically and dialogically (Holland et al., 2001: 49). For example, in the case of a failed experiment, the

scientist draws from a frame of reference to revise his or her strategy. These processes can be viewed as tools for invoking agency because they, in Pickering's words, "capture" the various modalities of agency when evaluation takes the form of dialectic of resistance and accommodation because material and social agency have transformed or effected transformations in an event (Pickering, 1995).

Holland et al. (2001:51) contend that these "as-if" realms or figured worlds consist of characters, figures, or types where there are particular ways of doing things, saying things with a distinctive perspective and orientation. As a result, particular roles, actors, institutions, settings, durations, and organizational requirements are established. Activities, discourses, performances, and artifacts are socially mediated by figured worlds. Relative to the routinized, everyday activities and events, figured worlds are shaped and re-shaped by expectations in real-time and interpretations of past experiences. Therefore activities and events are initially appropriated, then objectified, and finally communicated. These activities and events are situated and have implications for learning and identity development.

Drawing from Lave and Wenger's (1991) situated learning in communities of practice, newcomers are recruited and gain perspective on practices as well as come to identify themselves as actors having a degree of influence, privilege, and power. From a conceptual perspective objectified meanings, joint activities, and structures of privilege and influence occur in meaningful contexts where actors are positioned relationally (Holland et al., 2001:60). Artifacts in figured worlds have the capacity to shift perceptual, cognitive, affective, and practical frames of activities. Consequently, artifacts mediate intentional human action where they are developed collectively and individually learned, as well as socially and personally powerful. In practice, artifacts constantly change through the improvisations of actors. The improvisations are the

“pivots” to identity development where Vygotsky (1978) maintains we learn to position ourselves for ourselves. One aspect shared by all the redesigned units is the view that human activities are a part of the physical environment, thus taking into account the human impacts on the environment and vice versa. These models of human-environment interactions come with the notion of reform where a better way of living is possible. This aspect is illustrated in the *My Skokomish River Challenge* unit, where the relation of the curriculum genre to science learning with agency, using a case study to trace a learners’ evidence-based reasoning throughout the unit, shows how curriculum genres mediate learner perspectives, stances, and emotions. The learner established contextualized meaning initially by the expository genre that is presented at the beginning of the unit. The learners’ contextualized meaning of the expository genre then shifts in relation to the stakeholders’ narratives about flooding. The “loose pebbles, gravel and rocks” are not longer framed as identifying features of Site 2, which are also isolated descriptions of the processes involved in erosion and deposition. Instead the learners’ frame of reference for types of soils is keyed as the agent “posing a threat.” Through this process of tuning, the learners’ descriptions of the characteristics of Site 2, which initially were foregrounded because of her accrued conceptual knowledge of erosion and deposition gained from previous experiments and the expository texts related propositionally in the context of the overall challenge. The expository frame is backgrounded when the stakeholders’ narratives about flooding are introduced as a form of evidence. The learner restructures the information gleaned from the expository frame and that interacts with her new knowledge gained from the stakeholders’ narratives.

Narratives enable community-building where membership entails sharing experiences of the past as a basis for further action (Miller, 1984:75). Moreover, they hold heterogeneity

together by enabling meaningful differences to emerge within a common project, thus imposing intelligibility and means for social action. Miller (1984) maintains that from a pragmatic perspective, narration gives common sense to one's actions or intentions. Consequently, one is able to reconstruct what one knows by identifying similarities from differences.

Identity development in figured worlds is scaffolded through continued participation in collaborative activities, learning to produce and perform particular cultural practices, and taking up particular cultural practices to mediate one's own conception of self and the world. Therefore, expertise, relevance, and emotional investment provide the tools for agency and identity development in figured worlds (Holland et al., 2001: 119). Positioning is a constitutive element of agency and identity development because one identifies one's position relative to others, one's sense of social place, and one's sense of entitlement. These identifications are mediated by how we are feeling comfortable or constrained in the figured world. These positional identities become important in figured worlds because participation is viewed as entitled, obliged, or expected. In concert with the conceptualization of figured worlds of Holland et al. (2001), I draw on the Cultural Learning Pathways Theoretical Framework (Bell, Tzou, Bricker & Baines, 2012) to make visible the ways in which agency is invoked in designed learning environments.

#### 2.1.4 *Cultural Learning Pathways Theoretical Framework*

Learning takes place across settings. Dreier (2009) states that we learn across settings that are materially and socially arranged in ways that allow us to act within diversities of structures of social practice. Bell et al. (2012:272) highlight that: "it is important to realize that persons can, and often have to, exercise agency in these settings as they construct, leverage, repurpose, and transform social and material arrangements in order to provide meaningful, cross-setting

connections related to their goals and concerns.” Bell et al. (2012) begin to surface a means to address what is missing in the agency literature: how agency shapes social action; how social reproduction can become social transformation. By focusing on affording and/or constraining modes of participation, individuals coordinate and accomplish what they take to be of interest or concern for themselves. The cultural learning pathways model helps us understand the variegated cultural learning pathways that emerge for different individuals at any given place, space, and time.

By drawing on Inden’s (1990:23) definition of agency—where people have the capacity to “act as ‘instruments’ of other agents, to be ‘patients’, and to be the recipients of the acts of others”—we may understand how it shapes social action through a range of learning abilities or capacities associated with social practices that one develops through cultural experiences (Bell et al. 2012). Learning pathways stem from one’s interests and from personal or shared concerns, challenges or desires. Bell et al. (2012) state that interests and concerns can lead to goal-directed learning, which may open up more learning interests and concerns. As one pursues their interests and concerns, they go about it in increasingly sophisticated and socially coordinated ways. Participating in specific forms of social practices may be in legitimate peripheral ways or in deeper, coordinate ways. Bell et al. state that learning is a social endeavor and the development of pragmatically useful and /or meaningful social relationships is a necessary part of learning. Finally, this situated learning perspective is about developing stabilized and flexible identities (see also Lave & Wenger, 1991).

Building upon the theorizing of Dreier (2009), Bell et al. maintain that the pursuit of practice-linked identities rests upon ones understanding of the social practices as well as having access to situations that make available scopes of possibility for learning and identification. This

type of learning occurs across contexts through “connected constellations of situated events”. Learning is accomplished across time, in a variety of locations that have shifting and sustained qualities. Learning becomes visible through talk and action in a situation by taking a stance. By taking a stance or choosing not to take a stance requires agency. In discourse, when learners take a position or stance, they speak “from” a particular point in history, and they always speak “on” history (Blommaert, 2005: 126). It is at this juncture in the cultural learning pathways model that I conjecture we can understand agency as a dimension to learning.

Learning occurs in relation to the social and material circumstances of particular places or locations. Social practices associated with science make specific use of specific materials in specific places/structures. These materials and places/structures are laced with political, epistemic, and social power (Latour, 1995; Rouse 1996 as cited in Bell et al.). These technologies of power prohibit or invite action. As we participate in social activity, we are constantly positioned by others or things and by ourselves. Context and practice become intertwined, which highlight our actions and positions in social activity. The cultural learning pathways model accounts for the ways in which actions, positions, and locations define the scopes of possibility for participants—and makes room for their agency in shaping local action that contributes to learning and identification.

#### 2.1.5 *Summary*

The kinds of learner agencies I am advocating for draw on these various perspectives of agency. The way in which agency is operationalized in Action Theory and Practice Theory where it requires intention, motivation, responsibility, and or expectations of recognition or rewards is one aspect. In addition, as highlighted in the *Cultural Learning Pathways Model*, identity and learning across situated events and time are constitutive of agency. Engaging

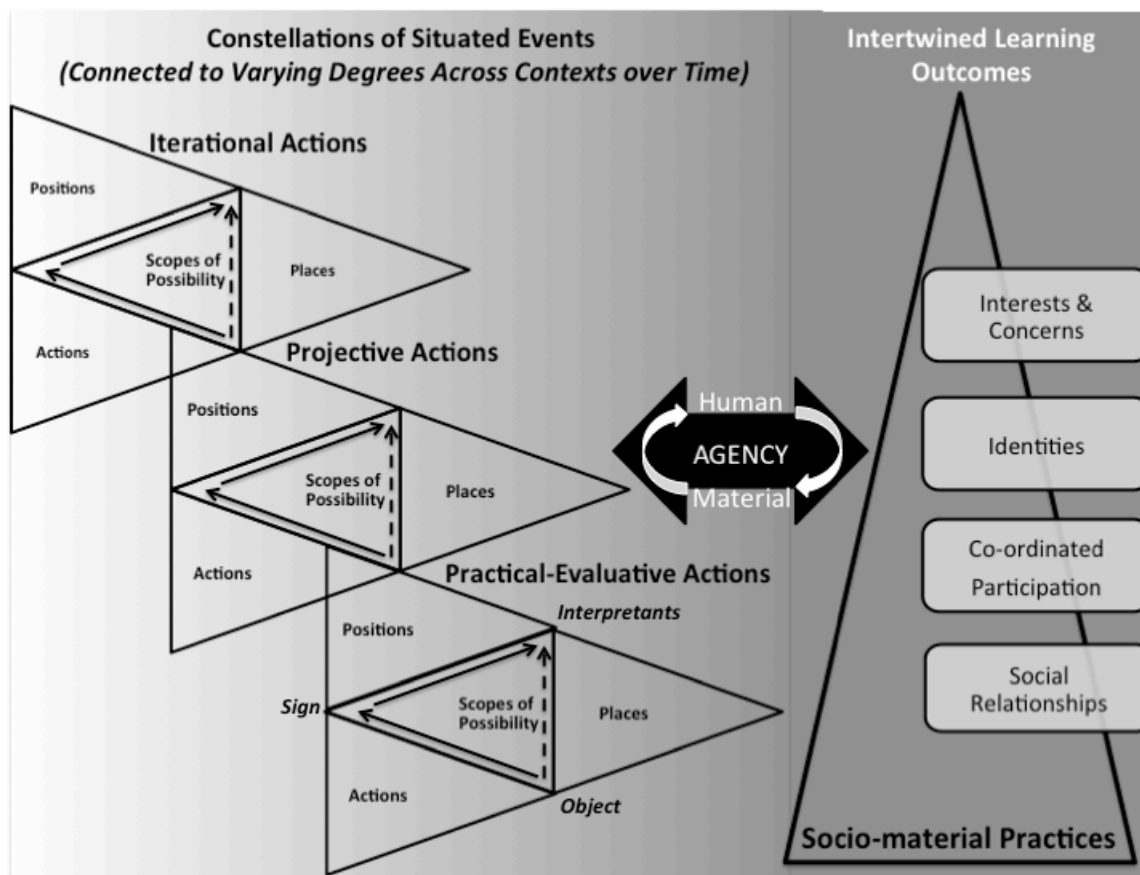
students in consequential, authentic scientific work where the content is resonant and transferable to their lives and thoughts about choices involving social action (Bell, Bricker, Reeve, Zimmerman, & Tzou, 2012), enables students to subject their own agentic orientations to imaginative transformations and critical judgments. Consequently, by repositioning and reframing their relationship to the enabling and constraining contexts, students develop *greater capacity* for creative and critical intervention. Consequently, I conjecture that student agency highlights the degree to which science excites, motivates, or changes the choices learners make in their everyday lives in relation to science.

## **Part II: Applying a Semiotic Perspective to Agency Along Cultural Learning Pathways**

Agency has been conceptualized from (a) a sociological perspective where social structures enable or constrain human agency; (b) a socio-cognitive perspective, where agency is understood as epistemic in collaborative, knowledge-related activities; (c) a cultural anthropological perspective, which accounts for the ways roles of context, position, knowledge, and identity are constitutive of agency (Calabrese Barton & Tan, 2010) and; (d) a cultural learning pathways perspective where agency is embodied, enminded or embedded in actions, positions, and places that define the scopes of possibilities for participants. As illustrated in Figure 2-1, I have leveraged a theory of semiosis to highlight how these perspectives on agency contribute to the meaning-making processes of language, culture, and mind. A theory of semiosis highlights ways in which meaning-making processes are understood. These meaning making processes leverage language as a resource and it can be viewed as a series of integrative levels in

which each level, as nested in the aforementioned perspectives, constitutes a particular view of human experience from a systemic functional linguistic perspective.

Participation in particular social practices, such as school science instruction, establishes forms of participation and common forms of meaning interpretation which are distributed among community members. Thibault (2004) states that the development of one's linguistic semiosis has a type-specific dimension. In other words, one's particular life history, experiences, and ways of using language associated with meaning-making practices will be different and re-elaborated in ways that are unique to one and the specific circumstances.



*Figure 2-1 Semiotic Perspective to Agency along Cultural Learning Pathways*

Meaning making in particular communities of practice is established through apprenticed participation in activities that mediate interactions. Meaning is mediated and made in and

through inter-textual thematic formations where they are instantiated in texts and enacted in particular social practices. Different inter-textual thematic formations yield different relations in meaning and content for the same lexicogrammatical form<sup>4</sup>. Moreover, the potential for meaning making is also based on the value one ascribes to something and its relation to other things in an ordered hierarchy of linguistic relations and particular community of practice. Thus, meaning making and the notion of relations between relations shows how students learn how to mean in the context of the science classroom and beyond. Kockelman (2013) maintains that these processes reveal one's intentions, goals, or desires as well as their meanings. Hence, given that language is a resource for making meaning and that meaning emerges from systemic patterns of choice, the relations between learner agency and the relations between grammatical and wording choices made by students becomes salient for understanding student agency in relation to learning and identity development. Moreover, the way language is used by students and teachers to realize various contexts during science provides a way to talk about the variations we see in language use among speakers, their social positionings, and the purposes for which it is used (Halliday, 1964 as cited in Schleppegrell, 2004). Similarly, Duranti (2011) found that the use of particular grammatical constructions reveal what a person is trying to do with words. For example, when the teacher sets up the activity for students and uses particular words to guide students' activities:

Excerpt 1: From *My Skokomish River Challenge*

**Teacher:** And what did we measure our effect by? How did we find out what our effect was? Student 1?

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<sup>4</sup> The lexicogrammatical form incorporates the clause where meaning is realized by grammatical categories (Halliday & Matthiessen, 2004).

- Student 1:** Uh, we got the averages
- Teacher:** Of what? What were we measuring?
- Student 1:** Uh, delta. No, the...
- Student 2:** Measure the [inaudible].
- Teacher:** Measure of what?
- Student 2:** Length, length of the delta.
- Teacher:** The length of the delta!

In this illustration, the teacher uses the preposition *by* to elicit what the students will be measuring – *the length of the delta*. The use of the preposition *by* expresses the means whereby a process takes place – *our effect*. Moreover, expressions of means include concepts of agency and instrumentality where the instrument is a kind of means. For example, the teachers' use of *we* positions the students as the agent [doer – measurer]. The use of *our effect* refers to the changed variable, which had an effect on the measure. The cause, in this instance, is instrumental or material and the agent because the object of the preposition is the agent of the action indicated by the use of the preposition *by* in a passive construction.

Duranti (2011) talks about agency in language and social action. Agency is defined when individuals have control over their own behavior, they participate in actions that affect other individuals and sometimes their own, and what and how an individual does or says things are evaluated from a practical, action, and moral perspective. This definition of agency emphasizes a particular kind of causation: an individual is viewed to have control over their own actions in local situations as evaluated from practical, action, and moral stances. Practical evaluations refer to our everyday routinized ways of doing things across settings and time. Duranti adds that it

also refers to one's interest in problem solving and accomplishing things individually or collaboratively because one "cares" about the affect of doing and saying things (Heidegger, 1962 as cited in Duranti, 2011: 158). Hence, individuals with a degree of control over their own actions suggests a sociological view of agency and evaluations from the practical, action, and moral stances captures Damşa et al. (2010) view of shared epistemic agency. Finally, Duranti (2011) highlights affect as a condition for agency, which highlights a student positioning as well as levels of engagement during science.

Kockelman's (2013) processes of 'selection' and 'signification' become relevant for explaining the emergence of learner agency in relation to Peirce's terms sign, object, and interpretant. Selection is understood as an agent exercising a means for an end and significance comprises a sign representing an object that bears an interpretant (Kockleman, 2013). I approach the communicative act as a type of causation, which at the same time makes the question of agency relevant. Language and semiotic modalities are constitutive of consciousness and agency and, therefore, cannot be separated without failing to understand the nature of human meaning-making activity (Thibault, 2003). Consciousness and agency emerge in and through transactions with others. As a result, a theory of semiosis highlights the interactions between consciousness and agency.

Kockelman (2013) outlines a theory of semiosis, drawing from Peirce's Theory of Signs, to define relations between relations (see Appendix 1, Table 12). A theory of semiosis/signs illustrates the meaning making processes of language, culture, and mind. Meaning, in this perspective, is understood as a "relation between two relations". In other words, any process involves a particular relation between a sign, an object, and an interpretant. A *sign* stands for its object and interpretant, thus it stands as something for somebody in some capacity (Peirce). The

object represents the purchases and/or functions from the first sign which creates another sign. Kockelman calls the reproduced sign the *interpretant* of the first sign. A sign creates a relation between the interpretant and the object by corresponding to its own relation to the object. A sign, object and interpretant can be understood concomitantly as an entity. Kockelman (2005) refers to this as “semiotic framing”. This semiotic process unfolds during any interaction such as: The teacher asks the students a question (first phase of action, or a sign), a student responds (answer, or the interpretant) and the teacher evaluates the response (second phase of action, or the object). Everyday interactions are seen as “pair-part structures” where for example a question is generally followed by a response that gives information or indicates yes or no (Polarity). In these types of utterances the sign and the interpretant are highlighted and the objects remain backgrounded or in mind.

When considering the modes of expression in an utterance the grammatical units are useful to create logogenetic patterns and mark cohesion. As a text (spoken or written language) unfolds patterns emerge from instantiations. On the one hand, the pattern of instances unfolding establish meaning in some particular context that are specific to a text; on the other hand, repeated patterns of instances unfold meaning particular to a context. This gives rise to a generalized system<sup>5</sup>, which is an attribute of a certain type of text or register. The textual resources that mark cohesion show the meaning making relations in the unfolding text. Cohesion includes conjunctions for marking textual transitions; and reference, ellipsis and substitution, and lexical cohesion to exploit the positioning or rank of textual resources in the flow of information.

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<sup>5</sup> Halliday and Matthiessen (2004) define “system” as a resource for potential meaning making

At the semantic level, these patterns of meaning unfold in a particular context of situation. One reason is because text is a unit in the flow of meaning and is realized by clauses. The clauses are located at the lexicogrammar (wording) level and are in relation to the semantic (meaning) level. Clauses are the unit of analysis in the lexicogrammar level as the grammatical resources enable meaning making and describe categories by reference to what they mean. The clause as a multifunctional construct realizes three different units of meaning for each metafunction: textually by the message, interpersonally by means of a proposition or proposal, and experientially by a figure. This type of analysis shows the functions of language in relation to the environment where one can make sense of experiences and enact interpersonal relations.

The ways in which language construes human experience is by the functions of the resources of the lexicogrammar. In other words, grammar is viewed as a tool for representing knowledge and it creates meaning within three metafunctions: the ideational (representation), the interpersonal (interaction), and the textual (information flow) metafunctions. The “ideational metafunction” is distinguished into the experiential component and logical component. As one uses language one is also enacting their personal and social relationships with others. Again the clause represents a process (e.g. doing, being, saying, etc.) with other participants and circumstances; and it functions as a proposition or a proposal. Functions are inherent in language and so when we consider the term “metafunction”, it gives us a way to talk about them as components of a theory of human experience. Language viewed as reflection and as action has a “interpersonal” metafunction (i.e., propositions or proposals form patterns of exchange involving interactants), suggesting its interactive and personal nature. Drawing from Trevarthen (1978 as cited in Thibault 2004), by orienting or attending to an activity reveals the level of attention, interest or engagement during interactions. The exchange of information, in

this case, is iconically (as a sign) related to the contextual exchanges to which the interpretants relate. As a result, the varying exchange of information is interpreted as shifting degrees of attention, interest, engagement, etc. The affect, motivation, or interest is consciously attended to more than the exchange of information. Relevance here is “implicit felt meaning” (Gendlin, 1962 as cited in Thibault, 2004:59). One feels the meaning of something as a felt sense that is related to a particular sign or experience. For example, when students are asked if they consider themselves a scientist, their responses, whether they self-identify as a scientist or not, is expressed as an implicit felt meaning because the activities are hands-on, students control their learning through choices, which heightens their level of interest or attention.

Another mode of meaning related to the construction of texts is the “textual” metafunction. As the ideational and interpersonal metafunctions construe experience and meaning is realized via interpersonal relations, the “textual” metafunction facilitates functionality by constructing sequenced patterns from instantiations and the flow of discourse is organized and generated by means of cohesion. Thus the unfolding meaning in text is logogenetic.

Dimensions of time enable language to be organized in grammatical systems. Halliday and Matthiessen (2004) recognize three dimensions of time in meaning making: *ontogenetic time* refers to language development where proto-grammatical and then grammatical systems are created; *phylogenetic time* refers to the evolution of language or texts; and *logogenetic time* traces the unfolding of discourse. In sum, unfolding meaning in text is instantiated and understood by the grammatical systems in all three dimensions of time.

Meta-functions enable one to make sense of experiences and they are a means in which one interacts with others. Thus as language construes human experience (Halliday & Matthiessen, 2004 ), meaning is achieved by the functions of grammar. For example, a clause

can be understood as a figure with three components: a process unfolding through time; the participants involved in the process; and the circumstances related with the process. These components are specifically organized to provide the models for construing experience<sup>6</sup>.

Circumstantial elements are always optional components but participants are inherent in the meaning making process – with the exception of meteorological processes or Goffman's (1974) natural frameworks. Participant and process constitutes the experiential metafunction of the clause and circumstantial elements may extend meaning temporally, spatially, causally, etc., yet remain peripheral to the process.

The process, participant, and circumstance is realized by units marking contributions that model change. The process and the participants make up the center of the clause and are understood as complimentary to change. These two complimentary aspects are “transience” and “permanence”. Transience is experience unfolding through time; and is actualized by a verbal group serving as the process. Permanence refers to stable experience located in space; nominal groups serving as participants actualize it. In sum, change entails both transience and permanence, and experience is understood as a transient process or as a permanent participant. The semantic categories of process, participant and circumstance generally explain how human experience is understood as linguistic structures.

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<sup>6</sup> Examples of models that construe experience could be expressed as a semantic configuration entailing something expressed. During an investigation exploring the effect of erosion in the stream-table, a student from the Inquiry group says, “The water is not going down.” The process ‘is not going’, the Actor ‘the water’. In this material clause of motion, ‘the water’ is a mobile entity and the process is circumstantial.

### **Part III: Mapping the Agency Framework to the Work of Science**

#### **2.2 Sociology of Scientific Knowledge and Agency**

Science studies have focused on science as a body of knowledge, that is the self-containment of the science object. Specifically, Science, Technology, and Society (STS) perspectives document the production and use of scientific knowledge from a social perspective, taking into account social structure, social interests, human skills, and materiality (Pickering, 1995; Gooding, 1992). STS challenges the notion of scientific culture as only a field of knowledge. From an STS perspective, scientific culture includes science-in-the-making – conceptual, social, material components, and scientific practice, which is understood as extending the notion of scientific culture; and the transformation in time of social and material practices in the production of knowledge.

Pickering's (1995) focus on understanding of practice from a temporal perspective draws on agency, particularly material agency, and doing. Thus understanding scientific practice as performative. This perspective rebalances our understanding of science as a unitary body of knowledge and toward a focus on agency in science.

The sociology of scientific knowledge (SSK) perspective has shown how the production, evaluation, and use of scientific knowledge is structured by social interest and constraints upon “human agents”. In addition, within a SSK perspective, accounts of material agency fold into the domain of scientific knowledge and are analyzed as products of human agents. Pickering states that one can have human or material agency, but not both because it is the scientists themselves that have the instruments and conceptual resources required to inform us, as researchers, what material agency is. There is an asymmetric stance regarding human and material agency (cf. Collins & Yearley, 1992). Pickering rejects this move and draws on actor-network theory to

show how reflexivity and semiotics brings human and material agency to symmetry. Emirbayer and Mische claim one can trace the variability in one's maneuverability, inventiveness, and reflective choice. Thus, they define agency as "the temporally constructed engagement by actors of different structural environments – which, through the interplay of habit, imagination, and judgment, both reproduces and transforms those structures in interactive response to the problems posed by changing historical situations" (1998:970).

I adopt the view that human agency is embedded and emergent in the flow of time and activity, it is mediated reflexively and semiotically (Holland et al., 2001), and there is a constitutive intertwining that exists between material and human agency. Material agency is enveloped by routinized scientific practices and its performativity is repetitive (Pickering, 1995). "Disciplined" human agency and "captured" material agency are "reciprocally and emergently defining and sustaining each other through a processes of tuning (Pickering, 1995:16), making them "interactively stabilized".

Another aspect of agency is the temporal emergence of the intentional structure of human action and its transformability in encounters with material agency. For Pickering human intentionality refers to plans and goals that relate to future states that are then realized or materialized. Scientific practice is pre-disciplined or keyed (Goffman, 1974: 83) in the present state; thus goals of scientific practice are planned from existing science via a process of modeling – the goals of scientific practice emerge in the real time of practice. Consequently, existing science partially pre-disciplines human intentionality because modeling is an open-ended process with multiple possibilities. In addition, tuning may transform the goals of scientific practice. Thus Pickering states that human agency is bound by material agency.

Consequently, intentional human agency is reconfigured in the real time of practice, and redefined by the contours of material agency in tuning.

Pickering's notion of tuning reveals the interplay between human agency and material agency. A scientist takes an active role when setting up an experiment and when the experiment is run; the scientist adopts a passive role, monitoring the performance of materials. This is when material agency manifests itself. The intended performance is evaluated and depending on the outcome, the role of the scientist becomes active again. The intended performance of an experiment may fail, producing resistance. The scientist, drawing from a frame of reference, accommodates this resistance by revising her strategy. Pickering maintains that evaluation takes the form of dialectic of resistance and accommodation because material and social agency have transformed or effected transformations.

Scientific practice is organized around the making and breaking of associations between activities related to empirical investigation, activities related to developing explanations and solutions, and the practice of evaluation. Locating resistance in epistemic agency – socially sustained routines of human agency that includes modeling. Modeling situates goals and purposes with respect to the cultural field in which they are constructed. Cultural situatedness implies a degree of both temporal emergence and posthumanist intertwining in human intentionality (Pickering, 1995:56). Goals of scientific practice must at least be as emergent as the models on which they are based although they are subject to “mangling” in practice. Part of modeling is bridging that tentatively fixes a trajectory of cultural extension to be explored. Bridging marks a space for transcription (that is, the copying or keying of established moves from the normative into the new space fixed by the process of bridging (Pickering, 1995: 116). Filling completes the new system in the absence of any clear guidance from the base model.

Bridging and filling are activities in which scientists display choice and discretion, the classic attribute of human agency. They are free moves. Transcription or a guided doing is where discipline asserts itself, where disciplinary agency carries scientists along and they become passive in the face of their training and established procedures. Guided doings are disciplined forced moves. The point of bridging as a free move is to invoke the guided doings that follow from it. Without such invocation, conceptual practice would be empty. There is an intertwining of free and forced moves because scientists are not fully in control of where trajectories of conceptual practice will lead. Conceptual structures (theories, models) relate to disciplinary agency as machines to material agency (Pickering, 1995: 116).

Scientific knowledge is sustained in extended representational chains spanning multiple levels of theoretical abstraction, and that alignments along such chains should themselves be understood as subject to, and the products of, mangling in practice (Pickering, 1995: 70). Science practices are understood as mangled and interactively stabilized together with the material and conceptual strata of scientific culture. Scientific knowledge should be understood as sustained by, and as part of, interactive stabilizations situated in a multiple and heterogeneous space of materials, concepts, practices, social actors and their relations (Pickering, 1995: 70). Concepts are extended in relation to other concepts and material performances, which contain no blueprint for their own extension – the overall process of empirical practice being oriented to the achievement of impure, material-conceptual, interactive stabilizations (Pickering, 1995: 92).

Thus relations between experiments, facts, and theory in science are typically complex representational chains that stem from the instruments and material performances through successive layers of abstraction. Concepts of scientific culture are multiple, rather than the traditional accounts of science that have been developed in terms of a unitary view of culture,

and many different layers of conceptualizations, models, approximation techniques, etc. are linked in bringing experiment into relation with theory (Pickering, 1995: 98).

A reciprocal tuning is at work in scientific practice, which simultaneously delineates the material contours of ‘machines’ and their performances and the routinized human actions that accompany them. Pickering maintains that the “the open-ended dance of agency that is scientific practice becomes frozen in moments of interactive stabilization into a relatively fixed cultural choreography, encompassing captures and miming of material agency and regularized, routinized, standardized, disciplined human practices (Pickering, 1995: 102).

Agency has been defined in three dimensions. The sign, object, and interpretant dimensions enable a particular understanding of meaning. The various modalities of agency and the three dimensions of meaning depend on the conditions for interpretation and the consequences of interpretation (Kockelman, 2013). The ‘interpreting agent(s)’ are viewed as a set of various kinds, which include social statuses, mental states, and objects. Consequently, identities are developed as a result of these sets of various ‘kinds’. The signifying, objectifying, and interpreting practices that are embodied, embedded, articulated, enminded, iterative, reflexive, and reframed are considered indices of ‘kinds’ to other interpreting agents as well as the agent(s).

Thus the relation between flexibility and accountability over time, place, entities, and individuals defines agency as constituting processes that are by varying degrees multidimensional, distributed, contextualized, interactionally emergent, and ontologically framed.

### 2.3 **Summary**

In sum, agency is related to performativity and the conditions and consequences of interpretations are related to ones agentic orientations, as Kockelman (2013: 84) succinctly states:

“Insofar as actors have more or less practical or theoretical agency over their semiotic processes, they have more or less semiotic agency over the worlds (contexts, situations, or conditions) that constitute the causal and normative roots and fruits of such processes. In semiotically acting, then, we can both widen or narrow the capacities of ourselves and others to semiotically act; thus, we should be differentially accountable to ourselves and others for these actions.”

Performativity and language are essential resources related to learner agency. A semiotic approach enables one to understand how language is a system of meaning that embodies human experience; it has potential for intersubjectivity in everyday interactions as well as meaning creating (semogenic). The lexicogrammar, as determined by the environment or genre in texts, is metafunctional. Viewed from a trinocular perspective, language is metafunctional ideationally, interpersonally, and textually. Thus, language as the root for meaning making is actuated by and actuates consciousness. The linguistic choices a learner makes stem from the metafunctions. Therefore, to mean is always to choose and the choices selected are fashioned by value. In a learning context, these choices and values inherent in language use are relational to learner agency outside of language, but ensouled in performative curating where solidarity, intention, creativity, emotion, accountability, anticipation, cognition, and rewards enable the capacity to transform the self, others, and communities.

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**Chapter 3 ‘I’m a consumer, I’m not a scientist’: Cultivating Student Domain  
Identification, Agency, and Affect through Engagement in  
Scientific Practices**

Learning takes place by identification (Keller, 1983). This means “ensouling” what one sees and creating relations associated with an object, concept, community of practice, or person. Identities, as parts of self, take on and are shaped by our self-conceptions and the ways we are positioned by others (Bell, et al., 2012). As identities emerge in and are reflective of the enabling and constraining social structures, Varelas (2012) maintains one has, to some extent, agentic control too.

Varelas (2012) states that an understanding of how learners’ practice-linked identities develop in science entails: (1) “Who are students obligated to be in a setting?” (2) “Who are students becoming in a setting?” The questions posed by Varelas raise equity issues regarding learning and identification in science. Equitable science learning opportunities enable access to content, concepts, and practices that should be conceived of as relating to a socially, situated developing self. Students’ practice-linked identities are thus considered in relation to the learning processes of being, becoming, knowing, and doing, which are constructed dialogically through engagement, emotion, intentionality, innovation, and solidarity (Petrich, Wilkinson & Bevan, 2013). Social structures create relations of alliance, dominance, or subordination, which influences participation, knowledge construction, emotions, and actions. One’s position in social structures is enabled or constrained by the arrangement of social and material resources. These resources reciprocally define and are defined by our positional and relational identities. The notion of ‘self’—also as “an anchor point for our sense of agency” (Wolf, 1990: 183 as cited in

Bredel, 2003)—becomes essential for understanding how students develop practice-linked identities in science. In the context of social and material processes, the self is “enacted and negotiated in and through the self’s relations to [others]” (Thibault: 2004:15). The enabling and constraining social structures give path to reframing’s in actions and stances in the ‘self perspective’. Thibault (2004) adds that a reframed self-perspective elaborates on our meaning systems through which we draw on to guide our actions, anticipate possible courses of action, and evaluate from a self-self perspective. While social and material resources reciprocally define and are defined by students’ positional and relational identities, this dissertation considers the following research questions:

1. What forms of youth thinking occur as they engage in sustained challenge-based inquiry science learning environments designed to support learner agency?
  - a. What are the particular social and material scaffolds that result?
  - b. How can these scaffolds inform pre- and in-service teachers when teaching to support learner agency?
2. How are students’ practice-linked identities developed as they engage in challenge-based, designed learning environments?
  - a. What strategies can inform pre- and in-service teachers to cultivate students’ practice-linked identities?

Studying identity construction helps us understand how students learn science and how teachers or other members of a community teach science to facilitate learning (Varelas, 2012). Concurrently, as identities are negotiated in science during the flow of activity, students’ agency is mediated and conceptualized as it develops in practice (Holland et al. 2001). For teachers, mediating learner agency and science identification becomes a challenging act when she treats

agency as a way to think through her students' capacities to take action and to think of the multiple ways they have been and "are actively involved in emergent, innovative, experimental, and substantive forms of solidarity and coexistence" (Oswell (2013).

Finally, mediating learner agency and science identification begins to acknowledge and address prevailing science literacy issues. As outlined in the workshop report exploring "Literacy in Science" in the Common Core State Standards for English/Language Arts (CCSS for ELA) and the practices in the Next Generation Science Standards (NGSS):

the literacy in science portion of the CCSS for ELA standards only apply to grades 6-12. However, there are CCSS for ELA elements of the standards in grades K-5 that are potentially relevant to science, but no guidance is provided for teachers as to how to address them in the context of science. In the *Framework for K-12 Science Education* and *NGSS*, the intent is that the practice of obtaining and communicating information will be addressed across grades K-12 (NRC, 2014: 2).

The National Research Council acknowledges that there are no science literacy standards relevant in grades K-5 in the Common Core State Standards, and the practice of obtaining and communicating information in the Framework for K-12 Science Education and NGSS has begun to address the issue with an emphasis on multimodal texts for communicating ideas, results, and stances (cf. NRC, 2012: 53). A critique of the report is that the "intent" on developing science literacy from the practice of obtaining and communicating information underplays the relevance of the remaining seven practices, which play a critical role when youth engage with the practices because they come to recognize how scientific knowledge is constructed under various instances in the unfolding of time and place and why some scientific theories are more established than

others (NRC, 2012: 44). Learner agency can be powerfully supported by engaging students in sustained investigations that involve a sequencing of different epistemic practices.

Suggestions for developing science literacy draw on the language of scientific argumentation where Reiser (NRC, 2014) asserts that teacher discourse practices should shift from Initiation-Response-Evaluation (IRE) structures to Claims, Evidence, and Reasoning (CER) structures (p. 12). This approach is purported to give teachers and students agency. However, I propose that if we expect students to engage in the Claims, Evidence, and Reasoning approach, we have to acknowledge how meaning is made and understood within the context of social groups of inquiring students. Schleppegrell (2010) argues that particularly in writing, youth have difficulties connecting abstract ideas in a CER structure, having a perspective, and structuring the response appropriately.

Viewing scientific argument as a critical discussion highlights how language, as a linguistic resource, has a *representational function* to encode experiences of the world, an *interpersonal function* to encode interaction, attitudes, and relationships, and a *textual function* that organizes our experiential and interpersonal meanings into a coherent whole (Butt et al., 2003). Hence, meaning in relation to context is understood as a resource for (i) *Ideational meaning* – domain knowledge construction and enabling peripheral or deeper participation in activities through connected constellations of situated events; (ii) *Interpersonal meaning* – valuing activities and enacting power and solidarity in relation to shared values; and (iii) *Textual meaning* – staging ideational and interpersonal meaning in modes responding to the communicative demands of spoken and written discourse of communities of practice (Martin, 2009: 11-12.) The point I want to highlight is that the CER framework by itself does not address the interpersonal kinds of meanings that evaluate students’ feelings, attitudes, and emotions—the

attitude and evaluative stances central to agency. Interpersonal meanings facilitate and embody thought, emotion and behavior (Vygotsky, 1967), which are expressed explicitly as self-evident evaluations, hence having attitudinal significance.

Another point at issue is that the CER approach does not take into account the importance of how students develop control over *grammatical metaphor* (cf. Christie & Derewianka, 2008). Martin (2013) explains that grammatical metaphor is used in scientific communication to define and explain processes by compacting information. Longitudinal studies showing cohesion as a key feature in the development of writing addresses challenges youth encounter when they engage with genres at various levels of abstraction (Derewianka, 1996, 1999, 2003; Christie, 1998, 2002). This indicates that as youth develop control over grammatical metaphor—learning the principles and core ideas of science, engaging in scientific practices, and understanding the scientific enterprise—cohesion acts as a linguistic resource for applying information and evidence to different levels of organization, thus moving an argument to resolution. On this account, the CER approach values the content and quality of student writing found in persuasive texts. While this is an important aspect, the pith of the matter is in not recognizing that writing is also an act in itself. LeCourt (2004) contends that the ways in which acts of writing are embedded in socio-material arrangements of school science impacts youths' positional identities in science because the expectation is typically only to reproduce meaning from the genres found in scientific texts and not to produce alternative new meanings that reflect who the students are and becoming, what they know, and what they care about.

Here I advocate Mary Schleppegrell's (NRC, 2014: 22) approach where Functional Grammar Analysis can be used to help students develop scientific literacy with teachers as learning partners. Using genre as a construct for thinking about the purpose and context of a text

and identifying the language features that have particular forms and functions at each stage in accomplishing a purpose has potential to help youth relate language and content. However, as an ambitious endeavor, where even Hasan (2009:182) discloses that “[t]o actually create a substantial contextualization system network of all three parameters with realization statements that reach lexicogrammatical choices via the semantic ones is a huge enterprise requiring a lifetime of work.” The implications are serious if the CCSS for ELA and NGSS adopt such an approach without having an already established Systemic Functional Linguistics (SFL) program running in teacher education programs and in Departments/Colleges of Education – not solely in Linguistics Departments. Moreover, Butt et al. (2003) caution that time and effort are required of teachers as well as ‘professional judgment’ when deciding how much linguistic instruction to share with students in order to achieve successful learning outcomes. A successful implementation that does not compromise youths’ future possibilities has potential benefits. Martin (2009) makes a concrete case based on their research informing the development of discourse semantics resources for analyzing meaning beyond the clause. Martin affirms that the resources made it possible to be explicit about what had to be learned and taught across the curriculum in all sectors of schooling, so that teaching and learning could be mobilized as transitive verbs—as social activities with concrete goals as far as apprenticeship into literacy was concerned (Martin, 2009: 11).

With these issues in mind, this chapter on identity and agency endeavors to address and demonstrate the potential benefits of designing learning environments for student agency and the development of science identities that leverages youth’s interests, personal or shared concerns, challenges or desires.

### 3.1 Theoretical Background

The frameworks I adopted draw from the Cultural Learning Pathways Framework (Bell et al., 2012), cognitive- and socio-cultural anthropology (e.g. Holland, et al. 2001), and Social Semiotics (Halliday & Matthiessen, 1999). Each framework can be used to represent a level of structure (macro-, meso- or micro-levels) that elucidates processes and meanings in identity construction. Structures can refer to the normative and local practices of a community that enable or constrain group- or individual-levels of participation, knowledge construction, emotions, and actions, for example scientific practices, school science practices and/or science literacy practices. As a result, practices enable researchers to identify the co-development of students' relational and positional identities in science that are determined by the macro-level social structures (e.g., race, gender, class) as well as the micro-level structures that constitute students' sense of place, history, language, experiences, and agency.

Structure can represent interests and concerns at both the individual- and group-level. I use the Cultural Learning Pathways Framework (Bell et al., 2012) to describe identity development in terms of the enabling and constraining social structures in relation to agency and identity. This macro-level of structure enables me to look at the ways interests and concerns function in either constraining or enabling future possibilities— sustained and flexible identities and agency. The Cultural Learning Pathways Framework provides a lens for understanding the relation between learning and identity construction, highlighting the role of local attributes or models to learning. Cognitive and socio-cultural Anthropology considers cognition and culture and provides explanations for why students understand science in the ways that they do. This meso-level of structure highlights the processes generating a particular distribution of local

attributes or models. Finally, Semiotics establishes the micro-level and perspective shifts to the metafunctions of meanings established in experience through texts—spoken or written.

Holland et al. focus on the situatedness of identity in collectively formed activities. The “identities” of interest are ones that trace our participation, especially our agency, in socially produced, culturally constructed activities—what they call *figured worlds*. For Holland et al. (2001: 4) identities in culturally constructed worlds (e.g., schools) are improvised during the flow of activity, they are possibilities for mediating agency, and they are conceptualized as they develop in practice. Agency is viewed as a capacity and process that is shaped by human action by mediating behavior through reflection. Taking stances that objectify, monitor, and evaluate our behavior. As a result, we are subject to positioning by powerful discourses and their artifacts (e.g., science talk and experiments in the classroom). Holland et al. view semiotic mediation as a tool of agency and so agency and identities can be traced through participation in figured worlds. Figured worlds have socio-historical phenomena, they are socially instanced and located in time and place, they are socially organized and produced, and they are distributed. Holland et al. (2001: 41) maintain that identities developed in figured worlds are historical developments that extend through continued participation in the positions defined by culturally constructed worlds.

In any social activity we are constantly positioned by others or things and by ourselves, and particular places define our scopes of possibility (Bell et al., 2012). As we participate in social activities, we bring perspective, what is known, to particular spaces, relationships, activities, and voice. However, personal activities occur in a social field of ordered and inter-related positions of possible activity (e.g., particular ideas about the role of students as they engage in science inquiry). As a result, perspectives position one as an entitled or disentitled participant to particular spaces, relationships, activities, and voice (i.e., forms of expression). In

turn, Holland et al. maintain that these positioning's are indexes of identity. When we are confronted with the unknown or unfamiliar in the flow of activity, we improvise. Improvisations mark a difference for the next performance—evoking agency and identity formation—dialectically and dialogically, thereby positioning one and mediating one's repositioning (Holland et al., 2001:45).

Improvisations gain impetus in ones' imaginary worlds or "as-if" realms by modeling possibilities that either inspire new actions or withdrawal from actions. Vygotsky's (1978) emphasis on play, in which the everyday meaning of objects is detached as new meanings are applied, enables one to enter a conceptual world and repurpose the objects and events of that world. Objects become stabilized through habitual use and function as resources as well as facilitate and embody thought, emotion, and behavior. Vygotsky's notion of a "pivot" enables one to shift to one's "as-if" realms. A pivot is regarded as a mediating or symbolic device that enables the shift (Holland et al., 2001: 50), and I argue it is a tool for invoking agency because it is in these worlds of possibilities that one's identity and agency is formed dialectically and dialogically (Holland et al., 2001: 49). For example, in the case of a failed experiment, the scientist draws from a frame of reference to revise his or her strategy. These processes can be viewed as tools for invoking agency because they, in Pickering's words, "capture" the various modalities of agency when evaluation takes the form of a dialectic of resistance and accommodation because material and social agency have transformed or effected transformations in an event (Pickering, 1995).

Holland et al. (2001:51) contend that these "as-if" realms or figured worlds consist of characters, figures, or types where there are particular ways of doing things, saying things with a distinctive perspective and orientation. As a result, particular roles, actors, institutions, settings,

durations, and organizational requirements are established. Activities, discourses, performances, and artifacts are socially mediated by figured worlds. Relative to the routinized, everyday activities and events, figured worlds are shaped and re-shaped by expectations in real-time and interpretations of past experiences. Therefore activities and events are initially appropriated, then objectified, and finally communicated. These activities and events are situated and have implications for learning and identity development.

Drawing from Lave and Wenger's (1991) situated learning in communities of practice, newcomers are recruited and gain perspective on practices as well as come to identify themselves as actors having a degree of influence, privilege, and power. From a conceptual perspective objectified meanings, joint activities, and structures of privilege and influence occur in meaningful contexts where actors are positioned relationally (Holland et al., 2001:60). Artifacts in figured worlds have the capacity to shift perceptual, cognitive, affective, and practical frames of activities. Consequently, artifacts mediate intentional human action where they are developed collectively and individually learned, as well as socially and personally powerful. In practice, artifacts constantly change through the improvisations of actors. The improvisations are the "pivots" to identity development where Vygotsky (1978) maintains we learn to position ourselves for ourselves. One aspect shared by all the redesigned science curriculum units in this study is the view that human activities are a part of the physical environment, thus taking into account the human impacts on the environment and vice versa. These models of human-environment interactions come with the notion of reform where a better way of living is possible. This aspect is illustrated in the *My Skokomish River Challenge* unit, where the relation of the curriculum genre to science learning in agentic environments, using a case study to trace a

learners' evidence-based reasoning throughout the unit, shows how curriculum genres mediate learner perspectives, stances, and emotions.

Identity development in figured worlds is scaffolded through continued participation in collaborative activities, learning to produce and perform particular cultural practices, and taking up particular cultural practices to mediate one's own conception of self and the world. Therefore, expertise, relevance, and emotional investment provide the tools for agency and identity development in figured worlds (Holland et al., 2001: 119). Positioning is a constitutive element of agency and identity development because one identifies one's position relative to others, one's sense of social place, and one's sense of entitlement. These identifications are mediated by how we are feeling comfortable or constrained in the figured world. These positional identities become important in figured worlds because participation is viewed as entitled, obliged, or expected. In concert with the conceptualization of figured worlds of Holland et al. (2001), I draw on the Cultural Learning Pathways Theoretical Framework (Bell, Tzou, Bricker & Baines, 2012) to make visible the ways in which agency is invoked in designed learning environments (e.g., through available actions, constructions of the "place" of learning, leveraging prior interests and identities).

Learning takes place across settings. Dreier (2009) states that we learn across settings that are materially and socially arranged in ways that allow us to act within diversities of structures of social practice. Building upon this perspective, Bell et al. (2012:272) highlight that:

"it is important to realize that persons can, and often have to, exercise agency in these settings as they construct, leverage, repurpose, and transform social and material arrangements in order to provide meaningful, cross-setting connections related to their goals and concerns."

Bell et al. (2012) show how we may trace the development of practice-linked identities across constellations of situated events. By focusing on affording and/or constraining modes of participation, individuals coordinate and accomplish what they take to be of interest or concern for themselves. The Cultural Learning Pathways model helps us understand the variegated cultural learning pathways that emerge at any given place, space, and time.

Learning pathways stem from one's interests and from personal or shared concerns, challenges, or desires. Bell et al. (2012) state that interests and concerns can lead to goal-directed learning, which may open up more learning interests and concerns. As one pursues their interests and concerns, one goes about it in increasingly sophisticated and socially coordinated ways. Participating in specific forms of social practices may be in legitimate peripheral ways or in deeper, coordinate ways. Bell et al. state that learning is a social endeavor and the development of pragmatically useful and/or meaningful social relationships is a necessary part of learning. In these ways, situated learning is generally about developing stabilized and flexible identities (Lave & Wenger, 1991).

Our science learning environments are designed around agency where we endeavor to mediate practice-linked identities through deep disciplinary learning. Bell et al. mention the processes involved when one engages in deep disciplinary learning: identifying a sustained interest and/or concern and participating in that domain, appropriating the discourses of communities one belongs to, seeing value in the communities one belongs to relative to one's personal goals and commitments, wanting to contribute to these communities, and becoming and being recognized as an expert in the associated domain (Wenger, 1998). Similarly, Wenger (1998) discusses three modes in which identities are constructed within communities of practice; namely, engagement, imagination, and alignment. Engagement refers to how a learner

participates in a community of practice; this also includes nonparticipation. Imagination refers to how the learner sees himself or herself connected to the broader community of doers; and alignment refers to how youths' actions within that community come to be aligned toward a broader goal. We can draw parallels to process-related activities as well as how identities are constructed in practice. Wenger (1998) also adds that the process of identity development includes identification (e.g., a learner becomes a participant in the science community) and negotiability (e.g., learners having ownership and agency for transformation within a community of practice).

Bell et al. maintain that the pursuit of practice-linked identities rests upon ones understanding of the social practices as well as having access to situations that make available scopes of possibility for learning and identification. This type of learning occurs across contexts through “connected constellations of situated events”—similar to how Azevedo (2011) has conceptualized learning along “lines of practice.” Learning is accomplished across time, in a variety of locations that have both shifting and sustained qualities. Learning becomes visible through talk and action in a situation by taking a stance. By taking a stance or choosing not to take a stance requires having agency. In discourse, when learners take a position or stance, they speak “from” a particular point in history, and they always speak “on” history (Blommaert, 2005: 126).

Learning occurs in relation to the social and material circumstances of particular places or locations. Social practices associated with science make specific use of specialized materials within relatively precise places/structures. These materials and places/structures are laced with political, epistemic, and social power (Latour, 1995; Rouse 1996). These technologies of power prohibit or invite action. As we participate in social activity, we are constantly positioned by

others or things and by ourselves. Context and practice become intertwined, which highlight our actions and positions in social activity. The Cultural Learning Pathways model accounts for the ways in which actions, positions, and locations define the scopes of possibility for participants that relate to learning and identification.

### 3.1.1 *Applying a Semiotic Perspective to Identity Development and Student Agency Along Cultural Learning Pathways*

When considering the modes of expression in an utterance the grammatical units create logogenetic patterns and mark cohesion. As a text (spoken or written language) unfolds patterns emerge from instantiations. On the one hand, the patterns of instances unfolding establish meaning in some particular context that is specific to a text; on the other hand, repeated patterns of instances unfold meaning particular to a context. This gives rise to a generalized system<sup>7</sup>, which is an attribute of a certain type of text or register. The textual resources that mark cohesion show the meaning making relations in the unfolding text. Cohesion includes conjunctions for marking textual transitions; and reference, ellipsis and substitution, and lexical cohesion to exploit the positioning or rank of textual resources in the flow of information.

At the semantic level, patterns of meaning unfold in a particular situation in context. One reason is because text is a unit in the flow of meaning and is realized by clauses. The clauses are located at the lexicogrammar (wording) level and are in relation to the semantic (meaning) level. Clauses are the unit of analysis in the lexicogrammar level as the grammatical resources enable meaning making and describe categories by reference to what they mean. The clause as a multifunctional construct realizes three different units of meaning for each metafunction:

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<sup>7</sup> Halliday and Matthiessen (2004) define “system” as a resource for potential meaning making

textually by the message (field), interpersonally by means of a proposition or proposal (tenor), and experientially by a figure. This type of analysis shows the functions of language in relation to the environment where one can make sense of experiences and enact social relations.

The ways in which language construes human experience is by the grammatical resources of the lexicogrammar. Halliday and Matthiessen (2004) define the first function the “ideational metafunction” and distinguish it into the experiential component and logical component. As one uses language one is also enacting their personal and social relationships with others. Again the clause represents a process (e.g., doing, being, saying, etc.) with other participants and circumstances; and it functions as a proposition or a proposal. Functions are inherent in language and so when we consider the term “metafunction,” it gives us a way to talk about them as components of a theory of human experience. Language viewed as reflection and as action has an “interpersonal” metafunction, suggesting its interactive and personal nature. Propositions or proposals form patterns of exchange involving interlocutors.

Another mode of meaning related to the construction of texts is the “textual” metafunction. As the ideational and interpersonal metafunctions construe experience and meaning is realized via interpersonal relations, the “textual” metafunction facilitates functionality by constructing sequenced patterns from instantiations and the flow of discourse is organized and generated by means of cohesion. Thus the unfolding meaning in text is logogenetic.

From a semiotic perspective, Kockelman (2013) refers to the association indexes (first- and second order) as a network of channels where selection, combination and value make-up structure (syntagmatic relationship) and practice (paradigmatic relationship). Structure refers to how one should talk and/or speak (syntax) and practice refers to any sentence in a particular

context (an utterance) that can both instantiate and undermine the set of constraints established by structure; for example, the use of metaphors. Value is understood as a way to interpret how the agent, in this case the student, frames the features of an object or vice versa.

The agent is viewed and defined in relation to objects and its sign and interpretants. The object and its sign and interpretants have value in context, in relation to particular communities of practice. Agents<sup>8</sup>, which are human or objects, then are distributed, multidimensional, and, by degrees of proximity, occasionally coincide, under particular framings, with other agentive entities, such as animals, people, instruments, etc.

The constraints of structure sets, also known as principles or protocols, determine how communities of practice are interrelated through a process of selection and combination. For example, a student may talk about science from a school-science perspective as well as a world-science perspective but the way these inter-related communities of science are expressed are in typical school science talk, whereas another student may express his or her thoughts metaphorically (e.g., “*Science is the gears of life*”). These produced expressions represent the practice of channels, which are constrained or enabled by the structure of channels, which constantly change in the flow of time. As a student expresses a thought, which can be seen as a code for a particular context (for example, ‘*experiment*’ is a code for ‘*what is science?*’), it constitutes a particular grammar that was selected and combined at a particular moment. This code changes through time as well as the grammar that constitutes that particular code and is

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<sup>8</sup> A Systemic Functional Grammar (SFG) distinguishes the term ‘Actor’ from ‘Agent’. The experiential metafunction in the transitive model marks the participant in the clause as ‘Actor’ in a material clause; but in the ergative transitivity model ‘Agent’ is understood as the participant in the clause that realizes a Process + Medium. I use the terms interchangeably in discussions but in the SFL analyses, I have applied the terms precisely.

transformed to refer to something else or remain the same. Kockelman (2013) suggests, “one is selecting (focusing on meaning and through motivation) what and whose instigations one will sense and what or who will sense one’s instigations.” Therefore the first- and second-order indexes operate at a selection and significance level that are mediated relationally. First-order indexes focus on the co-occurrences between word pairs. Second-order indexes focus on the similarity between features, referring to their use and meaning of the corresponding words.

Meaning making is viewed as an intersubjective process where collaborative engagement driven by interest or attention is required. Drawing from Trevarthen (1978 as cited in Thibault 2004), by orienting or attending to an activity reveals the level of attention, interest or engagement during interactions. The exchange of information, in this case, is iconically related to the contextual exchanges to which the interpretants relate. As a result, the varying exchange of information is interpreted as shifting degrees of attention, interest, engagement, etc. The affect, motivation, or interest is consciously attended to more than the exchange of information. Relevance here is “implicit felt meaning” (Gendlin, 1962 as cited in Thibault, 2004:59). One feels the meaning of something as a felt sense that is related to a particular sign or experience. For example, when students are asked if they consider themselves a scientist, their responses, whether they self-identify as a scientist or not, is expressed as an implicit felt meaning because the activities are hands-on, students control their learning through choices, which heightens their level of interest or attention.

### 3.2 Study Context and Curriculum Designs

The data presented in this dissertation was collected as part of the *Agency in Sustained Problem-Based Inquiry: Learning Science through Innovation* (DRK12) project for understanding how we

can design inquiry-based curricula for teacher and student agency and develop practice-linked identities. Our partner school district is a mid-sized suburban school district with 16 elementary schools, and a district-wide enrollment of more than 17,000 students. There are 72 languages spoken in the district, and 34.5% of students speak a first language other than English. Approximately, 17% of students are ESL (English as a Second Language) learners. Across the 16 elementary schools, the average percentage of students qualifying for free or reduced lunch ranges from 5% to 66% (see Appendix 2 for School Demographics).

For this study, data from 2012-2013 comes from seven elementary schools where teachers and students were recruited as volunteers to participate in the research. A “waitlist control” design in that all teacher-volunteers in a school were assigned to teach either the existing science curriculum unit, which include *Landforms, Environments, and Mixtures and Solutions* (henceforth MixSol); or our experimental units (namely, *My Skokomish River Challenge* (henceforth MSRC), *Algae Invasion* (henceforth Algae), and *My Solution to Pollution* (henceforth PolSol) - which have been adapted to promote learner agency (see Appendix 3 for unit descriptions). Inquiry classes served as comparison classes. Schools were matched demographically and were randomly assigned to either the experimental or comparison condition. The research includes schools that represent the district’s range of socioeconomic diversity. Each unit, experimental and comparison, was enacted at different times of the school year, which is represented by two cohorts (see Appendix 4 for unit enactments and student cohorts). This is due to the school districts inquiry science kit rotation schedule.

The classrooms using curriculum materials that had been redesigned (the Agency condition), guided by learning principles (see Appendix 5 for a description of the design principles and related activities) and comparison classrooms using the original commercial

curriculum materials (the Inquiry condition) units where and then systematically studied during implementation by participating teachers and researchers. By iteratively changing the redesigned units over the duration of the project, we were able to examine how systematic changes influenced learning, practice, agency and identity development.

### 3.3 **Methods and Data**

*Interviews:* Data sources include semi-structured interviews (See Appendix 6) that were conducted at the end of each unit, both Inquiry and Agency classes. The interview was designed by the research team and then reviewed and refined by the steering committee. The goal of the interview was to elicit from students their opinions and ideas about science and the science units they had completed through open- and closed-ended questions. From an etic stance, the interviews focus on students' perspectives on science at school and outside of school, their science experiences and how they related to their learning, the enterprise of science and their identification with science over the course of the intervention. Three researchers, myself, another graduate researcher involved in the project and one of the project principle investigators conducted the coding of the interviews. In our coding sessions, we reviewed our coding schemes and agreed on decision-rules for analyzing interview responses. Once we had coded 20% of interview responses and highlighted excerpts that were difficult to code, we discussed and resolved our differences and established key codes. The inter-rater reliability, which was calculated by the percentage of agreements, ranged from 70 to 94%. Subsequently, all transcribed interviews were entered into *Dedoose*, a software program for qualitative and mix-methods research, for qualitative analysis. The coding results were used to construct graphs and tables showing the emerging themes, which were subsequently reviewed a second time using

Excel to further refine emergent themes (see Appendix 7 for descriptions and examples of key codes).

The transcribed interviews were also analyzed using *T-Lab* version 9.2 (Lancia, 2012), which is a software program with linguistic, statistical and graphical tools designed to execute automated thematic analyses. *T-Lab* was used to firstly, triangulate the results with the researcher-coded results and understand, from an emic perspective, the reciprocal relationships between the context of a particular interview question under analysis and the words or lexical units used by the students. The analyses highlight occurrences of contiguity<sup>i</sup> and similarity. The meaning of each lexical unit is achieved through the relationships with the contexts, thus the distribution of its occurrences or co-occurrences within the Context Units. The Thematic analysis uses a bottom-up method to map the meanings of student responses to particular identity- and agency-related questions. Similar to a Grounded Theory (Glaser & Strauss, 1967) approach, bottom-up methods construct a coding system with a repertoire of thematic contents. Finally, both etic and emic approaches are compared for reliability and discussed.

*Systematic observations* took place in the school, during science where audio-video recordings and field notes describe ways in which students' participation develops over time. Observations show what teachers and students are doing in context by drawing inferences. These inferences, in some cases, would otherwise not be captured in other ways, for example in the student interviews. Maxwell (2005) states that observations get at tacit understandings as well as views that are not shared during interviews. Observations are oriented to understanding the interpersonal interactions between students in groups and the teacher addressing the whole class as well as documenting how conceptual dimensions of the National Research Council's (2011)

*Framework for K-12 Science Education* translate in the context of curriculum enactments designed for learner agency. Videotaped episodes of instructional framing and student positioning as well as student group discourse across investigations were analyzed to understand: (a) the extent to which students identities are mis/aligned to learning, and (b) the characteristics of learning environments that enable or constrain student agency and positive identification in science and science learning.

*Videotaped episodes:* From my field notes, I first located episodes marked as significant moments when a difference of opinion arose during student-led investigation, which were then transcribed using *InqScribe* and an interactional analysis (cf. Jordan & Henderson, 1995) of interpersonal interactions during the evidence-gathering phase of inquiry was analyzed. The analyses were conducted in stages where the interviews, student artifacts, and systematic observations provided a background against which video analysis is carried out, while the detailed understanding provided by the microanalysis of interaction, in turn, informed my general ethnographic understanding (Jordan & Henderson, 1995). When a group of students engages in scientific practices their capacity to act and interact is distributed between participants. As a result, students are positioned differently regarding the capacities attributed to them by others or by themselves. Moreover, Goffman (1974) explains that participant roles in an activity are often differentiated as they direct different spans and levels of focus due to different interests that generate different motivational relevancies. Participation structures and roles that emerge during teacher-student and student-student interactions reveal differences in positioning, involving entitlements and expectations of the individual for initiating interaction (Greeno, 2006). Following the analytical process used by Tannen (1993), I first draw on the notion of

framing (Goffman, 1974) as a guide to examine student expectations during science. Tannen (1993) describes expectations as measuring new perceptions against what we know of the world from prior experience. Expectations allow us to, firstly, perceive and interpret objects and events; and secondly, shape our perceptions to our model of the world. In other words, we form a general impression, which is the *frame*, and we inform our frame from prior knowledge and experience. Frames establish and regulate social positioning dynamically from storylines that flow during participation in a setting. Tannen (1993:21) claims that interpretation is possible through structures of expectation where we reflect back on our scripts to justify an interpretation, which is actualized in discourse.

## **Chapter 4 Findings**

### **Part I: The Social and Material Divisions of Labor in Teacher Instructional Framings**

#### **4.1 Analytical Lens: Functional Grammar**

Systemic Functional Grammar (henceforth SFG) (cf. Halliday & Matthiessen, 2014), as a resource for meaning making – ‘transforming experience into meaning’, was used for analyzing teacher and student positioning. Language is constitutive of meaning and social context and so the language of school science may be considered as actively constructing a particular realm of scientific reality, and constructing roles for students within this realm. Meaning in science discourse is realized by particular linguistic forms and functions; for example, nominalization where processes as verbs (‘I predict...’) become ‘things’ which are nominal groups (‘The prediction...’) functioning as participants/theme/subject. As an example of grammatical metaphor, Webster (2009: 4) states “the scientist can make the world stand still, or turn it into one consisting only of things, or even create new, virtual realities.” Nominalization restructures congruent clauses to metaphorical clauses. Science texts are also constructed using chains of reasoning, which linguistically is referred to as constructing sequential arguments as well as constructing technical taxonomies. Polias (2006) claims that student success in school depends on developing control of a variety of genres and registers. Using Halliday and Matthiessen’s (1994) functional grammar as a method to analyze how teacher and student discourse works to construe experience and enact social relationships three register variables will be highlighted:

Table 4-1 Register Continua (Adapted from Dare, 2010; Polias, 2006)

<b>Field - Ideational</b> 'what's going on?'		
←		→
Everyday knowledge concrete and specific	Specialized knowledge non-/specific Lifeworlds	Institutional knowledge generalizations and abstractions
<b>Tenor - Interpersonal</b> 'who's involved?'		
←		→
informal subjective status: novice	increasing formality	formal objective status: expert
<b>Mode - Textual</b> 'what channel of communication?'		
←		→
spoken doing dialogic close	spoken texts written down written texts spoken aloud genres: recounting/reporting	written reflecting monologic distant

*Field* illustrates the ways in which activities co-articulate everyday and science practices - which are on the abstract end; *Tenor* is enacted through power and solidarity in role relationships that range from informal, subjective writing with everyday vocabulary to formal, objective writing with nominalization and technical vocabulary; and *Mode* shows what part language is playing through text organization, status, and function in context, channel (spoken or written), what is achieved—persuasive, expository, didactic. These aspects of register in social context are structured by genres fulfilling particular purposes. The functions of language have three grammatical resources, namely:

1. Experiential metafunction – establishes experiences of the world
2. Interpersonal metafunction – enables one to interact or negotiate social relations

3. Textual metafunction – manages information flow coherently and cohesively.

The experiential meta-function, the modeling of a domain of knowledge, realizes students' behavior by material, behavioral, or mental processes; and the relational or existential processes actualize the nature of tasks (Christie, 1998; cf. Halliday, 2014 Transitivity Model). Butt et al. (2003) illustrates the relationship between speakers and addressees in discourse where different roles are assumed by the first, second or third person. The type of exchange, as related to the identity of 'I' and 'you', shows the relationship between first and second person and determines the solidarity or distance of the addressee by including or excluding them in first person plural pronouns (i.e. inclusive or exclusive 'we').

Butt, et al. (2003) explain that in the interpersonal meta-function the Subject/Finite relationship in discourse realizes the message as a statement (declarative), question (interrogative), or command (imperative). This is actualized by the Mood, which indicates whether the message is giving or demanding information or demanding goods and services. Consequently, student and teacher positioning's are revealed during the turns of exchange; namely by the way a teacher or student (a) gives or withholds information when questioned, (b) agrees or disagrees with information when responding to a statement, (c) observes or disregards given instructions, and (d) accepts or declines offers. The interpersonal meta-function, realizes the various strategies to express meaning during interactions and tenor—the context of meaning and action in which social positions and social relationships are named and conducted (Holland, et al., 2001: 60). Mood reveals identities in practice—the “suturing of the person to social position” (Hall, 1996), positioning—the power, status and rank of participants, and orchestrated authorship in responses (Holland, et al., 2001: 272). Correspondently, Trevarthen (1978 as cited in Thibault, 2004) asserts that participation reveals the shifting degrees of attention, interest, or

engagement during interactions. Frequently occurring instances of processes realizing students' behavior are regulated by student/teacher positioning, which relate to the student/teacher social positioning's. As a result, unequal distributions of power arise because teachers and students reveal what they perceive is relevant or irrelevant given their histories and the situation in context, which in turn always leaves the individual with a choice (Hasan, 2004).

Coherent and cohesive resources create 'texture' in the textual meta-function (Halliday, 2014: 88). A clause is organized as a message that fits in and contributes to the ongoing discourse. The Theme is indicated by position in the clause, which locates and orients the clause within its context. The Rheme makes up the remainder of the message. A clause consists of Theme, accompanied by a Rheme. Within a clause, whatever is chosen in the Theme is positioned first. The Theme of a clause is the first phrase that has a function in the experiential structure of a clause. The Theme in a clause serves as the point of departure of the message, thus Textual Theme choices are usually located in the beginning of the clause and they direct the construction and sequencing of discourse. Textual Theme choices operate in teacher talk and establish the regulative register. Marked and Unmarked Themes refer to states that are everyday and particular, respectively. Marked Themes make visible the purposes responsible for teachers or student's text patterns. Other functions include building coherence for sequencing. A thematic analysis shows how the initial position in the clause is meaningful for the construction of the clause as a message. It also anchors the clause in the realm of experience.

Table 4-2 Theme Constructions

Theme		Rheme
Textual (organization/ development of text)	<b>Unmarked (Theme as subject)</b> <b>Topical (Theme)</b>	
<b>So,</b> Interpersonal (creating relationships between speakers)	you <b>Topical</b>	have to decide,
<b>Can</b>	anybody	remember what some of those were?
Textual	<b>Marked (Theme is non-subject)</b> <b>Topical</b>	
<b>So,</b>	the same quantity of water running at the same rate across a plateau that was slightly on a slope, a 30 degrees slope	did have a huge effect.

Structurally, textual Theme choices show the construction and sequencing of the discourse. Christie (1995) highlights two types of textual themes: (1) continuative (for example, *Now*, *All right*, *So*, etc.) and (2) structural (for example, *and*, *next*). The continuative and structural themes develop the regulative register, which outlines and sequences the discourse and learning. Continuative textual themes occur at the opening of a genre or activity. Whether continuatives are used by students or in teacher talk, they highlight the stages for learning and the authority figure.

### **Finding 1 Pedagogic Discourse: Regulative and Instructional Registers**

I begin by showing the relation of logogenesis (the curriculum genre of My Skokomish River Challenge, henceforth MSRC) to ontogenesis (science learning of SK's (pseudonym for one of the teachers in the Agency group) focus group, particularly Student 1 (SK52 pseudonym)) from the Agency group. Christie (1998) explains that the logogenetic view traces the development in the organization of the science classroom text from the beginning of a unit, and the ways it expands, builds and sustains its meanings until the end of the unit. Drawing on the notion of a curriculum macrogenre (Martin & Rose, 2005), analogous to the redesigned units' challenge cycle, two registers are present (cf. Bernstein, 1996): a regulative register consisting of the teacher's goals for the activity; and an instructional register, which is knowledge related. The regulative register introduces, orders, and paces the instructional register (Christie, 1998). Bernstein (1990 as cited in Christie, 1998) describes pedagogic discourse as borrowing from other discourses and bringing them in relation with each other for selective communication and acquisition purposes.

While teachers make use of these registers, this analysis focuses on both teacher and students' use of instructional and regulative registers to guide activities and learning. According to Bernstein (as cited in Martin & Rose, 2005), the regulative register is the dominant discourse as it is actualized by a speaker, often the teacher, and it projects the instructional register. Consequently, this raises the issue of equity in the science classroom—Who is in control? Who has power? Moreover, drawing on Bernstein's formulation of the relations between the two registers, Martin and Rose (2005) state that the regulative discourse maintains a standard by

means of rules and regulations. Accordingly, the regulative register creates unequal relations of competence and identities developing or dislocating a scientific habit of mind.

The role of science education includes accountability for one's impact in the world. Genres in macrogenres are interdependent and extend or elaborate another, or are embedded in other genres. For example, a lab report represents a macrogenre because of the method stage as a procedural account, the results stage recounting what the students observed as a causal explanation, a discussion stage explaining observations and the conclusion stage stating what is according to the experiment as an information report. Polias (2006) asserts that developing an expertise of the prototypical genres enables students to successfully and in increasingly sophisticated ways negotiate complex meanings. Developing students' linguistic resources entails, as an example, using one genre to do the work of another genre (e.g., a causal explanation as a procedure). Moreover, Polias maintains that teaching activities and texts that match with how meaning is made within the text affords new meanings and increased learning.

The official Curriculum, My Skokomish River Challenge—a redesign of the Inquiry Landforms Unit sets the context (see Appendix 8 for unit outline). The following analysis begins at Investigation 4, Part 1 after students have completed and reviewed, as a class, their whole-class experiment on factors of erosion that establishes their control variable in the stream-table investigation. Participants include the teacher, SK, and a focus group: Student 1 (female), Student 2 (female), Student 3 (male), and Student 4 (male). In this lesson students generated a list of factors they thought affect erosion and deposition. As a class, students planned, conducted, and evaluated an experiment on one factor that affects erosion and deposition. The factor explored was slope. Given the results from the experiment, students were expected to find evidence to support the Site they were intending on choosing.

This analysis first focuses on how the teacher, SK, frames the lesson and then on the ensuing discussions of a focal group in SK's class, illustrating the interplay between the curriculum macrogenre and student agency, identity, and learning. The lesson is structured to afford theoretical and practical agency (Kockelman, 2013) as students work in small groups to choose a question to investigate. Kockleman (2013) explains choice as exercising a means for an end and relevance comprises a sign representing an object that bears an interpretant.

Communicative acts function as a type of causation, which at the same time makes the question of identity and agency relevant for learning. Language and semiotic modalities are constitutive of consciousness, identity, and agency and, therefore, cannot be separated without failing to understand the nature of human meaning-making activity (Thibault, 2004). Thus, as the teacher, SK (pseudonym), sets the goals for the lesson, students then work in groups to design their own investigations and determine the measured variable. Students have the opportunity to think critically about their peers' methodology, as well as to learn from their own work, thereby illustrating how consciousness, identity, and agency emerge in and through transactions with others and objects in time and space. The following example traces these "social divisions of labor" (Hasan, 2004: 37) in the Agency group, which includes the teacher, SK's, instructional framing:

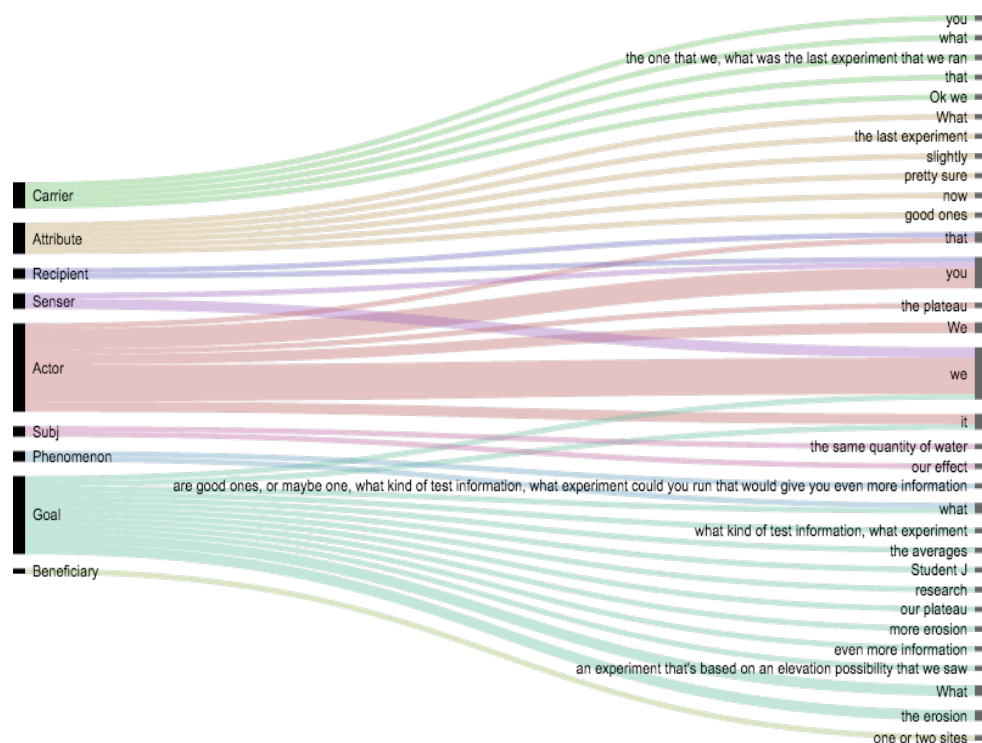
- 1 Teacher: Ok, um, we're now to the part where you've done research, you've checked out the different sites with information and visual
- 2 information, we've run an experiment that's based on an elevation possibility that we saw. We compared it with a level platform,
- 3 plateau. And now you have to take everything that you've been seeing, learning, thinking about and discussing, and you have to decide
- 4 what experiment your team can create that can best answer a question you still have, or will best give you the information that you
- 5 need to help refine or make a decision. And if you've already got one or two sites that you're pretty sure you think are good ones, or
- 6 maybe one, what kind of test information, what experiment could you run that would give you even more information? So basically,
- 7 with your team, you're going to have to think about and talk about and come up with an experiment, ok? What was the one that we,
- 8 what was the last experiment that we ran? What were we testing for?
- 9 Student J, what were we testing for?

Lines 1-2: The prelude is a monologue with a regulative register as shown by the boundary marker “ok” that signals the start of the lesson or prelude where the teachers’ goal creates a common focus as she states “we’re” by collectively positioning the class and herself as the Medium where the temporal adjunct “now” directs them to the present circumstances as a result of previous activities. As an embedded enhancing clause with the relative adverb “where”, it functions circumstantially describing past activities, thus functioning as regulative register sequencing activities. Consequently, the teacher shifts the positioning of the class to focusing on the student as the Possessor, “you’ve done”, by explicitly recalling the research done and the information collected. Students are framed as ‘doers’, signaled by “done” and ‘examiners’ of information. The teacher holds authority as she recounts what the class has done so far for selecting a site. She shifts her position again by recalling the whole class experiment, placing authority in the class as Actor - ‘operator’, expressed by “run an experiment”. This opening sentence is a paratactic clause of expansion that lists past events as discrete yet pertinent to the projective events.

Lines 3-5: The structural themes actualized by continuatives demonstrate how the teacher’s discourse shifts positions from “we” to “you” realized by the temporal adverbial modification “now”. Consequently, the student is repositioned as Actor, Senser and Sayer realized in taker as well as viewer ‘see: view’, student ‘learn: subject’, knower ‘think: thought’, and discussant ‘discuss: talk’ because of the verbs in the present participle functioning as predicator and then projected as decider because of the modulation ‘have to decide’. In this instance the teacher relegates her position to thematize the students by explicitly positioning the student as Actor using “we” and “you” to indicate that they will be in control of their actions. Individual student agency shifts to collective student agency as the teacher gives the “team” the

possibility to “create” or to be an impeller to action by what they already possess or own ‘have: possession’, that is, to create or decide based on the information, as an epistemic process, they already have, recalling previous activities. The teacher also topicalizes the task stating, “you have to decide what experiment your team can create that can best answer a question you still have, or will best give you the information that you need to help refine or make a decision”.

While the teacher is the sole Actor because she uses declarative statements, “you have to decide”, to impart directions. The students’ roles assigned either by the teacher or the object – information, experiment, questions – as Medium, positions students as a ‘needer’, ‘decider’, ‘creator’, ‘helper’, ‘refiner’ and ‘owner’. It is within these parameters that students’ agency may be both understood and realized. So far, SK positions the class in the participant role of Actor, “we”, as well as identifying “an experiment” in the participant role of Goal (see Appendix 9 for SK and AY Participant Roles). The use of the nominal, “an experiment”, by the teacher establishes expectations in the regulative register, which introduces, orders and paces the instructional register.



*Figure 4-1 SK My Skokomish River Challenge Participant Roles*

Figure 4-1 highlights the participant roles established by the teacher, SK, during her instructional framing. The transitivity system acts as a resource for construing experience in the experiential metafunction. Various processes realize participant roles as well as circumstances. The majority of processes that realize student roles entail material processes, which is a process of doing or happening. The Actor is the key participant performing the action; the Goal is understood as the entity or thing affected by the action; the Attribute refers to the quality ascribed or attributed to an entity; and the Recipient refers to the receiver of goods or services. Other processes include mental processes, which construe cognition, perception or affection. Participant roles in mental processes include Senser, which is related to how the participant thinks, perceives, and feels, and Phenomenon is that which is thought about, perceived or felt emotionally. These parameters shown in Figure 4-1 invoke epistemic agency: The teacher,

through joint construction, created awareness for the students within the context of the MSRC unit by identifying a problem and having the students gather information and possibly collect more information, “what kind of test information, what experiment could you run that would give you even more information?” She creates a shared understanding before releasing the students to their group activities, namely generating new ideas, taking up and refining previous ideas, or negotiating new ideas. These epistemic actions enable projective actions: “with your team, you're going to have to think about and talk about and come up with an experiment” (see Appendix 9 for SK and AY Transitivity Analysis: Processes).

In Lines 6-9, the teacher reinforces her directions by bringing the students back to creating a shared understanding by questioning students about previous activities and how they relate to future activities: “What was the one that we, what was the last experiment that we ran? What were we testing for? Student J, what were we testing for?”

In the prelude, the teacher sets the goals for the lesson and the regulative register is foregrounded regularly. As the teacher goes into more detail, the instructional register is foregrounded. This is realized in the use of transitivity, “you have to decide what experiment your team can create...” and “you have to base it on things...” The instructional register is actualized in the participant role of Goal, “[the] experiment”.

#### 4.2 **Textual Metafunction: Theme and Rheme**

A thematic analysis shows how the initial position in the clause is meaningful for the construction of the clause as a message. It also anchors the clause in the realm of experience. Topical Themes in the experiential metafunction identifies the Participant, Process or Circumstance as an opening for a course of action. Emphasis on ‘place’ shows where the first element of experience unfolds. Topical themes realize the regulative register where the students

in ‘you’ and ‘we’ are foregrounded as subject and the Rheme outlines the processes that regulate student behavior by marking previous stream table experiments. The Wh-clauses realize the regulative and instructional registers simultaneously by foregrounding previous activities and making connections to scientific practices and concepts such as changed or measured variables. From this short excerpt, the teacher uses both registers to highlight the science content students are expected to recount by highlighting points for the class to reflect on. The Interpersonal vocative Theme calling the attention of the student, Ja, marks the relationship, thereby claiming superior status or power.

*Table 4-3 SK My Skokomish River Challenge Topical Themes*

<b>Theme</b>	<b>Rheme</b>
We	‘re now to the part
We	compared it with
You	‘ve already got
basically	with your team
What	was the one that
What	were we testing
Student J	what were
So	if we put our plateau
what	did we discover
How	did it affect
what	did we measure
How	did we find out

Textual Themes preface experiential meanings with conjunctions, as an example, to map meanings between clauses. Textual Themes establish cohesive texts by relating experiential meanings to adjacent clauses. The use of conjunctions in teacher discourse realizes the regulative register and marks the various stages in the lesson focusing on scientific vocabulary (‘what did we measure?’) and instructions, thus shifting the focus from reflecting →presenting →outlining consequential instances, which suggests the teacher moves from abstract to concrete themes. For

example, the unmarked Theme, WH-interrogative functions to search for a missing piece of information, where the WH-interrogative expresses the nature of the missing piece:

“And what + did we measure our effect by?” → Theme: by what | Rheme: did we measure our effect

Here the WH-element is combined with the minor Complement of a prepositional phrase that serves as a circumstantial Adjunct in the clause. In addition, the preposition by indicates that the teacher wants a unit of measurement [length of the delta].

*Table 4-4 SK My Skokomish River Challenge Textual Themes*

And [coordinating-conjunction; extending – addition]	if you’ve already
If [subordinating conjunction]	you've already go
So [arguing - consequence]	basically, [adjunct]
And [coordinating-conjunction; extending – addition]	What did we discuss
So [arguing - consequence]	the same quantity
And [coordinating-conjunction; extending – addition]	what did we measure

## **Finding 2 Comparing Teachers’ Uses of Registers in Instructional Framings**

### **4.3 Ideational Metafunction: Participants, Processes, and Circumstances**

It is important to understand how teachers frame instructional tasks for learners to engage in. Teacher instructional framings organize texts as sequences of messages when modeling knowledge. As meanings unfold patterns emerge from instantiations that either establish meaning in some particular context that are specific to a text (regulative register – classroom discourse); or, repeated patterns of instances unfold meaning particular to a context (instructional register – science discourse). The clause, as a unit of analysis, in the Ideational metafunction models the flow of events as a “figure” or a configuration of processes, participants, and circumstances—“goings-on” (Halliday & Matthiessen, 2014:213). Goings-on include ‘doings’,

‘happenings’, and ‘sensing,’ saying, ‘being or having’. The process and the participants make up the center of the clause and are understood as complimentary to change. Halliday and Matthiessen call these two complimentary aspects as “transience” and “permanence”.

Transience is experience unfolding through time; and actualized by a verbal group serving as the process. Permanence refers to stable experience located in space actualized by nominal groups serving as participants. In sum, change entails both transience and permanence, and experience is understood as a transient process or as a permanent participant.

Iconic texts that are field-structured (time/place) determine activity sequences in two ways: (1) around time through social actions, which are called “ancillary” because the organization of the text differs from the genre; and (2) by texts where sequences of events realized linguistically ‘monitor’. In the latter, the sequence is organized around time and so the sequences ‘monitor’ what is going on, ‘reconstruct’ past events, or ‘generalize’ about what goes on. Iconic texts that are genre-structured ‘review’ field-structured texts, and ‘theoretical’ texts (cf. Martin, 1992: 518).

Christie (1998) states that the instructional register is given significance when transitivity is used where the regulative register foregrounds the instructional register (e.g., the teacher SK states, “So if we put our plateau on a slope (regulative), (instructional) how did that affect the erosion?”). The regulative register outlines the over all goals of an activity and it sequences the activities and actions. The instructional register relates to knowledge or the content being taught. Regulative registers determine the manner in which the instructional register is realized. Davis (2004: 46) explains that pedagogic communication and communication in general is either made necessary as a consequence of a partially “unified social consciousness” or as a result of power at play -- as it differentiates between what and whom and establishes differential access to goods.

In Excerpts 1 and 2 (see Appendix 9) the interplay between regulative and instructional registers illustrates Davis' notion of 'power at play'.

Circumstantial information about a process is defined as a Circumstance (Butt et al., 2003) and it establishes an understanding of the processes and the instructional register is actualized as a Circumstance and in the participant role of Goal (see Appendix 9 for data related to registers). The Circumstances (see Figures 3-2 and 3-5 of the teacher talk related to instructional framing) foregrounded by the regulative register in the opening for the Agency group comprises circumstantial elements of Manner, which describes how the process is realized or expresses a causal connection between events. As a sub-category, Circumstance of means is defined as the way a process takes place; hence Halliday and Matthiessen (2014) state that both agency and instrumentality function as participants (Agent or Actor). This suggests instruction related to doing science (Polias, 2006) is used frequently by the teacher, SK, for drawing on a range of genres to fulfill particular instructional goals.

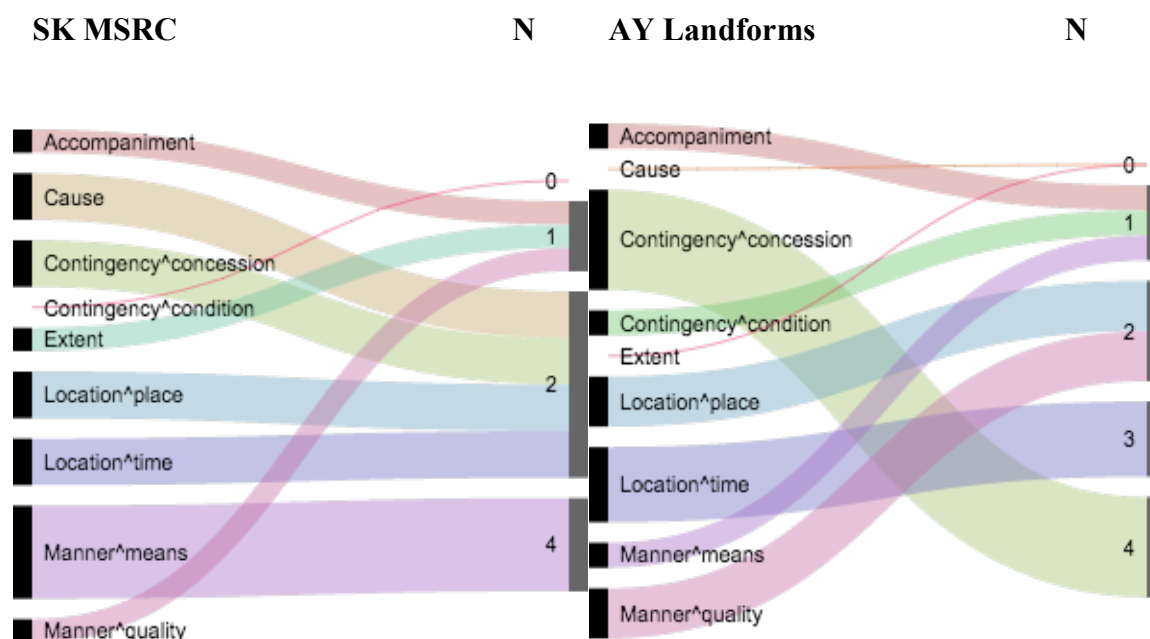
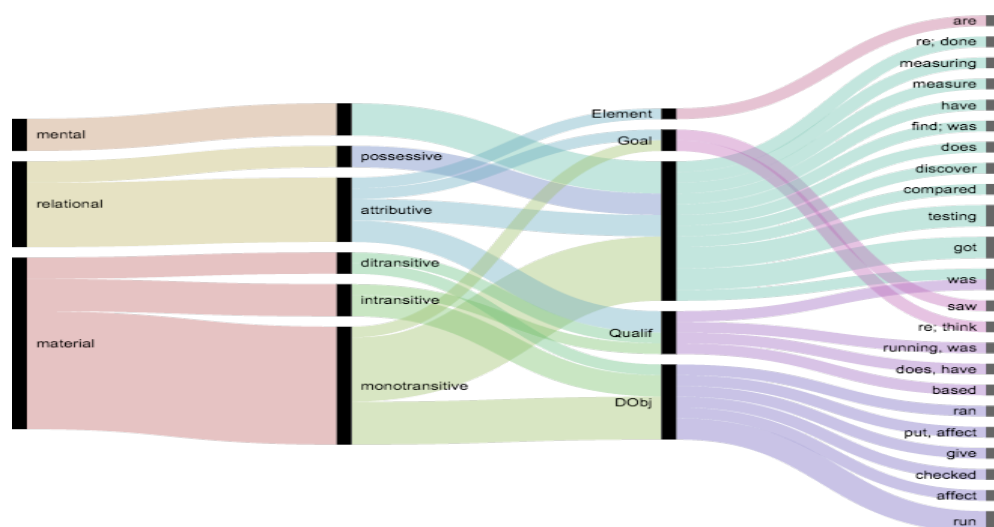


Figure 4-2 Circumstance Occurrences as Regulative Register

The circumstantials of Location construe the unfolding of a process in place and time. The excerpts represent an introduction to an activity and so Circumstances of Location in relation to time indexes past and future activities – connecting previous stages of the challenge cycle to the next. Placing emphasis on the agency curriculums as connected pieces that form a whole, the teacher, SK, operates in a manner that focuses on Location in relation to time.

The circumstantial element of Cause interprets the reason why the process is actualized, the purpose of the intended conditions for which the processes is actualized, or to denote a person – known as Behalf (Halliday & Matthiessen, 2014:322). In this example, SK elicits the reason why they were ‘testing’ for the effect of erosion.

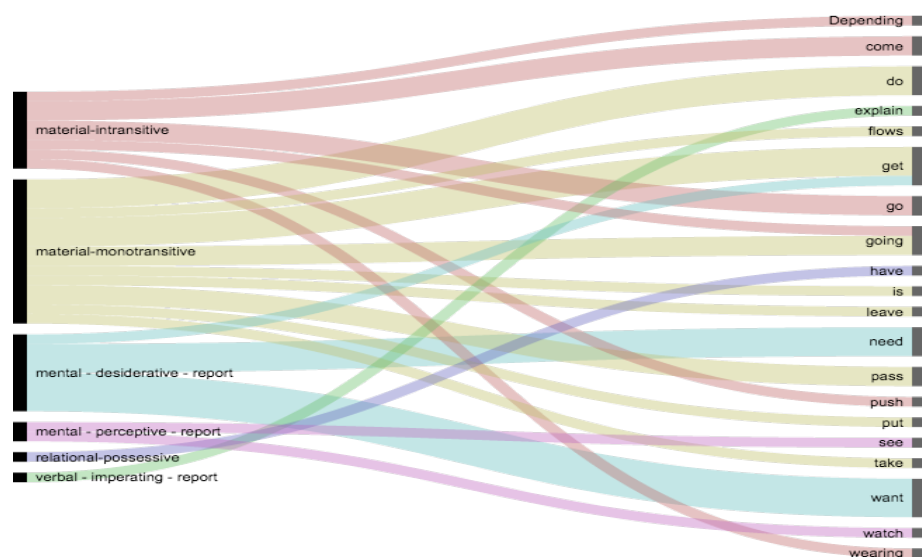
Finally, both teachers regularly use circumstances of contingency, which Halliday and Matthiessen (2014: 323) define as “an element on which the actualization of the process depends.” Concession circumstantials are used to justify instructions that steer the lesson or acknowledging, with hesitance, that something is correct – thus frequently occurring in teacher talk in the form of an evaluation. Typically, SK begins the lesson by reconstructing past activities and building on a particular understanding that is realized with material, relational, and mental processes (see Figure 4-3 SK MSRC Processes of the teacher instructional framing of the agency curriculum).



*Figure 4-3 SK My Skokomish River Challenge Processes*

From Figure 4-3, SK realizes material processes as they relate to what students had previously done. The majority are monotransitive clauses meaning they relate to a single object, in this excerpt, to the past and then ditransitive clauses relating to two objects to reach agreement on what affects erosion. The relational clauses construe being, possessing, or becoming. From Figure 4-3, SK use of attributive as well as possessive clauses positions students as possessing and becoming.

The Inquiry units constitute disconnected activities that are part of a connected unit—in other words, the ‘Big Ideas’ and Curriculum outline may be contextualized but the activities within those contextualized structures are unrelated. This suggests the teacher, AY, has fewer opportunities to make connections across the curriculum. This is evidenced in the instructional register where AY predominantly focuses on material handling practices in the current context, generally as a procedural register realized predominantly material processes (see Figure 4-4 AY Landforms Processes of the teacher instructional framing of the original inquiry curriculum).



*Figure 4-4 AY Landforms Processes*

With the Agency curriculum, the teacher positions youth as being principal agents of the investigations, and hence their learning. The teacher, SK, focuses on learner agency and instrumentality, which both function as participants (Agent or Actor). This suggests that doing science is performative and threaded into materiality for the production of knowledge. Finally, the Goals functioning as Participants suggest teacher-modeling strategies. Given their temporality and situatedness, Pickering contends they are “subject to mangling in practice” (1995: 56), thus opening up opportunities for becoming. With the Inquiry curriculum, the teacher positions youth to follow a more set of prescribed procedures. The generic structure of a procedure encompasses an aim, the materials needed, and the steps. While these stages make up the majority of teacher talk, the purpose is to facilitate observations and experiments that accounts for a regularized, routinized, standardized way of doing school science.

The regulative register is operationalized differently in each unit. The Agency curriculums function as a connected unit where the teacher, SK, use of circumstantial elements

of Manner to foreground past, current and future activities constitutes becoming and doing science where the genre of a practical report is used to recount methods undertaken in experiments, the results, conclusions, and temporal explanations for realizing the implications for future experiments or decisions (Polias, 2006). The Inquiry unit is also seen as doing science encompassing predominantly the genre of a Procedure and temporal/sequential explanations (Polias, 2006; Droga & Humphrey, 2005). The regular use of circumstantials of concession steer the lesson, thus expressed as procedural instructions that are object-related.

The Instructional register relates to knowledge (Christie, 1998) and typically it follows after or is embedded in the regulative register. The instructional register construes the issue of equity in the science classroom. As the regulative register is enacted to structure the flow of projected and enhancing activities – to clarify and define goals, the instructional register facilitates the transfer of knowledge. From Excerpt 1 and 2, fundamental differences emerge from the teachers' use of the instructional register (see Figure 4-5).

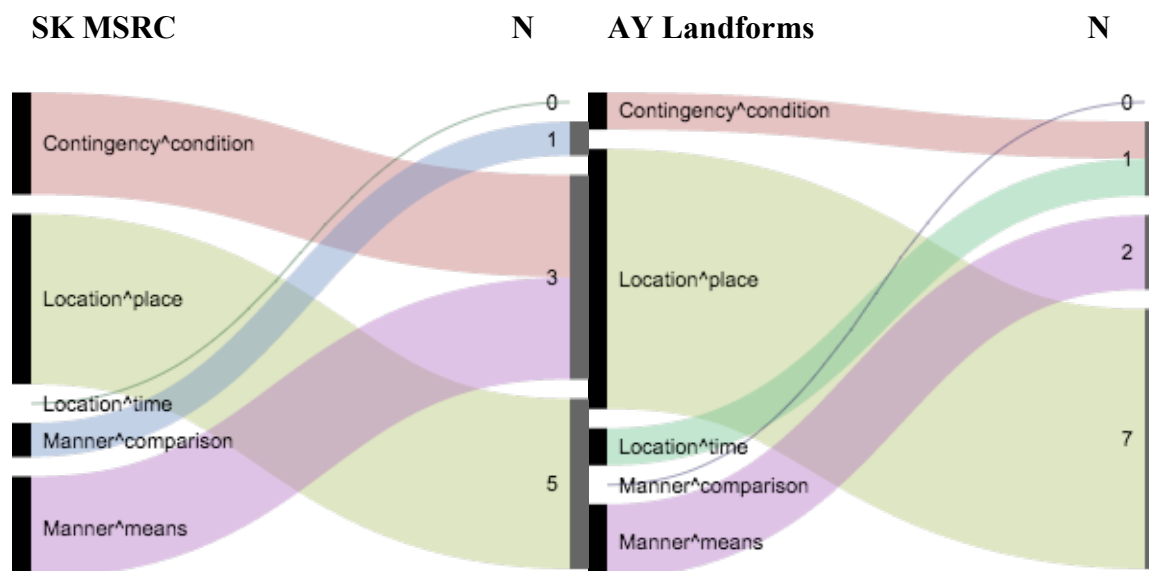


Figure 4-5 Circumstance Occurrences as Instructional Register

#### 4.4 Summary

The types of circumstances construed by the instructional register have implications for the kinds of knowledge that get (re)produced (see Appendix 9, Table 20 to see the underlying data). In SK's classroom the instructional register realizes and focuses on the conditions in which previous investigation results may inform future events and processes, thus as a function of the circumstantial elements of Manner<sup>^</sup>means and Location<sup>^</sup>place, students get positioned as an Agent in the learning experience. In the Inquiry group the teacher, AY, begins by outlining the necessary steps for the investigation. As an example of a “factual genre” (Martin, 1992), the instructional register realizes the activity structure as a procedure to be followed.

Butt et al. (2003) suggest teachers reflect on the impacts their interactions have on students. The relationships the teacher develops with her class in relation to degrees of power and status as authority impacts student participation often by dominating discussions and providing minimal opportunities for student-led discussions – sequestering student agency and apprenticeship in science.

### **Finding 3 Youth Positioning Across Conditions**

#### 4.5 A Case Study showing the relation of the curriculum genre to science learning with Agency

In groups, students discussed why the whole-class erosion / deposition experiment helped them choose a building site for the “flooding challenge” they had been posed by the curriculum.

Student 1 states her decision:

**Student 1:** It helped me choose Site 2 because Site 2 doesn't rain much so it won't erode much.

**Student 3:** And it's also at a moderate slope so it might [interrupted by Student 1] it's like; it's kind of like the stream thing we just did.

**Student 1:** It won't just pour buckets [gestures with hands water pouring down in a single stream].

Student 1's use of instructional register provides evidence from the results of the whole-class investigation, where at a 30° slope, the length of the delta increased. Student 1 also draws on her initial ideas (SK52<sup>9</sup>, Science Journal, p.2) about weather, especially rainfall, causing flooding in the Skokomish River area; exploring the context in Investigation 2, Part 2 by looking at the information provided in the topographic maps of each site (SK52, Science Journal, p.12); and in Investigation 3, Part 3 where students explored the three sites naming the properties – location, vegetation, population, weather – amount of rainfall, and the elements of topography, slope, and type of soil, “loose gravel and pebbles”, as evident in Figure 4-6 (SK52, Science Journal, p.13-14). Student 1 draws on the whole-class experiment, the information provided in the MSRC unit, as well as her propositions about the location:

Also, there is little rainfall at site 2, and even though it is next to Lake Cushman, it is probably unlikely that Site 2 will flood. (SK52, MSRC Science Journal, p.14)

In this clause of contrast, Student 1 propositions, with the subordinating conjunction (“even though”), a condition that is different from what is expected (“it is probably unlikely that Site 2 will flood”). In addition, Student 1's attitude or point of view inherent in the situation, flooding in Site 2, is expressed with certainty. This is indicated by the modal adverb “probably” which

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<sup>9</sup> SK52 (pseudonym) is ‘Student 1’ from the Agency group in one of the focus groups.

highlights Student 1’s personal, subjective view. Epistemic modality signals a commitment to the truth of the proposition expressed, and it reflects the certainty and authority of a proposition. Moreover, Student 1 makes reference to the logical status of what *will* happen in Site 2 by assessing the likelihood, which is demonstrated in her use of the modal “will” – a certain prediction of a future occurrence that “it is *probably unlikely* that Site 2 *will* flood.” As a result, Student 1 is taking a certain/strong stance, a position of authority that manages the possibility of a challenge or contradiction from other members in her group.

**Initial Site Recommendation**  
Investigation 3, Part 3

1. Given what you know right now about the three sites, which site would you recommend?

I would recommend Site 2.

2. Why would you recommend that site?

I would recommend Site 2 because it is lightly forested so it doesn't pose as much of a threat to the apartment buildings (falling trees). Also, there is little rainfall at Site 2 and even though it is next to Lake Couchichewick it is probably unlikely that Site 2 will flood. Plus, it has solid roads and it is on a moderate slope that sometimes will form stream channels, but won't do any damage to buildings.

location, weather-rainfall, vegetation, Elements of topography

3. What questions do you still have?

- Does Hood Canal flood often?
- Is Hood Canal likely to flood?
- Are there any negatives of building an apartment building on Site 2?
- Do the stream channels in Site 2 damage buildings?
- Do the loose pebbles, gravel and rocks pose a threat to building an apartment on site 2?

- Change earth material depending on the site.
- Change slope based on site.
- Size of cup drainage hole.
- Different amount of water.
- Different length of plateau.
- Stream channels in the earth materials.

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Figure 4-6 SK53 Science Journal

As student 1 accretes evidence to support her decision for selecting Site 2 and maintains her position of authority in the group, in Investigation 4, Part 1 she adds:

Student 1: Also Site 2 has loose sediment and gravel and pebbles so transportation is still possible when it rains.

In Investigation 3, Part 3 (see Figure 4-7), Student 1's pending questions about Site 2, specifically about the type of soil, "loose sediment and gravel and pebbles", is transformed in Investigation 3, Part 3 and a retransformation occurs in Investigation 4, Part 2. Students are introduced to the three sites in Investigation 3, Part 3 through descriptions, pictures, and 180° and/or 360° video views per site (see Figure 4-7).



*Figure 4-7 Site Photographs and Information*

Prior lessons in Investigation 3 gave students the tools to make an informed decision about which site to pick. They first construct a foam mountain, derived from the original Inquiry Landforms unit, to understand the representation of relief from a 2-D and 3-D perspective. Investigation 3, Part 2 shifts the general focus on topographic maps to specific topographic maps of each of the possible construction sites. In this lesson students identify the basic land features

in the Skokomish River area and how contour lines show shape and elevation of the terrain. Subsequently, they apply what they know about topographic maps to the three sites by gleaning key information about each site for empirical evidence. For each topographic map of each site, students are asked to find the contour interval, approximate elevation, and a description of the slope.

In Investigation 3, Part 3, students are asked to select useful information and then generate categories (which represents the properties as discussed and illustrated in Figure 4-6) within the context of erosion and deposition, by drawing on the topographic maps as well as photos, videos, and descriptions of each site. Finally, students listen and take notes on interviews that we had conducted with stakeholders in the Skokomish River area. The interviews focus on the impact of flooding in the Skokomish area and the stakeholders include a representative from Taylor Fish Company, where they farm shellfish in Hood Canal, and representatives from the Skokomish Indian Tribe. Jason Ragan, from Taylor Fish Company, comments that when people see water flowing, it goes downhill. He says that we need to be conscious of the fact that decisions made by people upstream affect people down stream. Alex Gouley (with Joseph Pavel), from the Skokomish Indian Tribe, notes that whether people realize it or not, they are impacting their watershed; for example, homes create increased run-off. He says that everybody contributes a little bit and so we each should try to minimize our impact.

From the interviews, students get a personal perspective from the stakeholders in terms of how they have been personally impacted by events further up in the watershed. The Skokomish Indian Tribe families lost their homes due to flooding and Taylor Fish Company sometimes has to temporarily shut down its harvesting operation because the flooding of farms upstream washes fertilizers and animal waste into Hood Canal.

Student 1's contextualized meaning of the expository genre presented earlier in Investigation 3–Part 3 shifts through a process of tuning in relation to the stakeholders' narratives about flooding. The “loose pebbles, gravel and rocks” are no longer framed as identifying features of Site 2, which are also isolated descriptions of the processes involved in erosion and deposition. Instead Student 1's frame of reference for types of soils is keyed as the agent posing a threat. Through this process of tuning, Student 1's descriptions of the characteristics of Site 2, which initially were foregrounded because of her accrued conceptual knowledge of erosion and deposition gained from Investigation 2, Part 1, which was the first experiment run to establish control data, and the expository texts become background information. The initial expository frame provided the means by which Student 1 could begin accruing information and constructing knowledge that is related propositionally in the context of the overall challenge. The expository frame is back-grounded when the stakeholders' narratives about flooding are introduced. Student 1 restructures the information gleaned from the expository frame and that interacts with her new knowledge gained from the stakeholders' narratives.

In addition to sense-making and learning, narratives also enable community-building where membership entails sharing experiences of the past as a basis for further action (Miller, 1984:75). Moreover, they hold heterogeneity together by enabling meaningful differences to emerge within a common project, thus imposing intelligibility and means for social action. Miller (1984) maintains that from a pragmatic perspective, narration gives common sense to one's actions or intentions. Consequently, one is able to reconstruct what one knows by identifying similarities from differences.

Student 1 foregrounds the narrative frame in Investigation 3, Part 3 by framing the “loose pebbles, gravel and rocks” as a ‘threat’ to Site 2 indicated by her choice of the verb “pose”. Finally, in Investigation 4–Part 1 – the whole-class experiment – Student 1 draws on what she knows from the expository and narrative texts, the class experiments, and the distinctive properties of each site. In her explanation for maintaining her selection of Site 2, she recalls the major factors that contribute to erosion and deposition but rekeys these factors as advantages for Site 2 (see Figure 4-8).

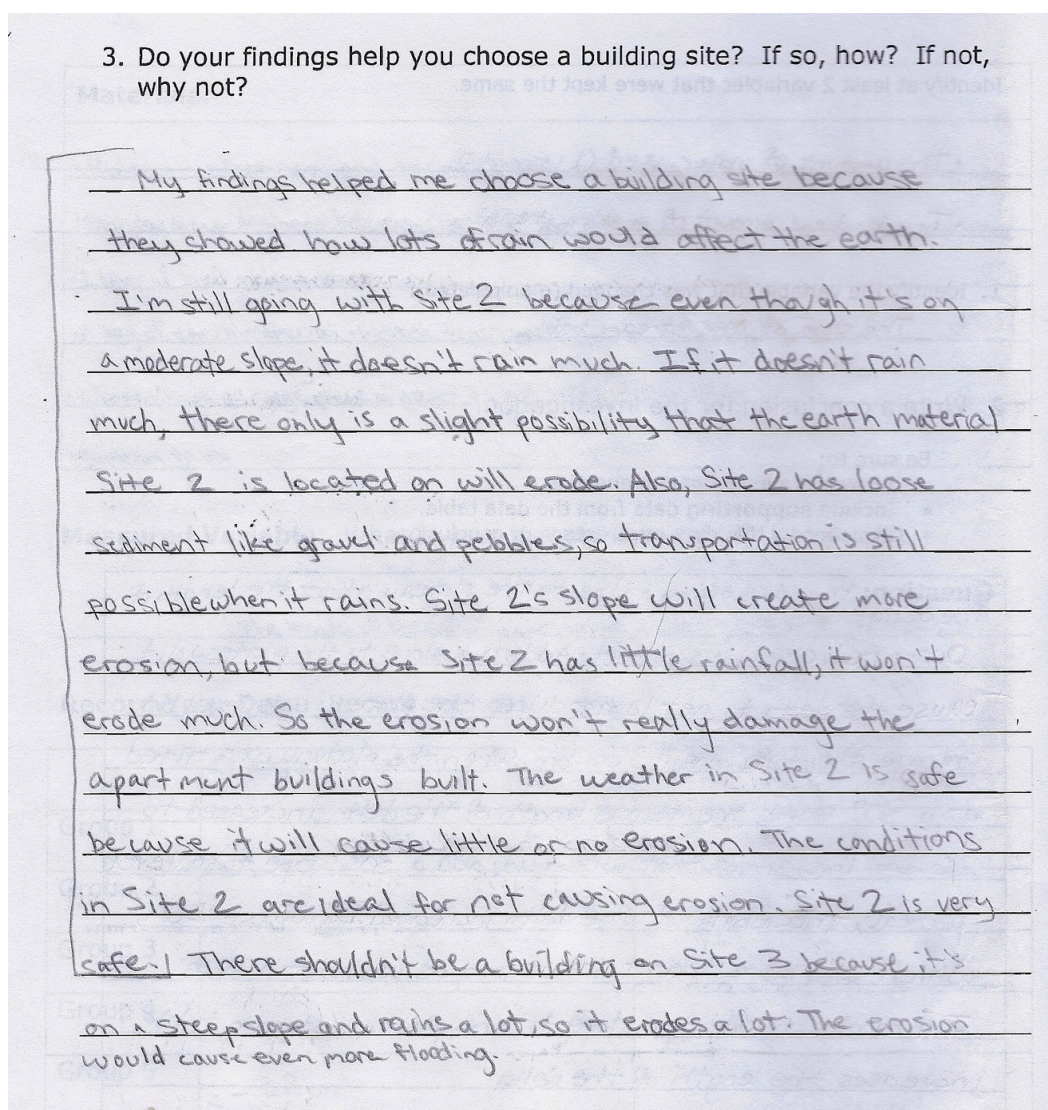


Figure 4-8 Student 1 Positioning, Science Journal Response

For Student 1, her understanding about the conditions at Site 2, which consists of loose pebbles and gravels, continues to travel (see Student Positioning Excerpt).

Student Positioning Excerpt:

109 [Instructional] **Student 1:** What if change the earth materials?

110 **Student 3:** Yeah, I believe that we should change the

111 earth materials

112 **Student 1:** Add a little.

113 **Student 3:** And also we should add last [inaudible] to create loam, and figure out.

114 **Student 4:** No.

115 [Regulative] Student 1: But isn't that for site 1? We want something for site 2.

116 **Student 2:** It would take a long time to make silt because we'd have to put dirt in the water and then we'd have to

117 wait for the water to evaporate and.

118 **Student 3:** That would be a good thing to wait for tomorrow, just leave it outside.

119 **Student 2:** Uh, what if it rains?

120 **Student 3:** We keep it undercover, like right now.

121 **Student 4:** But yeah, it's raining.

122 **Student 3:** It just started to rain, surprisingly enough.

123 **Teacher:** Here's what you need to do, you need to talk about what you're going to do and why.

124 [Instructional & Regulative] **Student 1:** I think we should just do the site 2 earth

125 materials because we've already decided not to do site one.

126 **Student 3:** And also do the slope unique for site 2, which is also kind of what we did  
on site 1, we kind of did that on the last experiment.

127 [Instructional] **Student 1:** Let's see how the different earth materials affects it.

128 **Student 2:** Well we could also do like, adding little branches of trees and stuff.

129 **Student 3:** Yeah, because it said on each one that they have a lot of forests.

130 **Student 2:** Shrubs...

131 **Student 3:** They were forested.

132 **Student 2:** Shrubs. 'Cause in site 2 there's not exactly that many shrubs and stuff.

133 **Student 3:** Well there might be, we don't know.

134 [Instructional & Regulative] **Student 1:** How about we just do the different earth  
material because we can just find some

135 gravel and put it on the earth material so that it floats.

136 **Student 2:** Maybe we could mix in some gravel into the dirt and stuff. That would  
make it more like site 2.

137 [Instructional & Regulative] **Student 1:** We could do that. Let's come up with a  
question now.

Student 1 influences her group by proposing changing materials and is aware that the group out of obligation/duty and belief that they share similar ideas. This excerpt shows how Student 1 establishes her position through the use of instructional and regulative register. She begins by posing her idea as a question to see how much buy-in she will have although, as it has been illustrated above, she has already made her decision. Student 3 reinforces her idea. Student 1 begins writing in her science journal when Student 3 builds on the idea of changing earth

materials in Line 113. In Line 115 she helps Student 3 revise his idea by reframing the problem and then reminding him what they need. Student 1 knows that in a fair test there can only be one changed variable and so by “creating loam” means adding two variables, yielding ambiguous results. Student 2 picks up Student 3’s idea and Student 1 regulates group discussion in Line 124 by being a little more forceful with her idea and pointing out that “the plan was to go with Site 2.” Student 3 continually supports her ideas but adds another variable again, indicating he may not understand that only one variable can be changed per experiment. Student 2 in Line 128 has the same misconception, which potentially comes from the frame they are working in. For Student 2 and 3, they want to model the actual sites whereas Student 1 knows that the stream table is not a real model of the site but a simulation. Student 1 employs the interrogative mood to maintain her idea and keep the group focused in Line 134 and creates a shared understanding when she corrects Student 4 later in their group discussion, “Student 1: It’s a flat plateau. If we change two variables then....”

#### 4.6 Summary

The Agency group has a different stance towards science as they engage with various multimodal genres during challenge cycle phases. All the redesigned units share the view that human activities are a part of the physical environment, thus taking into account the human impacts on the environment and vice versa (i.e., a relational epistemology of science, Bang, Warren, Rosebery, & Medin, 2012). These models of human-environment interaction come with the notion of reform where best practices ameliorate the quality of life. O’Riordan (1981 as cited in Veel, 1998) claims new ideas are organized around fairness, sharing, permanence, humility, and caring. As evidenced from Student 1’s evidence-based reasoning, student science discourse and writing remain objective (as evidenced in epistemic texts) until they get to the third

investigation where stakeholder interviews from the Skokomish River area influences their choices and perspectives for site selection (as evidenced in narrative texts).

Similarly, in the Algae Invasion unit students felt empowered when they interviewed the public about Harmful Algae Blooms (HABs):

“Um, I really liked the interviews 'cause I got to talk to others and to learn what they know about algae to tell them exactly what they need to learn more about it (SK44, Algae).”

Student's felt emotionally invested as a result of the accrued information from interviews with the public. The value placed on informing the public about HABs adds a community dimension to student learning which renders learning relevant to students and their communities. Students are positioned as authoritative, given they are fulfilling the role of a scientist by informing the public about a topic they know more about. As students develop control over their own actions in local situations as evaluated from practical, performative, and moral stances, Duranti projects that it also refers to one's interest in problem solving and accomplishing things individually or collaboratively because one “cares” about the affect of doing and saying things (Heidegger, 1962 as cited in Duranti, 2011: 158). Hence, individuals with a degree of control over their own actions (i.e., in the context of science investigations) invoke practical agency, and student stances in practical, performative, and moral evaluations characterize agency as shared and epistemic. On that account, Duranti (2011) importantly highlights affect as a condition for agency, which highlights student positioning's as well as levels of engagement during science. Thus curriculum content, practices, goals and activities aimed at intentional learning position

students as trusted, respected and valued community members that have as much capacity and intellect as adults to make valuable contributions in their classrooms and community.

From a science literacy perspective, students encounter various multimodal genres through their research, classroom and community-based activities, and investigations to enrich and authenticate their learning experiences. Student's apprenticed interactions with the various multimodal genres within the context of school science mediates their participation, identity and agency in science over time, particularly when teachers explicitly model how the relations of form and functional properties of genres encourage and embody thought, emotion, and action. The implication in raising student consciousness to the variegated ways scientists practice science inducts students into how scientists intentionally and purposefully employ these genres to engage in scientific ways of communicating. By placing emphasis on *how* genres are used to accomplish specific goals, demonstrates how they may mediate learning and establish credibility among peers. This suggests that through sustained practice students develop flexible and transferable communicative competences in science as well as a repertoire of texts elements, which then become resources serving the needs of the learners and school science. This latter suggestion draws attention to *how* we can marshal student's developing flexible and transferable competencies in science. Bransford and Schwartz (1999) suggest a Preparing for Future Learning (PFL) perspective where emphasis on learning that is perceptual entails "knowing with". This means providing learning opportunities that enable students to apply what they know so that they may refine and expand on their knowledge.

#### **4.7 Positioning in Pedagogic Science Discourse as Regimenting Student Apprenticeship**

Agency is possible in the language of efficient causality. An understanding of an action, in the present and future states, in interactions taking place in a community of practice means agency is grounded in the kinds of meanings that connect us to life-worlds and meanings that regulate and guide trajectories of action (Thibault, 2004: 85). Classroom videos show the Agency group hold a socio-scientific view of science whereas the Inquiry group anchors their science experiences in school science. As a result, a kind of scientific reality and positioning is constructed that regiments the Inquiry group apprenticeship in science. Students learn a regulated pedagogic science discourse as illustrated in the following excerpt from the *Landforms* unit (AY, Lesson 3, Part 2):

**Teacher:** The water will be flowing faster or slower. The delta will get longer or shorter or stay the same. Who said they think their delta will be longer? [Student 1 puts his hand up] Who thought the delta will be shorter? Who thought the delta will stay the same? Not everybody raised their hand. You have to pick one of those. One of those three and you don't have to be right. You don't get any points for being right or wrong. You get points for having a prediction, that's it! Scientists have an idea of what they think will happen and when they do an experiment and they get excited when they are surprised. When they are wrong, that makes them excited. Yes?

**Student 2:** May I say thinner?

**Teacher:** Nope, just longer, shorter, or it will stay the same. Yes?

Moreover, a pedagogic science discourse constitutes a regulative (i.e. teacher goals for lesson entailing principles of order, relation, and identity) and instructional (i.e. knowledge related) register that regulates purposes; that is, a school science or curriculum ideology that often differs from students' worldviews and in most cases even the teacher's worldview. The following example shows from the teacher's position how she distances herself from the curriculum suggesting she may not perceive herself as a member of her community:

**Teacher:** Ok. Great! Raise your hands if you think the delta will be longer?  
 Raise your hand if you think the delta will be shorter? Raise your hand if you don't think the delta will change. Won't look any different with the flood. Ok alright so let's read the materials...

**They're doing this for you. They did this part for you.**

**They're saying** with standard water the average delta length is 7cm.

**They gave that to you.** So we're just going to do the flood one today and we are going to say how long our flood delta is so that's what the measuring tape is for. So what's the measured variable?

Rose (1997) contends that a pedagogic science discourse positions students by means of the regulative register. Consequently, students' scopes of experience in science enable or constrain how they identify with the pedagogic science discourses. The Inquiry group relate to science from an affective dimension. Doing experiments invokes excitement, suspense, surprise, and sometimes disappointment when students hold themselves and others accountable for ruining an experiment. Classroom instructional framings, particularly regulative registers

regiment students' epistemic and relational processes and the activity structures are oftentimes constrained by time (e.g., students are allocated a set time to set-up and run investigations).

#### **Finding 4: Students' Affective Engagement in Science**

*All consciousness begins with the consciousness of the body. Our conscious perceptual experiences are precisely experiences of the world having an impact on our bodies, and our conscious intentional actions are typically of moving our bodies and of our bodies having an impact on the world. (Searle, 1997: 185)*

Commitment, motivation, reward, judgment are, to mention a few, qualities and values that regulate our emotions when imagination, agency, and creativity spark ideas and intentions in the brain, and exists because it is known, through Self as conscious, in the form of feelings (Damasio, 2010). Feelings can be understood as the conscious experience of the emotion (Tsuchiya & Adolphs, 2007).

#### **4.8 Analytical Lens: Appraisal Analysis**

Appraisal comprises attitude, engagement, and graduation (Martin & White, 2005). *Attitude* entails our feelings, emotional reactions, judgments of behavior, and evaluation of things. *Engagement* shows how a speaker is positioned in terms of their propositions or proposal and reactions to the respective value positions. *Graduation* ranks phenomena by how amplified or abated a feeling is in relation to a category. Thus, appraisal analysis is an interpersonal

resource relevant for understanding the discourse dynamics of solidarity (contact/involvement) and power (status) (see Appendix 10 for Appraisal Resources). For example,

Science is being able to figure things out on your own and being able to, science is I think [Engagement] it's really fun [Attitude: Affect] and I've always really liked science and when I was in first grade I remember that when I saw science on the schedule 'cause in kindergarten we didn't do science, so the first day of school when I saw science on the schedule I got really excited [Amplification] 'cause it was a new subject [Attitude: Judgment] for me and it was really fun, it had clicked with me [Attitude: Appreciation] right away [Graduation: Focus: Sharpen] so to me [Engagement] science is being able to figure things out on your own and being able to figure out cause and effect and if, if x happens then y will happen and it's being able to explain yourself in a reasonable way and an intelligible way [Appreciation: Valuation: Cognition] and I really like science (AD41, PolSol).

This example illustrates the positive categories and sub-categories of appraisal. From an Attitude perspective, this student, representing the Agency group, expresses a high grading affective stance towards science. A positive disposition and a feeling of satisfaction are amplified throughout the text and construed as mental processes. The students' Engagement is high and subjective in terms of orientation and value, suggesting solidarity, power, and agency. The following example from a student representing the Inquiry group highlights the critical categories and sub-categories of appraisal:

I don't really [Amplification] consider myself [Engagement] to be a scientist  
 [Judgment: Social Value: Normality – Criticize]. Well, I don't really study things, I use  
 things. I'm a consumer [Judgment: Social Value: Capacity – Admire]; I'm not a scientist  
 [Judgment: Social Value: Normality – Criticize]. We study things but we're not really  
 [Amplification] scientists doing that, we're students who are learning things  
 [Appreciation: Valuation: Cognition] from scientists or teachers. (JB40, Environments)

This example shows a different stance towards science where Judgments encompassing social values as well as sanctions are prominent. For this student appreciation is construed as a material process – *'I use things'* as well as a mental process, *'learning things from scientists or teachers'*. In this example, the student expresses institutionalized feelings whereas in the previous example, the student (AD41) expresses emotional reactions (Martin & White, 2005). Institutionalized feelings emerge as a result of the socioeconomic values attributed to science for its role in innovation, technology, and making the unknown known. The scientific enterprise is thus valued for its role in production and so it accrues commercial value because of its utility. However, this perception of science positions knowledge as a commodity that serves the values of sociopolitical ideologies (see Hyland, 2013 for a discussion on the rippling effects of scientific knowledge as a commodity).

#### 4.9 **Developing Cognition and Interest while having Fun in Science**

T-Lab<sup>10</sup> was used to perform concordances searches. Results from 'How Students Understand Science' show that the attributes/codes "fun", "interesting" and "learn" are anchored

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<sup>10</sup> Text Parameters:

in students' experiences, interpretations, and identification with science, highlighting the role of emotional investment in learning and identity development. Further analyses were performed to identify the dimensions of the attributes and their associations as they emerge within and between units across comparative groups.

Results from specific key terms, namely fun (occ. 140), cool (occ. 27), enjoy (occ. 10), favorite (occ. 21), feel (occ. 44), good (occ. 43), hard (occ. 40), hard to explain (occ. 11), interest (occ. 72), learn (occ. 213), learning (occ. 45), and love (occ. 16), were analyzed for their occurrences across the interview question (see Appendix 6 Identity-related Interview Questions) responses from each Agency and Inquiry units.

For the Agency group the key terms 'learn', 'learning', and 'interest'—as mental processes—express how students would describe science, and appreciate the cognitive rewards. Thus science enhances student affect as a result of their interested dispositions to science (see Appendix 11 for the full set of graphs). Students' directed feelings about science as 'fun' has the highest occurrence in the Agency MSRC unit and it gradually reduces in occurrences across the other units. Similarly, 'hard' follows the same pattern throughout the year, decreasing in

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Lemmatization: Yes

Text Segmentation: Chunks

Key-Term Selection: Chi Square

Stop-Word Check: Advanced

Multi-Word Check: Advanced

Key-Term Selection: 1000

occurrence. In most cases ‘hard’ and ‘hard to explain’ are conflated, yet in other instances ‘hard’ co-occurs with science as a subject or as a comment on the type of work done in science:

**Subject:** “sometimes it’s pretty **hard** to do so it’s not very, um, easy and then sometimes, uh, your science can not be accurate and then you get all frustrated and then you just, like, throw it down on the table and you get mad (AK48, MSRC).”

**Work:** “Um, it’s fun and interesting but sometimes it can be **hard**. Like, um, it can sometimes be confusing, like you don’t know how that works and, um, also... and also, um, it might be sometimes hard to explain things if you don’t know what it is (AD50, PolSol)”

The Agency Pollution Solutions (PolSol) unit, in Figure 4-9, shows more affective mental processes construing ‘feel’ and ‘good’ as dispositions:

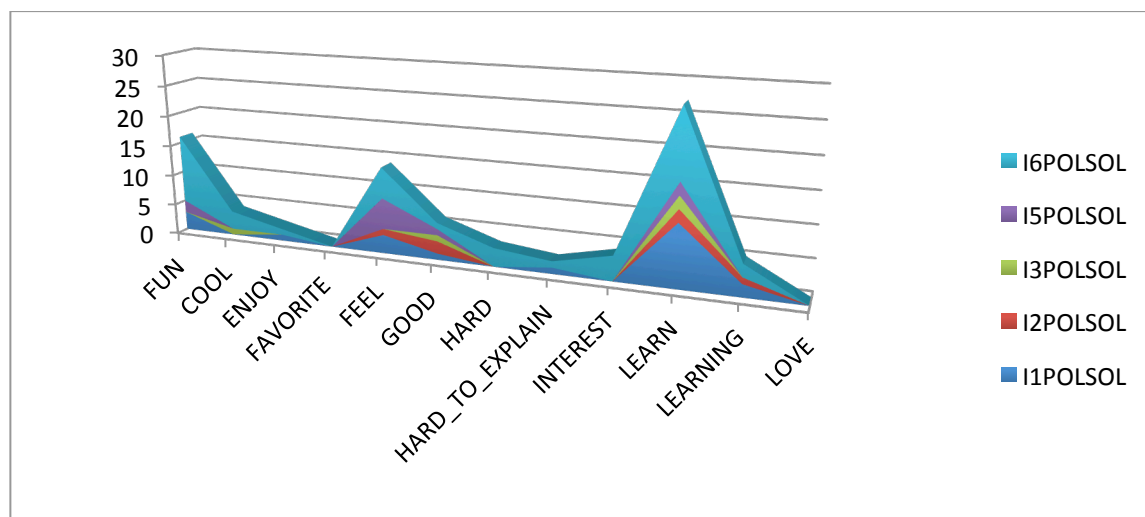


Figure 4-9 Agency: My Solution to Pollution, Cohort 1 (Winter 2013) and Cohort 2 (Spring 2013)

“I like **feeling** like I’m a **part** of something big, I like feeling, I like, I like the feeling of accomplishment when you figure something out for the first time and you say, ‘oh, this is

gonna happen because of this. I really like that **feeling** of accomplishment.” (AD41, PolSol)

“it just feels **good** to learn something new. (AK62, Algae)”

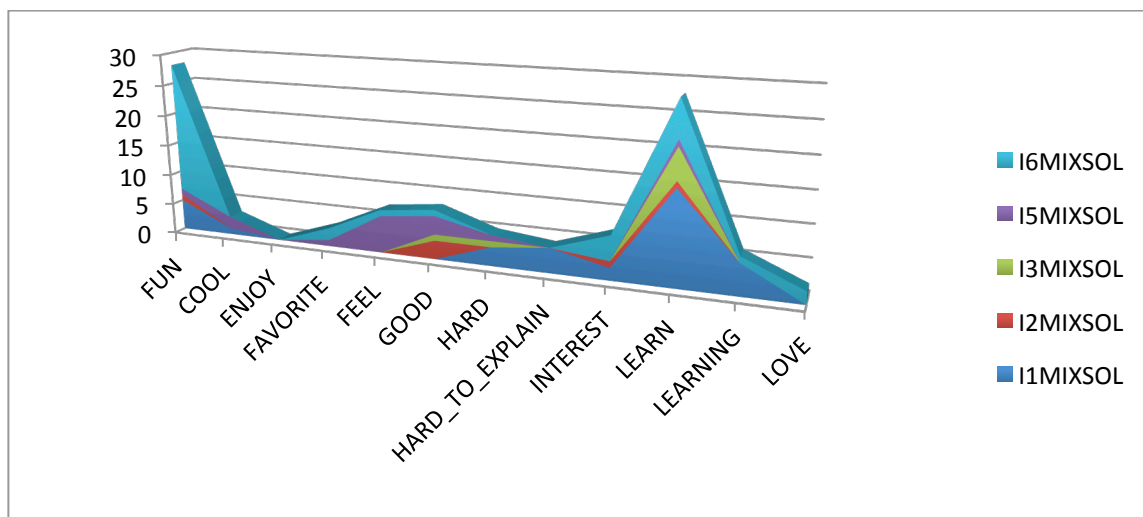


Figure 4-10 Inquiry: Mixtures and Solutions, Cohort 1 (Winter 2013) and Cohort 2 (Spring 2013)

The Agency group shows positive cognitive dispositions to science and emotional investment; whereas the Inquiry group shows a similar disposition towards science but their affect is higher (see Figure 4-10) and consistent throughout the year as shown by material processes:

“It’s really **fun**, like, you get to do lots of experiments and discover new things you never knew about and it’s just really **fun**” (JB60, MixSol).

These instances of instrumental modeling (Gooding, 1992: 82) enable the Inquiry group to “*feel like a scientist*”:

Well in school when we’re doing science I definitely **feel** like a scientist because we’re doing it, like, in class with a bunch of people so we’re taking observations and doing all that stuff (AH57, MixSol).

Doing science, as a material process, is understood as ‘feeling’ thus construed as a mental process, whereas the Agency group relate being and sensing to ‘feeling’ – understood as a mental and existential processes in that they construe processes of being. For both groups, these results have significant implications for identifying as a scientist. Keller posits,

“Good science cannot proceed without a deep emotional investment on the part of the scientist. It is that emotional investment that provides the motivating force for the endless hours of intense, often grueling, labor” (1983:198).

Keller’s point calls for a combination of processes: mental and material processes in science are a means to achieve a goal which recursively has an impact on dispositions, on identity. For McClintock, as an example, feelings constitute “a longing to embrace the world in its very being, through reason and beyond” (Keller, 1993: 199). Both the Agency and Inquiry groups share this view to a point where “need” and “interest” get construed separately. The Inquiry group place emphasis on experiments, on objectification as a need:

“I think it’s really fun because you know math you have to really do what you, um, are told but science there really is no doing what you’re told, you just go after it. But first I **need** to be taught how to do it” (JB55, MixSol).

For the Inquiry group participating in science means having the ability or ‘know how’. I draw on McClintock’s notion of scientific knowledge where scientific practices embedded in the scientific method as a way of knowing is limiting to one’s creativity, identity, and agency. McClintock goes beyond this notion when construing scientific knowledge. While she does state, as the Inquiry students do, that learning from experiments is “lot’s of fun”, one is only experiencing a partial truth marshaled by what the scientific method only allows one to conceive. For the most part, the subjective self has little room for expansion as one attempts to do what one is told or how one accrues knowledge. McClintock makes a case for “how you know”, which in the Inquiry group the majority of responses show knowing through material processes. For McClintock, as well as from my point of view, this is not enough. Knowing from material processes does not provide a complete understanding. Instead, one is provided with a partial truth that is construed as useful and valid and so you become a “user of science”, a consumer. Keller takes Niels Bohr (‘the father of quantum mechanics’) point, “For a parallel to the lesson of atomic theory...[we must turn] to those kinds of epistemological problems with which already thinkers like the Buddha and Lao Tzu have been confronted, when trying to harmonize our position as spectators and actors in the great drama of existence” (Keller, 1983: 204). Although such an approach embodies what Einstein calls “cosmic religiosity” or what McClintock calls mysticism, I prefer to perceive it as consciousness, akin to Rita Levi-Montalcini’s notion of intuition, perspicacity. To support this view, I refer to McClintock’s (Keller, 1983: 205-6) point of view regarding the restrictions of relying solely on the scientific method as a way of knowing:

*We’ve been spoiling the environment just dreadfully and thinking we were fine, because we were using the techniques of science. Then it turns into technology, and it’s slapping*

*us back because we didn't think it through. We were making assumptions we had no right to make. From the point of view of how the whole thing actually worked, we knew how part of it worked...We didn't even inquire, didn't even see how the rest was going on. All these other things were happening and we didn't see it"*

The whole-part metaphor that McClintock refers to provides a deeper insight into how the Agency and Inquiry students construe the nature of science and their position in relation to how science invokes institutionalized feelings and emotional investment. To recall McClintock's case that learning from experiments is "lot's of fun", but one is only experiencing a partial truth marshaled by what the scientific method only allows one to conceive. Hence McClintock's case for "how you know" bears relevance to emotion and learning. For the Agency group, the results show that their construal of science as a mental process, which stems from an explicit, subjective orientation, and accompanied with an interested disposition shows a developing consciousness about science that is fueled with emotional investment, thus developing an awareness for the "whole". The Inquiry group construes science from more of an objective perspective. Participation in science is circumstantial where material and cognitive "*know how*" are obligations. Once fulfilled, permission is granted and students' developing consciousness is grounded in institutionalized feelings, which indeed includes emotional investment, but with only partial know-how awareness. Thus the implication is that their identity and agency, at a median degree, are contingent and can potentially result in a discontinuous relationship to science.

From another point of view, Traweek (1988) describes how being fully conscious of the social and psychological workings during a postdoctoral phase in a Physics environment

circumvents success as it runs counter to the Physic's community's Values. The community Traweek describes envisions a successful post-doctoral candidate possessing an immature disposition, as "a mature person would have too much difficulty accepting the training without question and limiting doubts to a prescribed sphere. [T]his precondition kept most women and minorities from doing well: their social experience had taught them to doubt authority only too thoroughly (1988: 92)." Whether students are positioned as "Agents" or "Patients" (Inden, 2000), I conjecture developing a critical consciousness is essential for developing science identities and knowing our possibilities, so students may not only navigate the structuring structures in ways that supports their ways of knowing and learning, but also have the capacity to distinguish between opportunities and needs with an understanding of the uncertainties and the possibilities inherent in scientific practice.

#### 4.9.1 *Summary*

In summary, I have illustrated how the Agency group holds a socio-scientific view of science whereas the Inquiry group anchors their science experiences in school science. As a result the groups have different global and local perspectives in terms of how they talk about science and their positions within the scientific enterprise. The appraisal analysis provides a different dimension in that one can map the student's experiences to the way science invokes institutionalized feelings and emotional investment. Classroom instructional framings and curriculum structures regulate how students position themselves in relation to science and identify science as a material process, a mental process or a combination of both. These ways of knowing translate to inductive and deductive ways of knowing where knowing from thinking (as seen in the Agency group) and knowing from empirical evidence (as seen in the objective stance in the Inquiry group) (Varelas, 1996) invoke particular attitudes and statuses, such as doer,

“user”, “consumer”, “student”, “kid<sup>11</sup>”. The next section discusses student’s emergent views of science.

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<sup>11</sup> For the most part, students self-identifying as ‘kids’ in science suggest they position their ways of doing science as inferior to the way scientists carry out their work. At the same time, the schooling context authenticates the role of ‘student’ or ‘kid’; consequently, students endorse their role as ‘kids’.

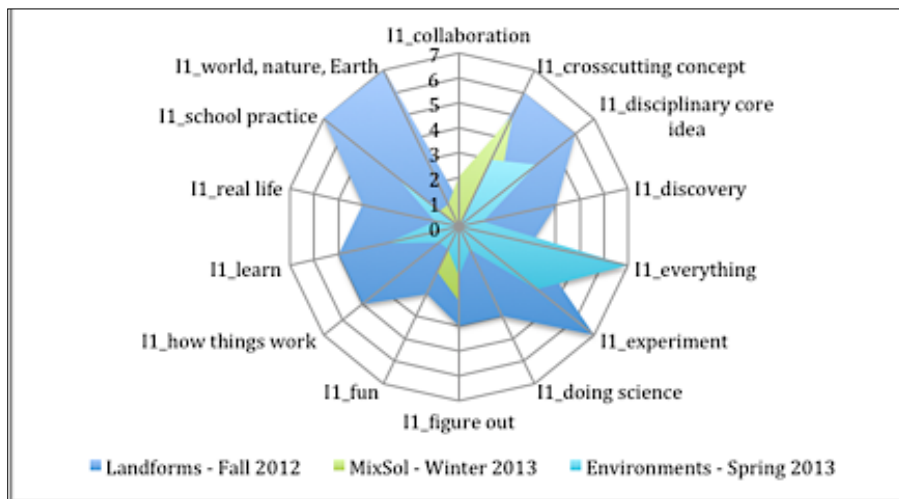
## **Part II: Students Talking about their Images of Science**

Student's perspectives, positioning, and emotional investments yield different ways of knowing. Students from both groups relate, juxtapose, attribute, and integrate knowledge and processes perceived or experienced to their own practices as well as others' practices. At the same time students identify with the work of scientists as different and the same as a result of their imaginings, participation, science materials, emotional commitments and relational positioning.

Student interview responses were hand-coded and reviewed with coding schemes with other researchers in the project. Once we had coded 20% of interview responses and highlighted excerpts that were difficult to code, we discussed and resolved our differences and established key codes. The inter-rater reliability, which was calculated by the percentage of agreements, ranged from 70 to 94%. Subsequently, all transcribed interviews were entered into *Dedoose*, a software program for qualitative and mix-methods research, for qualitative analysis. The coding results were used to construct graphs and tables showing the emerging themes, which were subsequently reviewed a second time using Excel to further refine emergent themes.

### **Finding 1 Socio-scientific and Stereotypical Perspectives**

#### **4.10 Inquiry Curriculum Design: How the Inquiry group Talk about Science**



*Figure 4-11 Cohort 1 Inquiry Group*

In the first trimester, the Inquiry group perceive science as an action that is regimented by the schooling practices when making predictions, observing, and “experimenting” (40%), where the purpose is to “learn things about the earth (27%) and a bunch of other fun facts and everything”. “Experimenting”, as an instrument affords learning, which students perceive as “fun” (30%). The curiosity students have for things that are yet to be discovered position science as desirable, even in a schooling context. Yet students’ images of science remain shaped by their school practices (30%)<sup>12</sup>.

<sup>12</sup> “I’d say, well science is about where you learn scientific, like, definitions and, like, where you observe a bunch of different things, like, the landforms and electricity and stuff like that.”

(AH57, Landforms Fall 2012)

The Inquiry group anchors their images of science in their school science experiences, drawing on previous science activities to establish a stance towards science<sup>13</sup>. An affective stance towards science is causally related to learning and discovering things. This stance extends to the second trimester where science is also about discovering things. Science is given an emblematic role because of how the Inquiry group orients to science. Science is framed in terms of its symbolic resources, “do experiments” (AH63, Landforms Fall 2012), and social and material practices of science taught in school.

The stance students have towards science being “everything” (17%) is illustrated in their attitudes towards the emblematic roles science plays in society. Science mediates discoveries of phenomena society is unable to explain, pushing the limits of one’s imagination. Thus science, represented as an intentional action, is valued for its discoveries, creations, and figuring out how things work around us. This raises students’ interest and curiosity given the phenomena students experience, either by seeing or doing inside and outside of school, are represented with positive affect and attributed as “weird”, which is based on an authority of justification.

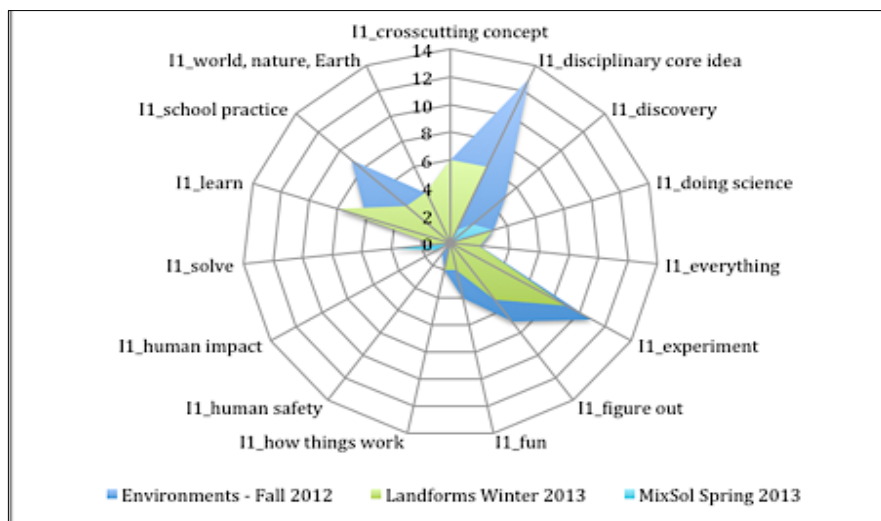
The Inquiry group describes science as performative in the final trimester. The notion of “doing science”, which is supported by students’ use of embodiment verbs to describe science, is a constituent part of science. The student notion of ‘science is everything’ (28%) and science solves problems as well as science leads to deeper learning highlights the enigmatic quality of

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<sup>13</sup> “I would explain it like, we learned about, in class, about solutions and mixtures and so when certain things mixture, mix there's a chemical reaction and that makes it so the two or more materials that you mix make something else.” (AH53, MixSol Winter 2013)

science, that is actualized by the content and processes of science that make the unknown known with a truth-value:

“Science, I would describe it as the kind of thing it's like it has now it doesn't have to do with math but as we get older we will learn more about science and science is what some people call is what most find is the answer so like if you don't have a religion, science is the entire religion. But if you do, a lot of people think it is has a lot of answers to it so like someone who doesn't know what oxygen is or water is H<sub>2</sub>O. Science is what tries to explain things as what we do to explain things that we don't know about and in my opinion some things that science does might not be true but I have to believe cos it's the best answer that we have gotten ever so like. If we didn't have science, we wouldn't know what some of the things are or what they do. So that's a big question in science. We have to try to like it's tries to be the answer for everything. Its learning, it's kind of math it's what people think is the answer and I kind of think it's the answer too in a way cos it has a lot of views and points are correct and we're all trying to learn about our world and other worlds cos we're learning about outer space too.” (AY48, Environments Spring 2013)



*Figure 4-12 Cohort 2 Inquiry Group*

The second cohort in the Inquiry group view science as a way to “experiment” (43%) from a school science perspective in order to “learn” (29%) about a disciplinary core idea as well as cross-cutting concepts (29%). Finally, students view science as a way to “figure out” (30%) phenomena by “experimenting” (48%) and “doing science” mediates “deep learning”(26%).

#### 4.11 Agency Curriculum Design: How the Agency Group Talk about Science

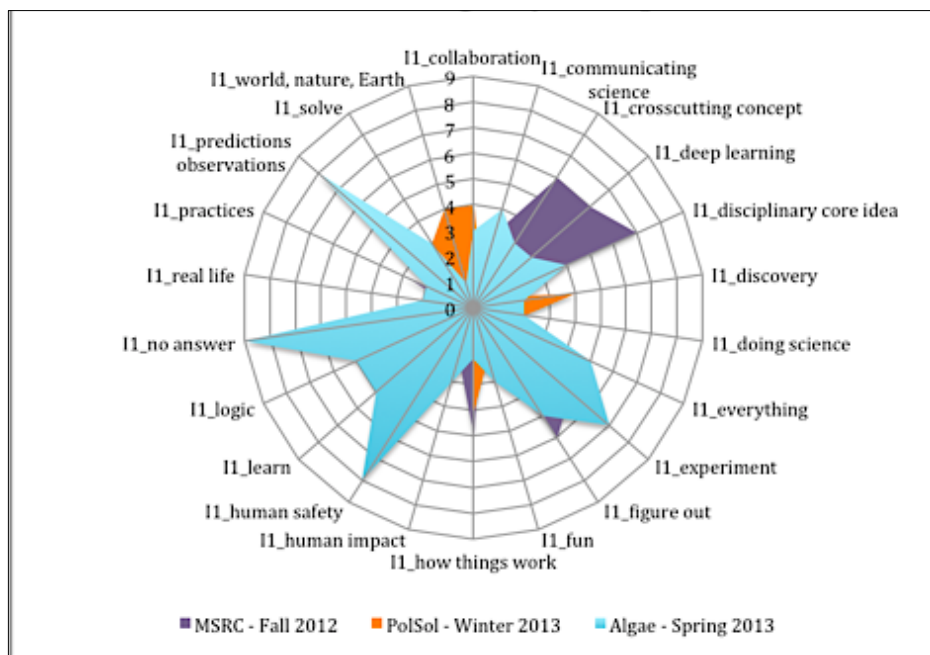


Figure 4-13 Cohort 1 Agency Group

A similar analysis was conducted for cohorts engaging in the Agency curricula. The first cohort of the Agency group initially describes science from a content and process perspective. Students' interpretations of science are framed as actions mediated by instruments with functions and by the roles science plays in relation to those actions. Thus science, as an instrument, is viewed as performative as it mediates learning in the context of 'everything' (26%) around us, as indexed by JB50 "learning something, like, about our earth's, like, features"<sup>14</sup>.

In Peirce's terms, students perceive the role of science by inferring to its status by means of objects and the properties of objects, thus interpreting science as performative in terms of the

<sup>14</sup> "Um, I think that science, it's, just, like, um...learning something, like, about our earth's, like, features so, like, um, earth's atmosphere or gravity or just, like, floods and, just, like, um, yeah our features and then it's, like, um learning about, yeah, our features." (JB50, MSRC Fall 2012)

roles it plays in society, “the gears of life” (AW57, MSRC, Fall 2012) and as a representation of its purposes, “figuring something out”(23%). This performative view of science, “doing science”, is contextualized in scientific practices as a process to an outcome by the second trimester. “Experiments” and “talking to fellow scientists”, as an action with a purpose to improve the quality of human lives as well as help the environment, yields “inventions” that take on the role of an instrument with a function. Thus an invention is a product of the “experiments”. Students begin to outline the desirable aspects of science by placing primary value on the outcomes of processes, such as “discoveries” and “inventions”, as well as secondary value on the functions of those outcomes – to improve the quality of human lives and the environment.

Finally by the third trimester, students position science as an affordance (innovation), which supports how they are responding to these affordances affectively. Science is performative and meaning is attained through doing. Subsequently, experiencing science raises emotions of surprise and interest, where the student, as a spectator, waits in anticipation for an outcome, which indicates where students are placing value and their interests in science.

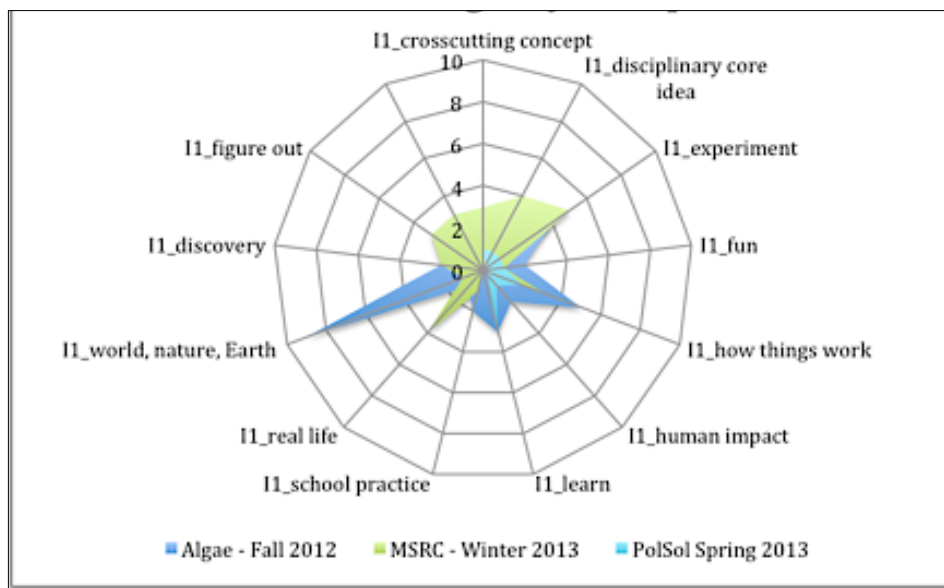


Figure 4-14 Cohort 2 Agency Group

In the second cohort, the Agency group initially view science as a way to understand the “world, nature, and Earth” and science enables one to see “how things work” (25%) with “experiments” (41%). In the second trimester, student views shift where science has an impact on human lives and science is about “how things work” by doing “experiments.” Finally, students consider science from a school science perspective where science also has an impact on human lives.

#### 4.12 Interpretation, Comparison, and Conclusions

Findings from the interviews show that the Agency and Inquiry groups initially view science as a way to figure out things about the world, nature, and Earth. The Inquiry groups held a stereotypical view of school science, as related to the scientific practices, where science is about observing and learning about the world, nature, or Earth. Accordingly, students

characterize science as playful, with attributes such as “fun” and “interesting”. These attributes, functioning also as ‘resultative’ attributes, are perceived as rewarding because they enable students, as Beneficiaries, a way to learn about their surroundings, thus mediating students’ identification with science. The Inquiry design group describes science as “everything”; yet focus on their immediate experiences in science at school or in the media. The view that science is “everything” can be construed as a ‘creative’ process (Halliday & Matthiessen, 2014: 231) where discoveries are made, which consequently generate interest because phenomena may be perceived as “weird” or something unknown. Finally, science is viewed as performative where the process of doing in science enables problem solving and deeper learning.

The Agency group holds a socio-scientific view of science and people doing science have knowledge creator, inventor roles. Students’ initial representations of science are embedded in topics where concepts and processes realize “how things work”. Subsequently, science is perceived as performative and scientific practices are foregrounded in the context of improving the quality of life. Finally, scientific practices are associated with the ways in which science is experienced where experiences are expressed as ontologically subjective phenomena. Therefore, students’ perceptions of science become increasingly sophisticated over time as sense-making, having fun in science, engaging in the scientific practices mediate learning of new phenomena. Moreover, the Agency students express positive and global views of science.

## **Finding 2 Student Expectations, Emotional Investments, and Knowing in Scientific Inquiry**

Participation in science stems from students' emotional investments as they engage in scientific practices. The next excerpt from the Inquiry group shows how meaning unfolds for Student 1 (Female) and Student 2 (Male) from previous experiences with their stream-table investigation, which resulted in a failed experiment due to issues associated with handling the materials. Meaning in relation to 'feeling' or felt sense can be understood as recognition where the students' previous felt sense of failure means there is a possibility of messing the experiment up again. In other words, the tasks organized for and by students restrict possible actions, new understandings:

Inquiry group, AY example: Landforms, Investigation 3, Part 1 – Slope Investigation

**Student 2:** I think we failed it.

**Student 1:** How could we fail it this time? It's imposs...it's scientifically impossible.

**Student 2:** Teacher AY

**Teacher AY:** Yes?

**Student 2:** We have [inaudible]

**Teacher AY:** No, it looks awesome. That's cool! Look at that erosion go so fast. That's like watching a million years all in a second.

**Student 1:** Although it's not going to the hole.

**Student 2:** [laughing] It's there trying to [inaudible] escape it. It's trying to escape.

**Student 1:** It's not escaping.

**Student 2:** Oh there it is!

**Student 1:** If I have to cup my hands around this again, I swear!

**Student 2:** What's that [inaudible - pointing to something on the stream table]

**Student 1:** Hey get off my chair [pulling him off]. Get your own chair.

**Student 2:** Ok.

**Student 1:** We should be standing anyway.

**Student 2:** [to water flowing in stream table] Come on Einstein!

[...]

**Student 2:** I wonder if water went through there.

[...]

**Student 2:** [Looking at the water source] It's not going anywhere.

*[Student 1 takes the remaining water in the water source and empties it out on the stream table. As she places the water source back, the ruler moves]*

**Student 1:** I still have not screwed up [Student 2 tries to take it from her hands]

**Student 1:** No, I'm not screwing this up [shaking the water source as little water coming out]

**Student 2:** It's not working.

**Student 1:** It is.

**Student 2:** It isn't. [Water spills on the desk]

**Student 1:** Well this is your desk so. Dude, come on! Stop it! I'm doing it. I'm not going to pour the entire thing ok?

**Student 2:** You are not doing it the correct way!

- Student 1:** Well then how do you do it?
- Student 2:** Ok give me it [taking it from Student 1's hands and pouring the water in]
- Student 1:** Stop!
- Student 2:** This is how it is supposed to be. It's useless.
- Student 1:** Oh you just ruined it!
- Student 2:** It's not ruined!
- Student 1:** It's ruined! [Walks to Teacher AY to give time]

The exchange between the students shows their tendency to 'get it right' which leads the group to expect that for which they are expecting. Consequently, establishing a habit of mind that overlooks the unexpected and focuses on the expected. The group's focus on avoiding a second experiment failure detracts from learning something new and it ignores that scientist's work through failure all the time. Working through failure is a normal fixture of the scientific enterprise. This is illustrated when the teacher, AY, comments, "*No, it looks awesome. That's cool! Look at that erosion go so fast. That's like watching a million years all in a second.*" The group's intentions for not failing have implied consequences, despite being praised by the teacher. Firstly, a failed experiment means not getting the answer right. Secondly, losing the opportunity to experience the emotional high of running a successful experiment. Finally, failing to report back to the class their groups' experiment results, thus losing accountability. Thus, students' expectation about how data should be limits their possibilities for discovery and their conception that science is about 'getting it right' restricts the production of knowledge.

In order to disrupt such negative cycles, the teacher recontextualizes the perceived failure into a success by praising the students' accomplishments with sharpened affect. Concomitantly, the teacher provides additional information related to the experiment. The kind of information provided to account for why the experiment is successful indexes the value attached to particular ways of knowing and doing. Thus, in this example, the teacher values formal, objective knowledge over student emotional, relational, intuitive knowledge by providing additional information related to erosion. Student concerns are marginalized as they are implicitly and partially addressed in an unrelated decontextualized manner, thus having a partial truth as it relates to the situation in context. Students' understanding at that given moment regarding the stream-table investigation as it relates to their expectations represents their realm of understanding from which they operate with, so for them constituting the whole truth—regardless of the fact that it may be a misconception. The teacher's response represents a subjective perception that partially coincides with the student's understanding of the activity where she negates their statement and provides an abstract representation of what is happening in the stream table. As a result, students' prevailing experiences and beliefs coupled with the teacher's response suggests student's knowledge and understanding is incomplete and unchanging. Other approaches for addressing a 'failed' science experiment raises the opportunity to explicitly discuss the role of indeterminacy in science as it relates to the situation in context and students' emotional, relational, intuitive knowledge. Correspondingly, Viechnicki and Kuipers (2006) show that in their study on failed school science experiments, students critically focus on the procedure during their investigations and not the conclusion, suggesting the teacher and students attribute authority to the investigation.

From a semiotic perspective, student actions and responses reveal that as they reference a successful investigation from a previous classroom experience, Bazerman (1998) explains that shifts in conciseness and abstractness in the unfolding activity occur. That is, past successful investigations are construed as Events that become Phenomena and into conceptualized processes. Nominal objects index these conceptual processes, which become taxonomies distinguishing processes, science objects/materials, and concepts. Verbs connect these taxonomies as descriptions of external events or internal logic operations—actions embedded in abstract nouns and verbs expressing abstracted relations. The verbs are relational intensive (‘to be’, ‘signal’, ‘embody’, ‘confirm’, ‘prove’), circumstantials (‘cause’) or causal implication sequences (causal verb phrases and the syntactic relations established among nouns) where a state transforms into another. Thus objects acted upon, such as pouring water in the stream-table, become a new object, which is represented through syntactic relations among nominal objects. Semantically, conceptual objects are nominalized grammatical forms that are in syntactic relations of ‘coexistence’, ‘revelation’ or ‘causation’. Therefore activities and events are initially appropriated, then objectified, and finally communicated. These activities and events are situated and have implications for student agency, learning, and identity development (Holland et al., 2001).

Erikson (1968) states that one is able to adapt to the world when one possesses both negative and positive qualities of self. When students reach elementary school age they are expected to develop a basic sense of industry, mostly through success in school. At this point in development, behavior is dominated by intellectual curiosity and performance. “If children are encouraged to make and do things well, helped to persevere, allowed to finish tasks, and praised

for trying, industry results. If their efforts are unsuccessful or treated marginally, feelings of inferiority result. These feelings prevent one from enjoying intellectual work.”

### **Finding 3 Tracing the inclination and obligation of doing science**

*The traditional recipe gives place to explicit and obligatory prescriptions. Over the whole surface of contact between the body and the object it handles, power is introduced, fastening them to one another. It constitutes a body-weapon, body-tool, body-machine complex. One is as far as possible from those forms of subjection that demanded of the body only signs or products, forms or expressions or the result of labour (Foucault, 1995: 153)*

Commands establish control and their legitimacy depends on participant status, affinity, or the situation. The following excerpt from the Inquiry group is used to illustrate how language establishes power and control – the underlined text represents the *Landforms* unit text, which the teacher reads to the class:

**Teacher:** Ok. Great! Raise your hands if you think the delta will be longer? Raise your hand if you think the delta will be shorter? Raise your hand if you don't think the delta will change. Won't look any different with the flood. Ok alright so let's read the materials: 'You need a tray with earth materials. You need a water, a flood water source. You need a liter container of water and a wooden angle, a hand lens, a measuring tape and a clock with

a second hand. Procedure.' [ORIENTATION]

Do you understand what all these materials are?

Ok,' Procedure. Set up the stream-table as you did in the previous investigation. Replace the water source container with the container labeled "flood". [COMMAND] Notice this container has a larger hole on the bottom allowing the water to flow more quickly out of the bottom. [LEGITIMIZING] Begin pouring the water into the flood source and time the event, time the events that take place. Record the data on the data table.' [COMMAND]

Here's the data table.

So 'Data analysis: Record on the data below [inaudible] data for source versus length of delta. [COMMAND] The water source is standard and flood.' [BACKGROUND]

They're doing this for you. They did this part for you. They're saying with standard water the average delta length is 7cm. They gave that to you. So, we're just going to do the flood one today and we are going to say how long our flood delta is so that's what the measuring tape is for. So, what's the measured variable?

Previously, I had discussed how a pedagogic science discourse constitutes regulative and instructional registers that regulate the goals of the curriculum ideology in ways that creates what Lemke (1987:6) terms "institutional distance" because of differing worldviews. Initially, when the teacher, AY, says, "*Ok alright so let's read the materials. You need a tray ... They're doing*

*this for you. They did this part for you. They're saying with standard water the average delta length is 7cm. They gave that to you.*” The ‘institutional distance’ created limits the teacher and, consequently, the students from critically evaluating the proposition that “*with standard water the average delta length is 7cm*” or from exploring alternative methods using a flood water source.

Iedema (1997) explains that Commands of this type—“depersonalized orders” (p. 74)—embody “shouldness” on behalf of the *Landform* Curriculum ideologies. *Shouldness* is realized by means of commands, where in this example the information from the *Landform* teacher material is a legitimate source of information and relevant to the ensuing activity. Drawing from Rick Iedema’s (1997) approach to evaluate ‘shouldness,’ (see Figure 4-16) commands are referred to as “directives”, which regulate actions. From this representative example, the instructions initially orient student attention to the prescribed materials: *‘You need a tray with earth materials. You need a water, a flood water source. You need a liter container of water and a wooden angle, a hand lens, a measuring tape and a clock with a second hand.’* Next, the command functions as prescriptive advice, *replace*, which is legitimized by the following directive as an extension to the previous prescriptive advice as well as the ensuing directives that are proactive. Finally, the prescriptive advice is again legitimized through extension, where additional background information is provided (see Iedema, 1997: 91 for a typology of ‘Different types of directives’).

The functions of directives from an interpersonal metafunction establish degrees of power and control through modalized and modulated constructions. As a result from Figure 4-16 representing ‘Shouldness’, the *Landforms* text establishes a high degree of authority as shouldness is experientialized through institutional distance. This is realized by the proposals

‘*you need*’ where the nouns construe modulations objectively as obligatory things. The extensions ‘*Notice this container has a larger hole on the bottom allowing the water to flow more quickly out of the bottom*’ and ‘*The water source is standard and flood*’ legitimize the directives by functioning as propositions. The objects are specified by the verbs ‘be’ and ‘have’ that function as predicators to signal assurance of the facts. These examples of modalizations control regularities of actions and events from a person-place or experiential perspective that defines and controls what is ‘usual’. Authority is then shifted from the *Landforms* text to the teacher when she states, ‘*So, we're just going to do the flood one today....*’

This example has illustrated how “depersonalized orders” embody “shouldness” and, as a result, create institutional distance. The *Landforms* institutional discourse is imposed and realized through modals of moral necessity, which set the conditions for duties, obligations and responsibilities for the teacher. Consequently, teachers are positioned to operate with high degrees of authority as the curriculum ideologies are realized through directives and explanations, thus experientializing shouldness.

#### 4.13 Control and Power in Student and Teacher Discourses for Regimenting Behavior

While the Inquiry group teachers are positioned to operate with high degrees of authority, the following discussion illustrates how teachers and students operate within and between high and low degrees of authority (see Figure 4-15). The texts used for analysis include the teacher, GL, and one focus group (GL\_S) discussion from the Inquiry group in the *MixSol* unit during an investigation where differences in opinions emerged, and from the Agency group the texts

analyzed are from the *MSRC* unit with the teacher, SK, and the same group of students (SK\_S) deciding on their final investigation<sup>15</sup>.

#### 4.14 Analytical Lens: Mood and Modality

Each text represents a fifty-minute science lesson with a focus on tenor—the clause as an exchange—Mood, thus illustrating equity in the relative status of participants to each other. Halliday (2014) defines modality as the space between ‘yes’ and ‘no’ having different meanings for propositions and proposals. Participants choose to attribute agentive dispositions to themselves or others by negotiating the location of agentive dispositions at particular person-places; by activating dispositions for particular courses of action, thus the agent/actor has been modalized to act in relation to one of a number of different possibilities of validity that correspond to various modalities; by expressing the speaker’s opinion; or by requesting a response and/or opinion in a question. These speech acts are recognized as declarative, interrogative, or imperative clauses. Clauses are organized around interactive events involving participants where they adopt and assign particular speech roles, which are complimentary. Interactants co-author text by taking turns, each time adopting a speech role and assigning a complimentary one to the other. Speech roles in an exchange are either expressed as proposals giving or demanding goods and services, or propositions when exchanging information. Declarative clauses dialogically orient to what is un/expected, un/known when assigning evaluative significance to others thus assigning value and prescribing emerging courses of action to adopt (Halliday & Matthiessen, 2004: 210). As propositions, declaratives influence or change

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<sup>15</sup> Transcripts have been omitted due to length but the descriptive statistics are available for each text in Appendix

knowledge or values as well as elicit and anticipate responses by agreeing or disagreeing. Interrogative clauses as propositions are concerned with modalized evaluations on objectified states, which in teacher instructional framing, functions as regulating future courses of action (Halliday & Matthiessen, 2004: 206). Imperative clauses act on and change present social relations between self and non-self by performing a service or giving a commodity. Obligations imposed invite particular actions at some future moment or imply a negative evaluation of here-now and a desire to bring change. While offers express inclination, commands assert obligations and so imperatives negotiate the gap between the negatively and positively valued present as well as desired future states by acting on the consciousness of another with a view of necessary action.

Modulations, defined by the meaning of the positive (yes) and negative (no) poles, occur as offers, commands or suggestions. The meaning of the positive pole is asserting, thus prescribing something that is realized by 'do it'. In propositions, commands have varying degrees of obligation ranging from 'required to' – 'supposed to' – 'allowed to'. In proposal, offers realize degrees of inclination ranging from 'determined to' – 'anxious to' – 'willing to'. The meaning of the negative pole is denying, thus proscribing something that is realized by 'don't do it', as obligations or inclinations.

Existential processes represent phenomena 'to be', establishing the existence of phenomena or participants. The verbs 'are', 'was', 'were' are generally preceded by 'there' construing 'being' as a simple existence or introducing new information, thus functioning as Theme. Consequently, Quirk, Greenbaum, Leech, and Svartvik (1985) refer to existential clauses as 'presentative' thus expressing usuality.

Modalization expresses the meaning of intermediate possibilities or indeterminacy. Thus the likelihood of something is expressed by degrees of probability that range from ‘certainly – probably – possibly’; and usuality representing degrees of oftenness that range from ‘always – usually – sometimes/sometimes not/not always.’

Modal verbs realizing inclination, such as ‘will’, ‘would’, and ‘should’, represent a proposed action that is evaluated in terms of its possible future grounding as an action performed. For example, ‘will’ expresses a prediction about the present (often occurring with the conditional ‘if’), and in a habitual sense to express the idea of predictability. The addresser is operating under a controlling field of probabilities (will, would) or expectations (should) that extend into the past, thus constraining the agents’ action by past regularities. These finite verbal operators denote something that is ‘always’ and ‘certain’; hence they are at the high end of the modality scale given the habitual characteristic or behavior as well as constant objective orientation construal.

#### 4.15 Expectations and Positioning

Prediction modals (e.g., will) are used the most among students from the Agency group, where the central focus is on predictability. For example, the focus group discussion regarding a prediction made by Student 1:

**Student 1:** I predict that mixing gravel...

**Student 4:** I predict that mixing gravel.

**Student 1:** into the earth material...

**Student 4:** ‘Into the earth material.’ Keep speaking.

**Student 1:** I predict that mixing gravel into the earth material will, uh.

**Student 2:** Affect the length.

**Student 1:** No, will, uh,

**Student 4:** Decrease. I think it will decrease it because it will make it stronger.

**Student 1:** No, because the water will just flow straight throw and it won't really erode much.

**Student 2:** No.

**Student 3:** Yeah, because it will slip right through it.

As I had previously shown in ‘Student Positioning,’ Student 1 takes the role of agent enforcing a rational plan or will to control certainties or permanencies of the stream-table investigation. As a result, the group is construed as motivated and achieving a goal through rational assessment of certainties and risks involved, hence realizing ‘cognitive-instrumental, purposive-rational actions (Thibault, 2004: 83). Modals denoting inclination in the Inquiry group are predominantly used during class discussions and often in question and answer forms.

Modal competencies or capacities realize the causes for an agent to know or possess a skill or ability. The potential for knowing, getting to know, learning, ability, and permission are subject to judgments. As modals construing probability, they are placed at the low end of the modality scale. ‘Can’, when the orientation is objective, reveals the circumstances of possibility as well as permission within the conditions of enablement, thus ‘could’ realizes a physical or moral possibility or occasional characteristic or behavior (Thibault, 2004). Students from the Inquiry group frequently use the modal ‘can’ during group discussion to gain permission from their peers during experiments to handle materials; for example, ‘Can I do the salt?’ ‘Can I shake it?’

The conditions of possibility can be expressed as a fact (it is possible that.../Experiments may...); an idea (it is possible for...) where ‘can’ is a weaker form of the factual possibility ‘may’, for example, ‘may have’ evinces the present possibility of a past happening; or hypothetical possibility expressing something that is possible but unlikely with ‘could’ or ‘might.’

Universality or generalizability of information is expressed as usuality, thereby establishing a high degree of authority given its universal validity (Herriman, 2003). Thibault (2004: 85) represents usuality as a modal category of moral necessity that expresses a moral-normative reason. As a result, statements or stances on a particular norm construe goodness or badness, rightness or wrongness. Consequently, expectations established by the teachers provide images of scientists so that the students conform to particular scientific norms. For example in the Inquiry group the teacher GL expresses a moral-normative practice:

**Teacher:** I said, do you think that this is plain water or water or water that has something dissolved inside of it? How would you be able to know? Jack?

**Jack:** It looks white-ish?

**Teacher:** There's nothing in here, there's nothing at the bottom it's very clear so I don't know. I could taste it, oops, but I know as a scientist I can't do that.

Positioning of the teacher and students within a controlling field of expectations defines and controls what is usual and right. The teacher as agent acts according to a moral logic of what is necessary because relevant norms have “always been” and “always will be”, therefore located

in the middle of the modality scale. Finally, polarity (yes or no) renders something arguable where propositions assert what is or denying what is not. Proposals prescribe 'do it' or proscribe 'don't do it'.

The modal category of moral necessity also includes conditions of enforcement connected to institutional power. Obligations, duties, and responsibilities establish the conditions for commands and requests (Thibault, 2004). Obligations expressed by 'must' reveal authority over something indicating a sense of duty or expressing a feeling of certainty when drawing a conclusion from evidence. Biber (2006) differentiates the use of 'must' in spoken from written registers suggesting that it expresses forceful obligations and so it occurs infrequently in spoken registers and it is often substituted with obligation or necessity modals such as 'have to', which expresses a personal obligation or directive.

The modal 'have to' expresses an obligation, which may not be fulfilled, and 'need to' indicates an internal obligation. Coates (1983: 233) states that when the speaker believes that the action referred to in the main predication has not already been achieved, it refers to obligations. Commands, recommendations and permission-granting utterances used frequently in the Inquiry group by the teacher refer to actions that will be carried out at a time subsequent to the utterance. Thus, 'must' is agent-orientated with the teacher, GL, having authority as she references the future as well as regulates future courses of action (Thibault, 2004: 207). The Inquiry students also have authority but among peers, where the frequent use of imperatives focus on roles when handling materials.

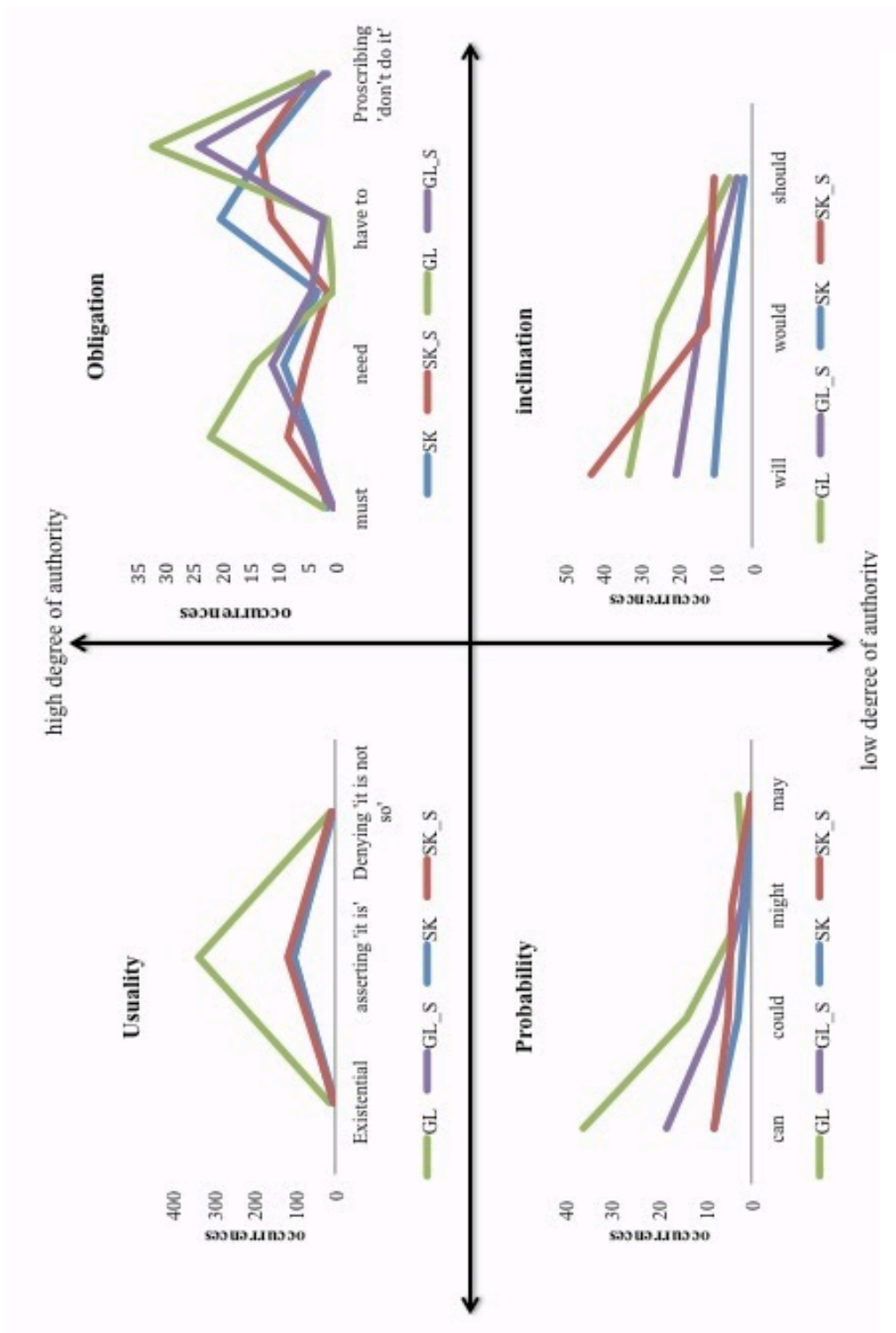


Figure 4-15 'Shouldness' in Mixtures and Solutions with GL and Students and in My Skokomish River Challenge with SK and Students

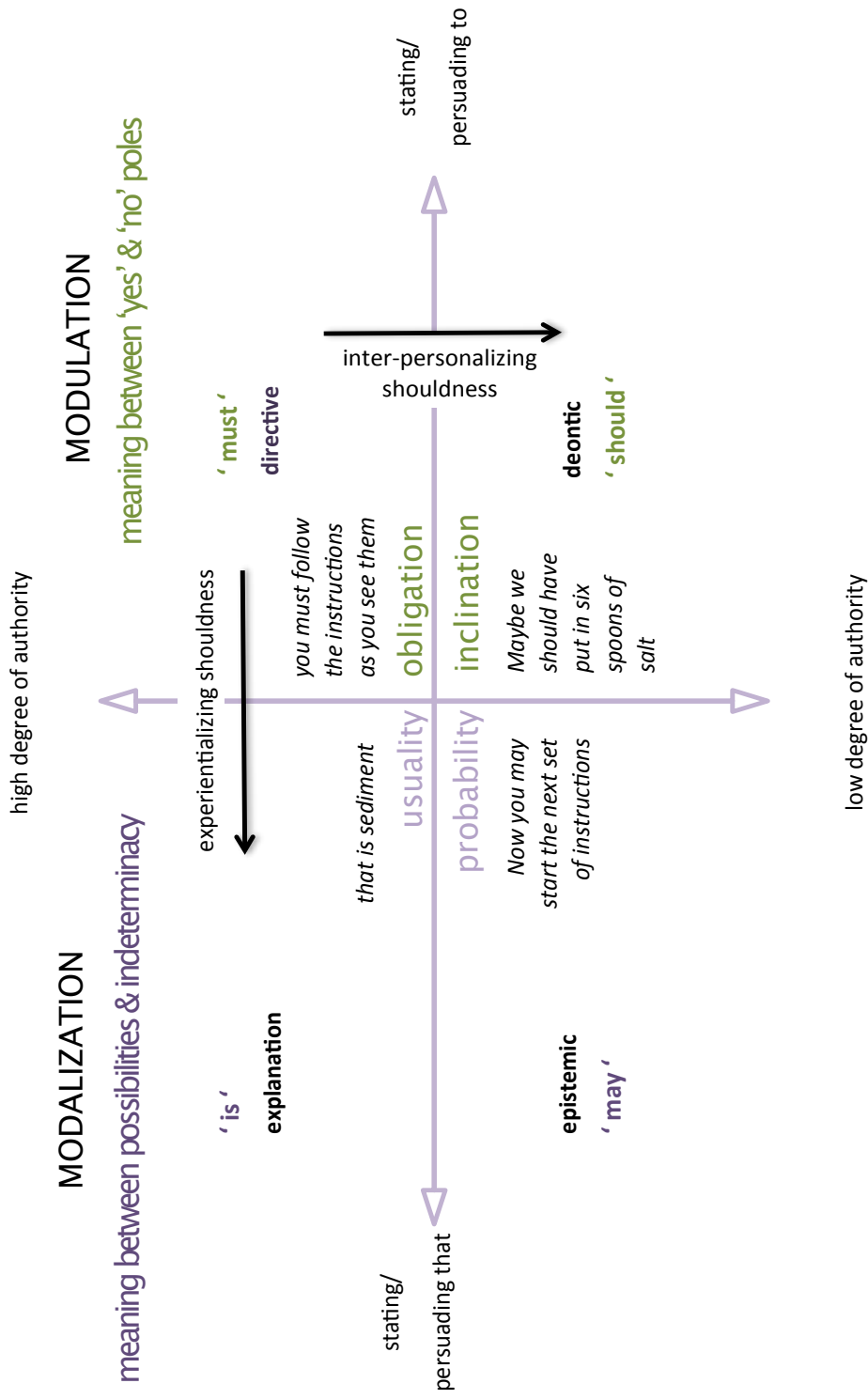


Figure 4-16 'Shouldness' and Degrees of Authority (adapted from Iedema, 1997)

#### 4.16 Student Perceptions of who does Science

Student views of who does science are characterized into two categories: those that are obliged to do science and those that have a scientific inclination. Expectations facilitate the perception and interpretation of objects and events by shaping one's perceptions to expected relevant ways of being in the world (Tannen, 1993). General impressions frame and are reframed from prior experiences, whereby justifications for interpretations emerge (Tannen, 1993:21) and can be realized by modal verbs as a linguistic resource.

Mood and modal verbs, such as *must*, *have to*, *need to*, convey the necessity or possibility of actions enacted by an agent under obligation and/or permission. These modal verbs constitute deontic modal meanings, which suggests an authority or source which may be a person, a set of rules, or a social norm that is responsible for imposing the necessity (obligation) or granting the possibility (permission).

Dynamic modality refers to actual ability, possibility and intention or will of an agent, that is, the performance of a physical activity or cognitive ability. The notion of ability or potentiality expresses *can* or *able to*, thus implying actualizing a situation. Judgments can be expressed in three ways: (1) Subjective – Implicit where modals refer to *can*, *can't* and reflect the degree of readiness or inclination and ability, and *can, is able to* suggest a low probability or potential to act and *will, is willing to* suggests a high probability or potential to act; (2) Objective – Implicit where modals include *be able to*; and (3) Objective – Explicit where modals express potentiality or possibility for action as in 'it is possible to' expressing potentiality.

The Agency and Inquiry student's experiential construal of who participates in science centers on the genres of science (cf. Polias, 2006). This encompasses 'doing' science in the present moment with the verb 'be' (clause occurrences=169) and interpreted as a material

Process; for example, “*it doesn't matter what you're doing, you kind of have to like, like, try things out, see if it works, see if it doesn't, and that's kind of like science.*” (EB49, MixSol); as a relational Process for the Inquiry group by perceptually interpreting a Phenomenon (“*trying things out*” – concrete, material object) as an instance of science; as predominantly a mental Process for the Agency group, as shown in the following representative example: “*Well I **think** everyone does science at some point, 'cause, um, you have to always think about stuff (SK41, PolSol).* The general characteristics of science are expressed using causal verbs ‘to have’, which realizes student’s attitudes to truth as related to ability as in, “*you just have to know how to use things um and do experiments. You need to know how to get research without copying word for word” (SK51, PolSol).*

For the Inquiry group, participation in science is circumstantial where socio-material arrangements are interpreted as obligations. The Agency group also shares this view but to a lesser extent. Their stance is grounded in certainty and it is construed subjectively in mental processes of cognition; for example, “*Us and well, scientists and I **think** almost...I **think** actually everyone **does** science but they don't know like in their everyday lives, like when they try to find stuff out, they are basically doing science” (AW58, Agency Algae). Student’s subjectively qualified information is made explicit by positioning the self as the source of information, which is inferred cognitively as an expression of evidentiality, hence a feature of epistemic agency and commitment in engagement. In terms of time-scales, student’s cognitive context shows the degree of participation as an inclination and identification in science as both episodic and long-term.*

The results show differences between the Agency and Inquiry groups in relation to how they are learning as well as how they identify and talk about who does science from an affective

and categorical perspective. The Agency group has a broader view of science, they initially identify with science from a social perspective, which encompasses a global perspective, where scientists and kids in school do science (63%), everybody does science (50%), and people could do science (88%) (see Appendix 13 ‘Who does science?’ Results of categories) whereas the Inquiry group identify with science from a local, restrictive perspective with 93% stating ‘scientists’ and ‘kids in school’ do science. Furthermore, the Agency group has a higher tendency aligning with science than the Inquiry group because they positively associate their abilities and possibilities in science. Their abilities and possibilities in science are construed with the verb ‘can’<sup>16</sup> as material processes (‘can do’ occ. 11), mental processes (‘can think’ occ. 5), relational processes (‘can be’ occ.3), existential processes (‘can affect’ occ. 3), and behavioral processes (‘can see’ occ. 2). Student responses construed as relational process characterize science as ‘it’s a profession...it’s generally everyone’ (AD41, MSRC), ‘it’s logical’ (SK47, MSRC), which are realized by relational attributive processes. These attributes are then elaborated on where students provide circumstantial information, thus locating who participates in science in time-place, ‘it’s during school’ (JB44, MSRC), and manner – the way in which a process is actualized as in, ‘it’s finding out a new thing that you didn’t know’ (PB55, Algae).

#### 4.17 Summary

The Inquiry group perceives science as an obligation where students are “experientializing shouldness” (Iedema, 2000) expressed by the fact noun *need* that is modulated, as ‘it is necessary.’ These distinct alignments are because of students’ experiences in science and the

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<sup>16</sup> In some instances the modal ‘can’ did not represent who has the ability to do science but to indicate a property of Agent.

units. The Agency units give students the capacity to act intentionally and design and manage their learning because they foster intentional reflection. Schools often cannot make space for introspection and the way science has been construed from an institutional perspective disables students from being creative and transformative (from becoming). Consciousness, functioning also as an anchor for agency and identity, triggers affect and learning in agent-orientated learning environments. Moreover, subjectivity versus materiality/objectivity in science impact how students perceive science. The Inquiry group perceives science as a commodity that is disconnected from the self-as-scientist, thus having an external perspective of the self-as-consumer. The Agency group works within their possibilities for solving problems in the challenges. Thus doing science in a more self-organizing way, transitioning from being to becoming.

### **Part III: Semantic Analysis of Student Images of Science**

Further analyses of the interview data were conducted by analyzing the syntagmatic and paradigmatic relationships of students' perceptions of science. Analyses were focused on the ways that students talk about science, thus taking an emic perspective for understanding meaning inherent in texts. First, a thematic analysis of student responses was conducted to identify the subjective viewpoints of how students are talking about science and subsequently observe how students' meanings are organized within a corpus and within its subsets.

T-Lab version 9.2 (Lancia, 2012) was used to identify patterns and emerging themes from student interview responses within the context of the identity-related question: *If you had to explain what science is to somebody who had never heard of it, how would you explain it?* Identified patterns highlight co-textual relations, that is, relations internal to a text – a text in this case would be the transcribed student interview responses. Patterns in a text are identified by co-occurring words. Emerging themes show the co-textual and contextual relations; hence the text is treated as a communicative event (Lancia, 2012). In T-Lab, the corpus is pre-processed and for this study I selected to have the corpus classified automatically. A way to triangulate the data was to compare the results from T-Lab with the inter-rater reliability measure. Before the T-Lab results were compared to my coding scores, I iterated on the data refining results to try account for emerging, existing, and disjunctive contextual relations. Further analyses were performed to identify the dimensions of the attributes and their associations as they emerge within and between units across comparative groups. Next, a comparison between textual units (e.g. sentences, paragraphs, text segments, or documents) and associated patterns (e.g. similarities) between co-occurring words is done algorithmically. Finally, the textual units are clustered

algorithmically into themes or categories where each cluster has internal homogeneity and external heterogeneity (Patton, 2002 as cited in Lancia, 2012). Word occurrences and word co-occurrences provide information about the number of times words occur within and between specified contexts (Lancia, 2012).

The context for the following analysis of student responses includes the Landforms unit, which accounts for 48.45% of the corpus and MSRC, which accounts for 51.55% of the corpus (corpus refers to all of the student responses in text). The co-word analysis shows the degree of correspondence between the distances between two words.

### Finding 1 Inquiry Curriculum Design: Co-Word Analysis

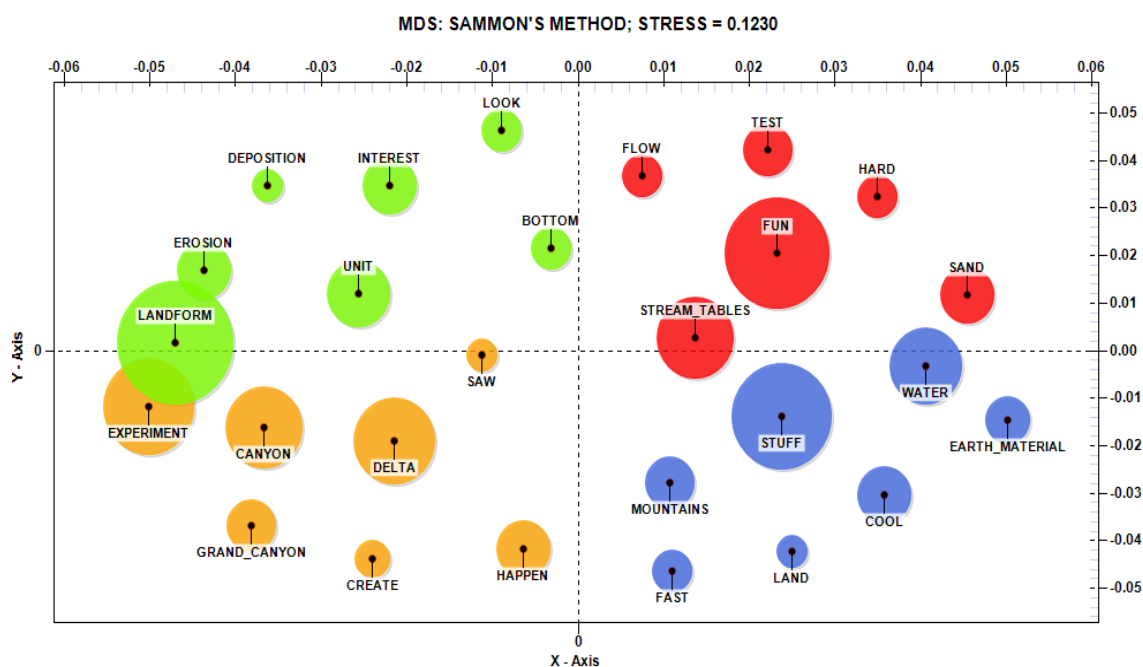


Figure 4-17 Inquiry Group C-Word Analysis MDS

The first quadrant on the upper right side represents the dominant relations between themes—which means that these themes are established and have developed over time. The principle themes, listed from high to low in centrality measures: ‘sand (0.148)’, ‘fun (0.141)’, ‘stream-table (0.103)’, ‘flow (0.099)’, ‘hard’ (0.057), and ‘test’ (0.052). Centrality measures yield an average of the association indexes, that is, relationships between clusters. While the clusters ‘sand’, ‘fun’, ‘stream tables’, and ‘flow’ have high centrality measures, ‘sand (8)’ and ‘flow (4)’ have low densities indicating a weak structure within those clusters. Density measures yield the average of word association indexes within clusters. This suggests that there are strong associations between (centrality) specific words or clusters in the corpus but within (density) the cluster the associations are weak (i.e., they are not related to each other). For example, ‘sand’ has a high chi-square value of 7.068 where there are strong associations between clusters, yet within clusters ‘sand’ occurs in 8 clusters, indicating a weaker association within clusters. Thus, density and centrality measures indicate the strength of local context and global contexts respectively. Across the two cohorts the word ‘sand’ refers to the materials used during experiments; when asked about the experience they would say things like:

It was a **fun experience**. First we, like, **learned** about the canyon and then we liter - like, we did what the canyon did, we had bo - like, bowls kind of and we put sand in them and made them all flat and we put water to make them go down the streams and sometimes we’d tip it to see if it would go faster or slower (JV48, CO2, Winter 2013, Landforms)

Um, I would tell them that in the Landforms unit we learn about different types of landforms and how they were created and we do experiments with stream tables and, like,

sand and water and, like, forming deltas and canyons. (JV52, CO2, Winter 2013, Landforms)

I would tell them it was fun because we got to, like, when we put the food coloring in the water, like, the sand got really red so it looked like, um, someone bled all, all over the sand. (AY47, CO1, Fall 2012, Landforms)

Strong associations between ‘sand’, ‘water’, and ‘earth material’ observed in the fourth quadrant on the lower right side refer to the kinds of the materials used in science in relation to the Landforms unit. Moreover, there is a strong association (chi-square 0.267) between ‘sand’ and ‘fun’. Materials in science enable students to learn about natural processes (e.g., how deltas or canyons are formed) during experiments, which students perceive as fun because of the associated experiences. This fits with the view within science education that hands-on inquiry science is very engaging to learners. Material arrangements are strongly regarded essential to learn about science, especially from an epistemic practices perspective, thus students were able to make those associations within the context of the Landforms unit. On the one hand, within the data corpus, these associations are weak when students talk about their images of science. On the other hand, material arrangements appeal to students’ affect where students make associations between fun and ‘stream tables’, ‘sand’ (quadrant 1), ‘water’ and ‘earth material’ (quadrant 4).

The ‘fun’ theme has a high centrality measure (0.141) and a weight score (21). This indicates that there is internal coherence and that it is relevant in students’ general images of science within this data corpus. This highlights that students routinely mention ‘fun’ when making associations to materials. Within the ‘fun’ theme strong co-occurrences are shown by the

association indexes, with ‘stream tables’ (0.34), ‘mountains’ (0.289), ‘stuff’ (0.286), ‘interest’ and ‘sand’ (0.267) and ‘flow’, ‘look’ (0.236). The contexts wherein the theme ‘fun’ co-occurs are illustrated through the following examples where the highest similarity measures (cosine) are shown:

It was **fun** because we got to investigate **stream tables**. (cosine .408, AH59, CO1, Fall 2012, Landforms)

Um, it was really **fun**, you get to do a lot of **stuff**, um, with **mountains** and landforms. It’s a lot of **fun**, you get your hands dirty but that’s nothing, uh, eh, yeah. (cosine .369, CJ52, CO2, Winter 2013 Landforms)

I would tell them that it’s pretty **fun** and you get to make **stream tables** and, um, see how different **flows** affect the process of making deltas [ inaudible ] stuff like that. (cosine .340, EB52, CO1, Fall 2012, Landforms)

The ‘fun’ theme also co-occurs with “hard” (association index 0.236) and there is a strong relation between ‘hard’ and ‘test’. In the context of the investigation, students perceive science as both fun and hard. This is further supported by the similarity coefficient where the mutual information index shows a high degree of relevance (fun: hard 0.579) between the two words, although the words are semantically dissimilar. The words in context show that students perceive science as fun but they also enjoy being challenged—as indicated in these sample statements:

Like, taking the test and doing some of the tests, it’s complicated 'cause, like, on the timer stuff you know, you have to do it right on time, like, but then it get, it’s really fun and it’s hard, though. (cosine .603, EB45, CO1, Fall 2012 Landforms)

Uh, just all of the vocabulary and stuff. That they told us to do, it was hard to use it.

(cosine .408, AY67, CO1, Fall 2012, Landforms)

For instruction, this suggests that although students are challenged in science, science is compelling. The experiments render science fun, likely in relative terms to other classroom instruction, even under rigorous inquiry conditions, which students prefer. Aspects such as challenging science problems yield interested dispositions, which subsequently shows students' emotional investment.

The tests or assessments and formal ways of talking science pose challenges for the students, thus students naturally express science as being hard. The tests also refer to the experiments conducted in the classroom, thus the words are synonymous, where the procedure for running experiments are viewed as complicated or hard.

Um, I would say that Landforms is a, um, a really cool, like, science unit to study 'cause it's like, it's challenging and it's fun 'cause you get to try different examples and stuff.

(cosine .226, CJ60, CO2, Winter 2013, Landforms)

The perception that science is also hard or challenging can be related to the coded interview results where the Inquiry group describe science as a way to figure things out. Problem solving in science relates to discoveries, innovations, and learning. For students, these attributes are valued because they appeal to their curiosity about local phenomena they are discovering in the classroom as well as global phenomena they see in media.

In summary, quadrants 1 and 4 can be interpreted as showing how material arrangements mediate students' positive emotional investments in science. Students find these material experiences enjoyable because they are challenging and they invoke interest.

Central concepts of the Landforms unit are relevant in the second quadrant when students explain their understanding of science. There are strong associations between 'unit' and 'landform' (0.373), and 'erosion' (0.252). Surprisingly, students made no association with 'deposition' when describing science in relation to the Landform unit although the unit equally stresses that scientific concept as well. The strong similarity relation between 'unit' and 'landform' indicates an example of a collocation (two words normally occurring together), which is further supported by looking at the collocated words in context from student responses describing what science is:

I would tell them that... uh... that, mm, that you learn in that **unit** about how landforms, like, form, really. And how, like, the Grand Canyon formed, like, it's kinda like that 'cause we do experiments on that and, like, we, in that experiment we see, like, how, like, an island was formed (AH60, CO1, Fall 2012, Landforms)

About the Landform **Unit** is that is really interesting how you get, like, the stream table and some sand, earth material thing and watch water flow through it into erosion. (JV49, CO2, Winter 2013, Landforms)

A relevant association is between 'erosion' and 'deposition' (0.267). 'Erosion' has a centrality measure of 0.118 and a weight score of 8. While these measures indicate a weak structure in the corpus, there are relevant associations within the 'erosion' theme. For example,

the relation between ‘erosion’ and ‘canyon’ (association index measure 0.327), ‘experiment’ (0.293), ‘interest’ (0.286), ‘deposition’ (0.267), ‘landform’ (0.254) and ‘delta’ (0.21). This indicates that student’s developing awareness of the concept ‘erosion’. This suggests that the associations made with particular natural processes come from what students learn in science and experience during investigations. Student representations of science are embedded by their reflections on their experiences in the Landform unit where from an epistemic frame students at least partially form stances about science. The clusters with the highest centrality scores (water 0.172; landform 0.166, sand 0.148; fun 0.141; stuff 0.139, canyon 0.138; experiment (0.134); delta and erosion (0.118) show that materials or tools mediate student affect on the right side and become embedded in student situational experiences (i.e., they talk about their experiences using these terms). From these situational experiences, students describe science in relation to the science processes and practices as represented on the left side.

In summary, students *thematize* the Landforms unit meaning they refer to it as the *topic* or talking point for expressing their images of science. Students also *characterize* scientific processes and practices, such as erosion and experiments, which are the *focus* of how students imagine and describe science. Finally, students *reason* with the landforms unit-processes and practices (i.e., Landform topic characterizes science establishing a theme-character relation) relations to *justify* their images of science. Therefore, the beliefs students hold about science are represented relationally, where their justifications draw on theme-character relations and are grounded in both prior and subsequent inferential and indexical processes (Kockelman, 2013:82). This suggests students attribute science a typifying role that is part of a circumstantial context dependent on materiality.

## Finding 2 Agency Curriculum Design: Co-Word Analysis

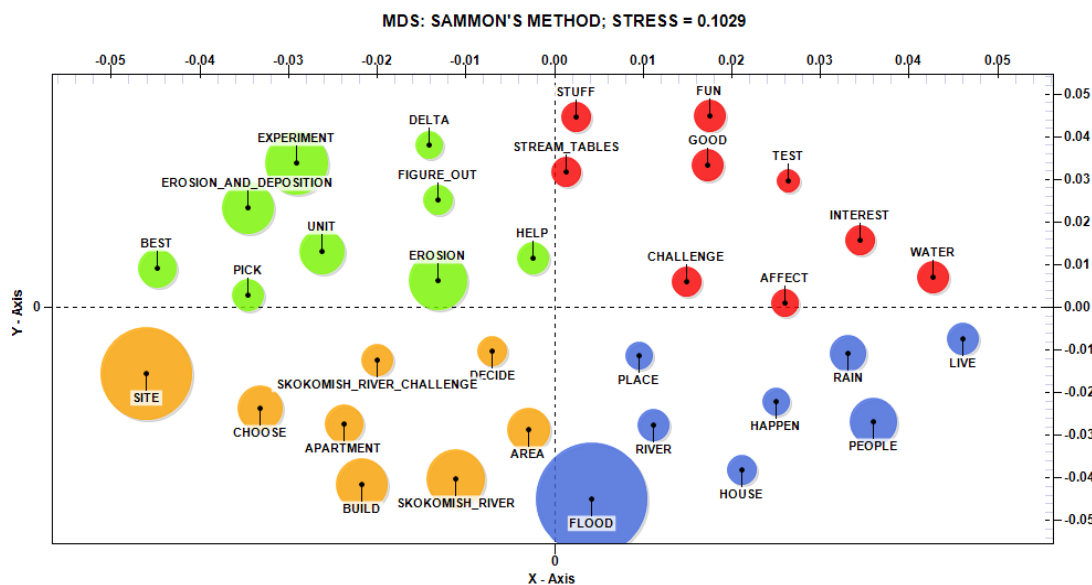


Figure 4-18 Agency Group Co-Word Analysis MDS

The upper right side has low centrality and weight scores (Stream tables (5, 0.089), Affect (8, 0.083), Good (5, 0.076), Stuff (4, 0.072), Fun (8, 0.068), Water (6, 0.064), Interest (5, 0.055), Test (4, 0.047), Challenge (5, 0.039) even though the themes in this quadrant are well developed (cf. Callon et al. 1991). Students' representations of science include references to materials and practices, for example Stream tables (5, 0.089), Water (6, 0.064) and Test (4, 0.047). Consequently, science materials and practices are referenced with professed enjoyed – Fun (8, 0.068). 'Fun' has a stronger weight score indicating a strong association within other themes (<Fun> stuff 0.447, good 0.4, experiment 0.346, test 0.316, delta 0.258, stream table 0.224, water 0.2).

Uh, it was really **fun** and you get to learn a lot of stuff that you regularly wouldn't learn if you weren't doing this. And it is, you get to do a lot of tests which is good 'cause you don't usually wanna do a lot of tests and it is pretty fun and you can learn a lot of data

and different data and it makes it **harder** and that makes it more fun (AD46, CO1, MSRC Fall 2012).

Um, it is **interesting** and it's, I think it's a good life lesson to learn. Um, just in case if, like, you live somewhere where that's a problem, you would know what to do (AD63, CO1, MSRC Fall 2012).

Materials and practices are an index of the students' representations about science, thus orienting to past experiences in science. These past experiences are subsequently oriented to the future where students infer that materials and practices not only invoke a positive experience but also have affordances in everyday life because of their functions. This affective dimension shows that as students participate in science their experiences become relevant because doing and seeing things becomes an epistemological warrant for truth (Knorr Cetina, 1999:97).

The bottom left represents the problems students have to negotiate within the curriculum, MRSC (Flood 42, 0.196; People 15, 0.108; House 5, 0.103; Live 5, 0.082; Place 4, 0.082; Rain 7, 0.074, Happen 4, 0.068; River 6, 0.06). Flood and People have both high centrality and weight scores, which indicates the basic theme of the unit:

I would probably tell them that, uh, about the Skokomish River area before I started with the challenge, like, uh, that it was the, it's the most likely to flood in our whole state and that flooding has caused a lot of, uh, effects on other, on people in the area and I would start with saying that and then I would talk about the challenge (ASA48, CO2, MSRC, Winter 2013).

Um, I would tell them about the, the flooding of the Skokomish River area and how it affects the people living there and, um, also with the erosion that hap – that is happening, um, and just get them really interested in, like, what's going on (SK44, CO1, MSRC Fall 2012).

As students highlight the issues of the challenge, the lower left side represents the context of the challenge—the Skokomish River where students were tasked to select a site to build apartments that will not contribute to the erosion and deposition in the area:

Well I would say, we are doing this three part challenge and our first part was finding out what erosion was and, like, how it affects people and then I would describe what erosion was and then I'd describe the second part and then the third part was our Go Public and presenting our findings to the Mason County Government and other people (ASA46, CO2, MSRC Winter 2013).

Finally, the upper left side represents the scientific processes and practices embedded in the MSRC (Experiment 18, 0.163; Erosion and Deposition 12, 0.139; Erosion 18, 0.138; Best 7, 0.13; Pick 7, 0.109; Unit 11, 0.103; Figure out 4, 0.075; Help 5, 0.072; Delta 4, 0.066), which students interpret as constituting science:

Well I would tell them that we're doing a unit on where we do many experiments to help prove that between three sites, uh , which one ' s the best to place an apartment that will cause the least erosion and deposition (SK43, CO1, MSRC Fall 2012).

In sum, the right side represents the *contents* of the unit, which specifies conditions needing to be addressed (Challenge, Flood, Rain). The left side represents the *mode*, which specifies how the specified conditions will be addressed (Experiment, Erosion and deposition,

Pick) (Kockelman, 2013:154). The contents of the MSRC function as keys that invoke expectations, attitudes, and inferential processes associated to students' images of science. The contents mediate the mode thus defining the associations between the referent—science and the activities in which students participate (cf. Duranti & Godwin, 1992). From an epistemic frame, the map shows that students talk about the process of erosion and the process of deposition as a single process. While these processes are closely related, they are different. In some cases misconceptions as well as associations are illustrated in the key contexts of “erosion and deposition”:

Well I would tell them that we're doing a unit on where we do many experiments to help prove that between three sites, uh, which one's the best to place an apartment that will cause the least erosion and deposition (cosine .462, SK43, CO1, MSRC Fall 2012).

Um, I would tell them what erosion is, what erosion and deposition is first, because they probably wouldn't know what that is.... (cosine .402, AW61, CO1, MSRC Fall 2012)

Um, I would tell them that we were, um, experimenting with, um, erosion and deposition and deltas and that it was, um, mainly about, um, seeing, uh, where, where we would experiment because we needed to recommend a site and we had to do, like, various experiments to find out which site was the best to recommend (cosine .385, AK52, CO1, MSRC Fall 2012).

The key contexts show that students thematically condense (Lemke, 1990: 96) these concepts. Lemke states this phenomenon occurs when students cannot differentiate or expand on

the full meanings of processes, thus condensing items. Students associate “erosion and deposition” as an object of study and a science unit that is related to picking the best site by experimenting with those processes to decide on the best site:

Well I would tell them that we're doing a unit on where we do many experiments to help prove that between three sites, uh, which one's the best to place an apartment that will cause the least erosion and deposition (cosine .480, SK43, CO1, MSRC Fall 2012)

Thus it is within the context of the unit that students establish practical experience through practical action. As students relate the contents and mode of the MSRC unit to science, they attribute value or “preferences” (Kockelman, 2013:188).

The situational contexts, student relational positioning, and their scopes of experience in science characterize students' images of science. As they draw on normative or prototypical representations of science to establish their image of science, they make judgments that encompass values. For example, “*Uh, it was really **fun** and you get to learn a lot of stuff that you regularly wouldn't learn if you weren't doing this*” (AD46, CO1, MSRC Fall 2012); and “*Um, it is **interesting** and it's, I think it's a good life lesson to learn. Um, just in case if, like, you live somewhere where that's a problem, you would know what to do*” (AD63, CO1, MSRC Fall 2012). Kockelman (2013:196) explains that values underlying an identity are important for guiding one's actions, thus enabling or constraining one's agency and identification. Students' initial images of science draw from the MSRC unit, which is represented as a theme and treated as the focus of their stance towards science. Students then justify their stances in relation to processes inferentially (logical reasoning) and indexically (through causal chaining).

Having students learn through scientific inquiry means transforming evidence (Bruner, 1961). By giving students agency over their learning, we are giving them the opportunity to learn about the means by which truth is derived within a discipline. This entails the collection, analysis, and interpretations of evidence, and then the development of knowledge claims supported by this evidence (Schwab, 1962).

#### 4.18 **Analysis of Agency Themes**

The student responses to the Agency-related interview questions (see Appendix 14 for processing steps, descriptive statistics, and results) are represented by significant thematic clusters, known as Elementary Contexts (E.C.).

### **Finding 1 Student Preferences Doing Science**

**A2:** Some students like it when the teacher tells how to do things in science. Other students prefer to figure things out on their own or with other students. Which do you prefer and why?

*Table 4-5 Student Preferences when Doing Science*

Units <sup>17</sup>	Cluster1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
	Learning	Interest	Student	Figure out	Table group	Direction
Unit_Algae	14.89%	8.51%	8.51%	34.04%	17.02%	17.02%
Unit_Environments	11.11%	16.67%	13.89%	27.78%	16.67%	13.89%
Unit_Landforms	7.69%	12.82%	15.38%	23.08%	30.77%	10.26%
Unit_MixSol	17.65%	11.76%	8.82%	26.47%	14.71%	20.59%
Unit_MSRC	8.7%	19.57%	17.39%	23.91%	17.39%	13.04%
Unit_PolSol	28.57%	8.57%	14.29%	20%	11.43%	17.14%
Total	14.35%	13.08%	13.08%	26.16%	18.14%	15.19%

The results from the thematic analysis of Elementary Contexts (ECs) in Table 5 shows 6 clusters related to student preferences when doing science either guided by the teacher or figuring things out with other students or individually. The first cluster, ‘Learning’ includes the following characteristic lemmas and words, which are shown, ordered from highest to lowest by their weighted scores:

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<sup>17</sup> Index (between-cluster variance/total variance): 0.189

*Table 4-6 Learning*

Lemma	Chi square	Word	Occurrence
Learn	96.859	Learn	27
Learn	96.859	Learned	2
Learn	96.859	Learning	14
Learning	40.315	Learning	10
Dissolve	25.603	Dissolves	3
Year	21.791	Year	6
Teacher telling	20.109	Teacher telling	5
People	13.351	People	6
Discover	12.939	Discover	3
Wrong	12.063	Wrong	8
Remember	11.41	Remember	5
Feel	10.913	Feel	8

#### Theme 1: Learning

The lemmas ‘learn’ (97%) and ‘learning’ (40%) in context represents how students characterize their preferences when doing science. Both the Agency and Inquiry groups prefer figuring things out on their own because they learn better; for example, I think learning on my own 'cause then I don't get, like, if the teacher tells you what to do, you're gonna probably learn, like, nothing but if you figure it out on your own you're gonna get it more and, like, so if the teacher tells you what to do with the experiments, like, ‘okay so you gotta do this and this, okay this is what you gotta write, this is your conclusion and everything.’ But if you do it on your own, um, you can, like, learn more and, um, work harder and not be all, like, lazy so I prefer doing it, learning on my own or with, like, my teammates (ASA41, CO2, Unit MSRC, Score: 200.071).

The majority of responses show that students generally prefer learning alone followed by learning with others. By having the opportunity to figure things out individually or collaboratively, student's felt they worked harder and they learn by actively doing something as expressed by the following statement:

*"I feel like you can learn more when you're actually doing it you, you're totally tuned in. You know what you're doing; you're not just sitting on the carpet. You could be daydreaming and your teacher could be talking and saying some really cool stuff but you're just in Lala Land and, but when you're doing it physically by yourself, no help you have to be completely engaged and know what's going on (AK59. CO1, Unit Algae, Score: 87.284).*

Moreover, by doing science individually or in groups, students stated feeling autonomous because they are problem solving without the guidance of the teacher or a textbook. Feeling empowered is also characterized by the way students engage emotionally. Despite the difficulties students may encounter in science, they find it '*really fun*' to engage in challenges and they are able to '*remember more*' (AD49, CO1, Unit PolSol, Score: 39.399) because they are '*researching and finding all these cool other facts*' (SK41, CO1, Unit PolSol, Score: 20.919).

Overall, students feel they are learning more on their own or collaboratively in the chemistry-related units, PolSol (Agency group) and MixSol (Inquiry group). Consequently, the Agency and Inquiry group responses differ due to the nature of the science units, where the Agency units provide student autonomy and they connect to students' "lifeworlds". As a result, the Agency group prefer figuring things out on their own or collaboratively because they are researching questions they have generated in groups; for example, "*I like figuring things out in a*

*group because you end up learning more stuff that way 'cause you, um, you're finding everything out for yourself like the questions and you're researching'* (SK41, CO1, Unit PolSol, Score: 20.919). Moreover, the Agency group consciously attends to how they feel during activities, once again illustrating how students feel the meaning of their agency and interest as a felt sense that relates to their science learning experiences (Gendlin, 1962 as cited in Thibault, 2004:59), such as *"Um, I kind of like to figure stuff out on my own, or with a little assistance 'cause if you don't have an assistance, you don't know what you're gonna do but it's fun to learn how do it by yourself or with other people. 'Cause you feel like you're being the one who's doing it, not your teacher telling you what to do. And so you feel more involved. That's how I feel, I feel more involved in the thing, in the, like, what we're doing instead of just knowing what to do* (AD55, CO1 Unit Algae Score: 58.554)." Student's felt affect, motivation, and interest assumes how students understand and regulate their learning, thereby demonstrating how consciousness empowers students to take a stance by orienting and attending to relevant activities as phenomena of experience. Concomitantly, student's developing consciousness capacitates them to modify and regulate their learning both from the perspective of the self and in responding to events by projecting actions during science activities that reshape the situation in context to accommodate student's 'wants', 'needs' and stances (Thibault, 2004).

Consequently, student learning is decontextualized and recontextualized as students primarily invest in their emotional commitments. On that account, students engage in a form of "symbolic play" (Thibault, 2004) where their roles and particular ways of knowing are embodied in their science experiences as processes of symbolic abstraction and generalization of relevant scientific practices from their formal and informal science contexts into their "as-if" realms. Thibault contends that experiences are embodied in activity as a type of procedural knowledge

(‘how to’), which emulates, in this case, scientific roles and practices. Accordingly, symbolic play in students’ ‘as-if’ realms acts as a powerful resource that mediates their science apprenticeship. Students’ identities, affective commitments and self-governing rules regulate participation in their ‘as-if’ realms, which recontextualize and function independently of the normative scientific roles and practices experienced in school science. Therefore, scientific roles and practices are experienced through symbolic play and student’s capacities to participate in science develop by means of an implicit reflection on and sensing scientific ways of being and doing. In turn, Thibault concludes that student’s capacities for explicit reflection, as illustrated in student’s utterances expressing felt emotions and interests to learning in science, develops as they realize their affective commitments through participation roles and science practices particular to their ‘as-if’ realms.

The Inquiry group prefers figuring things out on their own or collaboratively because they learn better, yet they do not always have opportunities to work collaboratively or independently. Student accounts of working independently or collaboratively in science predominantly engender previous science experiences; for instance, “*last year I did electricity too and the teacher's like, ‘okay do anything you want with the battery, find how you can make the light bulb light’, and that was really fun [...] it’s lighting, it’s lighting, it’s lighting!*” (CJ63, CO2, Unit Landforms, Score: 76.365).

The Inquiry group also positions the teacher as an obstruction to their learning because when the teacher instructs students, they feel like passive recipients and, for the most part, they are obliged to do what the teacher, as authority, instructs them to do, which displaces their sense of independence which they fervently desire, as expressed by a student in the Inquiry group, “*you know people are always, like, relying on the teacher as if, like, example a kid always relies*

*on his mom all the time.*” (CJ60, CO2, Unit Landforms, Score: 21.876). Consequently, students express their displaced autonomy as a by-product of teacher authority because they want to control their learning through trial and error, as articulated in the following excerpt: *“I don’t like it when somebody’s standing over my shoulder and telling me if I’m doing something wrong, I want to figure it out that I’m doing something wrong.”* (CJ49, CO2, Unit Environments, Score: 164.396). Although the Inquiry group prefers figuring things out independently or in groups and they consider instruction at times as irrelevant (e.g. *“I do better learning things on my own than learning with a teacher because my teacher’s just copying out of the book”* (AH60, CO1, Unit Environments, Score: 66.287)), they also perceive teacher guidance and/or ‘how-to’ steps as beneficial to their learning. For example, *“I also would like some general instructions so that I’m not trying to do a chemical reaction when we’re trying to learn about a mixture. So basic outline and then I fill in the details”* (CJ49, CO2, Unit Environments, Score: 164.396). As I illustrated earlier in the classroom video excerpt, student’s conception that science is about ‘getting it right’ re-emerges where students experience personal and social tensions when doing science. While the Inquiry group acknowledges the benefits of teacher guidance, which for the Inquiry group should encompass the right amount of scaffolding for their learning, students, nevertheless, express a desire to work independently or in groups. At the same time, student responses indicate group conflict in terms of the allocation of roles during science activities, which also disrupts their participation and affects their emotional commitments during science activities. For example, *“I would like to do it myself, well, because when I do it with a group it’s kind of, well you don’t get to do all the things by yourself and then well that means you don’t really get to, like, make sure or, like, solve it by yourself. Discover it, like, or you know. If you’re in the group then other people, like, say it for you, so. Well I don’t really like working in a group in science*

(MC51, CO1, Unit Environments, Score: 16.748).” As students negotiate and dispute roles they also jointly and independently allocate roles and responsibilities to themselves and others, indexing the degree of their emotional commitment, motivation and interest to participate and engage in science activities.

In general, the Inquiry group prefers to work independently and collaboratively with peers. By the same token, student’s value working in groups mainly for gaining others’ perspectives on a task, as expressed by a student in the Inquiry group, “*I prefer groups 'cause everybody has their own opinion and we learn from other peoples' opinions* (AH60, CO1, Unit MixSol, Score: 23.714).” Hence, the Inquiry group subscribe to a paradox where they prefer to figure things out on their own, yet their participation is constrained by teacher authority and in some instances by their peers acting as group leaders and dominating all the hands-on activities during science.

## Theme 2: Interest

*Table 4-7 Interests*

Lemmas	Chi <sup>2</sup>	Words	Occurrences
Interest	20.244	Interesting	4
Research	11.495	Research	4
Teacher Tells	9.82	Teacher Tells	11
Help	8.706	Help	10

The theme, *Interest*, in the second cluster is in opposition to the preferences students make for having the teacher tell them what to do – that is, for the most part students prefer to have the teacher tell them what to do and figure things out on their own. For example, “*I meant, like, um, a half-half so, like, some of the things the teacher would help us on, like, again the*

*procedure but the rest, like, the research, would kind of be up to the kids”* (JB60, CO1, Unit MSRC, Score: 432.790). However, having the teacher tell students what to do because the teacher ‘knows best’ and guides student learning is coupled with negative sentiments towards science as it again obliges students to subscribe to this paradox --*“Um, I like doing it with other students because it’s more of a chance to explore, it’s not, it’s a little less interesting when your teacher tells you, like, if you had, um, something and your teacher tells you what it will do, it’s not as exciting but if, um, you try to, um, figure it out yourself or, like, last year we did something with electricity. She didn’t tell us how to build it, she said to try to figure it out on your own”* (PB60, CO2, Unit MSRC, Score: 25.378). To an extent, the Agency group shares these sentiments mostly in the MSRC unit (20%), whereas the Inquiry group experienced negative emotions in the Environments (17%), Landforms (13%), and MixSol (12%) units.

The Inquiry group expresses a preference for the teacher telling them what to do in science because of how they position themselves in science; for example, *“The teacher because I can’t figure things out by myself, um, and I’m not that good at science so I seriously need the teacher to tell me what to do”* (GL66, CO2, Unit Landforms, Score: 16.747). While students’ beliefs regarding their abilities in science are perceived negatively, students position the teacher positively, especially in the MixSol unit, because the teacher demonstrates what is ‘safe’ to experiment with, as illustrated in the following response, *“It depends because sometimes when the teacher tells it probably means it’s, like, a safety, um, control, like, it has to do with safety but it’s cool trying, if you look up, um, science experiments and then you find an experiment that you think is really cool and you do it when you’re alone, I like that”* (MC52, CO1, Inquiry Unit MixSol, Score: 5.241). Although the Inquiry group prefers the teacher to initially guide their learning, students also expressed positive emotional states of ‘happiness’, ‘satisfaction’ and

‘surprise’ when they were able to figure something else independently or collaboratively —  
*“I prefer to figure things out on my own because then you don’t need cos then you learn more cos when the teacher tells you, you don’t learn as much cos when you do it by yourself you learn more and you are interested in and you’re surprised with the result”* (AY64, CO1, Unit Environments, Score: 2.614). Therefore, giving students the opportunity to be responsible for their own learning nurtures their emotional commitments, which are anchored in their agency and identities.

### Theme 3: Student

*Table 4-8 Student*

Lemma	Chi Square	Word	Occurrences
Student	41.416	Students	15
Teach	39.449	Taught	3
Teach	39.449	Teach	3
Hard	20.704	Hard	6
Hard	20.704	Harder	4
Test	15.346	Tests	2
Try to figure	14.492	Try to figure	5
Leader	13.644	Leader	3
Listen	10.313	Listen	3
Work	6.164	Work	8
Work	6.164	Working	5

The ‘Student’ cluster describes students’ preferences working with other students mostly in the MRSC (17%) and Landforms (15%) units. Students predominantly position the teacher as a resource when they encounter something ‘hard’. For example, *“some questions might be hard...*

*and... um, or some, yeah, it might be hard but some might be easy, so. Yeah if it's too hard and and you can't do it then we need some teacher's help. I think that's reasonable"* (ASA54, CO2, Unit MSRC, Score: 36.348). In Cluster 2, the Inquiry group had positioned themselves negatively because of their abilities, whereas the Agency group position themselves as having the capacity to do science independently or collaboratively and have the teacher as a resource when needed. Moreover, teacher monologues impact student engagement and participation as students expressed losing interest and getting bored – *"Oh, um, I would definitely, I definitely like, I don't like that, I like to, I like testing cause if it was that, I think I would definitely just, um, I would listen a little bit but I would space out sometimes and just go like, 'oh whatever!' Like, 'I don't wanna listen to this, I'm so bored"* (PB46, CO2, Unit MSRC, Score: 454.724). This suggests that student's capabilities and participation are structured by the institutional and interpersonal arrangements of the classroom. This raises the issue of when do students have the right to participate? The learning outcomes outlined in curriculums and the kinds of activities students engage in fashion how students get positioned in terms of how they can or must participate during activities. For example, the interviews show a number of students from the Agency group acknowledging instances or circumstances where their participation had beneficial outcomes.

"I really enjoyed it [State: Sensing] like one of my favorite parts was the MSRC debate [Accomplishment: Saying]. I had a big part in that [Achievement realized]. No debate is one of my things [State: Possession]. I want to be like involved [State: sensing & having possession] when I grow up [Accomplishment: doing] umm but yeah I got to say what I thought in all units [Accomplishment: saying—State: Saying]. I got to make choices [Activities]. I got to learn for myself and learn from mistakes [State: Cognition-

Benefactive + Accomplishment] and I got to apply [Achievement] it to real life cos all this had to do with real stuff and I learnt all sorts of different gadgets and stuff.”

[Achievement] (PB61, CO2, Unit Algae)

This example illustrates how a student interprets her current and projected goals and their value. This narrative account suggests the students’ established goals were actualized as a result of her participation in the units, which enabled her to achieve them during activities that met her ‘wants’ and desires—“debate.” Her motives and interests can be interpreted as purposive because her participation in debate enables her to actualize her interests as well as apply her skills, which she self-identifies as a value. In turn, her emotional commitments, capacities in debate, and her participation enable her to adopt what she currently believes is her long-term interest. Working towards her future goals suggests self-reflection and cooperating with her future self. The activities in the units - such as expressing personal thoughts, making choices, regulating one’s learning, and applying what one has learnt and knows in a real-life context that is personally consequential - elicit benefits, achievements and accomplishments, which are felt and realized through emotions. In addition, Castelfranchi (2012) explains that our behavior is also regulated by a “theory of us”, as illustrated in the utterance ‘*No debate is one of my things*’ where we have an image of ourselves in terms of who we are as a kind of person, what we can do, what we like, what we want to do, etc.

When teachers respect, value, reflect upon and act on student ways of knowing as a learning partner, it encourages students to develop a more sophisticated understanding of their situation in context, their identity and agency in relation to other social and material arrangements. Failing to acknowledge such tendencies conveys to students that their contributions and ways of knowing have little to no value inside and outside the classroom.

Concomitantly, this restricts their capacity to imagine their future-self and take social action in the real world on issues and concerns that may affect the students personally or their communities.

Both the Inquiry and Agency groups position the teacher as a resource but they also feel accountable for their grades, thus positioning the teacher also as the gatekeeper to their success or failure in science. For example, from the Inquiry group a student stated, *“I like the teacher, um, telling us kinda what to do because then I know what my expectations are instead of just saying, ‘oh I’ll just do this’, I like, I know what I’m supposed to do so it’s kinda like a guide for me”* (MC62, CO1, Unit MixSol, Score: 8.402). Thus the role attributed to the teacher is to manage student expectations and also guide student learning with the right amount of scaffolding. It must be acknowledged that this is not an easy feat. It is a challenging act for the teacher when treating student agency as a way to think through her students’ capacities to take action and to think of the multiple ways they have been and “are actively involved in emergent, innovative, experimental, and substantive forms of solidarity and coexistence” (Oswell, 2013). Dismissing opportunities for student agency has implications for student learning, which, consequently, impacts how students perceive the teacher is positioning them in science. In other words, when students are given the authority and responsibility to determine what they would like to investigate within a unit, students express positive attitudes towards science and assert ownership over their learning. For example, *“Um, I kind of prefer both, like, one designed investigation by the teacher, and then the rest we just kinda do by ourselves to kinda, so like the teacher kinda like shows what we’re supposed to do and then we kinda just get the trust in our hands and then get to kind of, like, work out stuff like that but, like, every once in a while you know we can ask for help and stuff like that”* (JB50, CO1, Unit Environments, Score: 33.609).

When students believe they have been endowed with trust, which is expressed as a critical attitude, it becomes self-evident that their intellectual skills and abilities are valued and supported. Accordingly, students show personal responsibility by committing to (cf. Giddens, 2013) and investing their efforts in a manner that is self-sufficient and self-regulating because they are conscious of the benefits. These benefits can be characterized in two ways: Firstly, attending to institutional expectations, thus subscribing to a paradox, as in “I could figure things out of my own and I could get **an extra credit on my report card**” (AK49, CO1, Unit MSRC, Score: 19.747); “she can give you **the exact definition that she will use for tests** so, like, if **she’ll tell you what she wants** and you can kind of, like, put that on a test 'cause that's what she wants on tests” (AY48, CO1, Unit Landforms, Score: 20.910). Secondly, attending to personal expectations by working cooperatively and ‘seriously’ with others – “I like working with students that actually, like, will work” (PB46, CO2, Unit MSRC, Score: 454.724); “if you **try to figure it out by yourself, you also remember it better**” (AK62, CO1, Unit Algae, Score: 88.931); “it makes us **work harder and think harder** I think” (AK40, CO1, Unit PolSol, Score: 13.133); “with others, uh, it’s easier to, um, **find out what we need** to know” (AK48, CO1, Unit MSRC, Score: 10.075); “it gives it a more **sense of adventure**” (MC49, CO1, Unit Environments, Score: 6.565); and “you can **be creative and you can learn** how, the actual way to do things and you can learn both of those at the same time” (AY65, CO1, Unit Landforms, Score: 5.918).

Students attending to both institutional and personal expectations reveal how they are navigating and negotiating their social positioning, which can be viewed as prescribed in most school settings where they are held in a kind of dependent status. Consequently, student’s get positioned implicitly as dependents, circumscribing their agency and identities.

## Theme 4: Figure out

*Table 4-9 Figure out*

Lemma	Chi Square	Word	Occurrences
Fine	16.153	Fine	6
Figure out	13.137	Figure out	25
Express	10.761	Express	4
Focus	10.761	Focus	4
Process	10.761	Process	4
Work	10.582	Work	17
Work	10.582	Working	7
Partner	9.301	Partner	5
Unit	7.446	Unit	7
Answer	7.358	Answer	12
Example	7.084	Example	4
Tell	6.986	Tell	16
Tell	6.986	Telling	6
Tell	6.986	Tells	11
Tell	6.986	Told	6
Explain	6.967	Explain	4
Second	6.967	Second	5
Teachers	6.412	Teachers	8
Group	5.827	Group	13
Group	5.827	Groups	6

As noted above, both students from the Agency and Inquiry groups prefer to figure things out on their own and or with other students. Students justify their preferences by identifying personal gains.

For the Inquiry group these benefits include:

- **remembering by doing** (“*if we’d figured it out on our own it might sink into our brain, um, more*” – MC45, CO1, Unit Environments, Score: 44.297),
- **collaborative problem solving** (“sometimes I don’t get stuff and it really helps if I have a partner, so then we would work together to do that.” EB55, CO1, Unit Landforms, Score: 9.452),
- **self-assessment** (“I just like to see if I’ll do it, like, right and, um, without, like, teachers’ extra instructions” CJ46, CO2, Unit Landforms, Score: 8.561),
- **thinking to understand** (“*really thinking about it helps me under - understand more*” EB48, CO1, Unit Landforms, Score: 8.466), and
- **interest** (“*I think it’s like more like interesting*” AY62, CO1 Unit Environments, Score: 7.418)

The Agency group warrants these benefits as opportunities for:

- **enhancing productivity** (“it’s easier to work in a group, you can get a lot more, a lot more done than if you worked alone” AD57, CO1, Unit MSRC, Score: 28.316)
- **peer-tutoring** (“I would work maybe with a partner’ cause it’s hard for myself, for me to work individually ‘cause I get frustrated and stuff but with, like, a partner I think it would be fine ‘cause I have the help I need and if I need help I’ll just ask.” PB42, CO2, Unit Algae, Score: 27.485)
- **regulating learning** (“I like to figure out how to get the experiment to work right if it’s not working” SK50, CO1, Unit PolSol, Score: 10.086)

- **engaging emotionally** (*“it’s fun to figure things out”* SK50, CO1, Unit Algae, Score: 8.409)

Overall students from both the Agency and Inquiry groups prefer to figure things out on their own or with other students. Students’ emotional commitments, the role of the teacher and groups, attending to institutional and personal expectations, and identifying personal gains as needs and opportunities encompass the prevailing themes. To a large extent, our beliefs are guided by emotions and our emotions regulate the goals we set. In other cases, purposive actions are means to prove to oneself what one is capable of doing or achieving, which quite often leads to unanticipated outcomes that are perceived positively or negatively. Accordingly, their preferences for participation can be viewed as intrinsic values, having implications on their engagement, imagination, and alignment in science.

The Inquiry group prefers to figure things out on their own or with other students because they felt they worked harder and learnt by actively doing science. Problem solving without the guidance of the teacher or a textbook encouraged student autonomy; this is clearly one of the original design rationales for the inquiry science kit curricula. Feeling empowered is also characterized by the way students engage emotionally, where students engender positive emotional states of ‘happiness’, ‘satisfaction’ and ‘surprise’ when they were able to figure things out independently or collaboratively.

The Agency group prefers figuring things out on their own or collaboratively because they are researching questions they have generated in groups. Student’s developing consciousness capacitates them to modify and regulate their learning both from the perspective of the self and in responding to events by projecting actions during science activities that reshape the situation in context to accommodate their ‘wants’, ‘needs’ and stances. Scientific roles and

practices are experienced through symbolic play and student's capacities to participate in science develop by means of an implicit reflection on and sensing scientific ways of being and doing.

The role of the teacher has implications for why both groups prefer to figure things out on their own or with other students. For the Inquiry group, the teacher is positioned as an obstruction for student learning. The reasons students expressed include feeling like passive recipients during teacher instruction, displaced autonomy, and learning through trial and error. However, teacher guidance and/or 'how-to' steps were also perceived as beneficial to their learning. Therefore, the Inquiry group also prefers to have the teacher tell them how to do things in science because their perceived abilities in science are positioned negatively, thus positioning the teacher positively because she demonstrates what is 'safe', 'knows best', guides their learning with the right amount of scaffolding, and is accountable for their grades. For both groups, the teacher is perceived as the gatekeeper to their success or failure in science as well as manages their expectations. The agency group perceives the teacher as a resource when they encounter a challenge.

The role of groups impacts student choices positively and negatively. Both groups stated that during group activities they allocate roles and responsibilities to themselves and others. Moreover, they benefitted working in groups mainly for gaining others' perspectives on a task. However, group conflict in terms of the allocation of roles tended to disrupt their participation and affect their emotional commitments.

The Agency group position themselves as having the capacity to do science independently or collaboratively and have the teacher as a resource when needed; concomitantly, student participation is perceived as beneficial as a result of the positive outcomes. Participation,

in a manner that is self-sufficient and self-regulating, enables students to adopt their long-term interests, thus working towards future goals, suggesting reflection and cooperating with future-selves. The activities in the units—such as expressing personal thoughts, making choices, regulating one’s learning, and applying what one has learnt and knows in a real-life context that is personally consequential—elicit benefits, achievements and accomplishments, which are felt and realized through emotions. Authority, personal responsibility, and trust nurture positive attitudes towards science and the capacity to assert ownership.

Finally, both the Agency and Inquiry groups prefer to figure things out on their own or with other students because they are obligated and capable of fulfilling institutional and personal expectations. *Institutional expectations* include (a) extra credit on report cards, (b) scientific definitions for assessments, (c) follow teacher instructions. *Personal expectations* defined as working cooperatively and ‘seriously’ with others includes: self-assessment, to remember, to motivate and think harder, to regulate activities, sense of adventure, be creative and, to learn.

These institutional and personal expectations differ between the Inquiry and Agency groups in terms of identifying personal gains. The Inquiry group identifies personal gains in figuring things out on their own or with other students as *Benefits*. These include (a) remembering by doing, (b) collaborative problem solving, (c) self-assessment, (d) thinking to understand, and (e) interest. The Agency group warrants these benefits as *Opportunities* for (1) enhancing productivity, (2) peer-tutoring, (3) regulating learning, (4) engaging emotionally, and (5) challenging capabilities.

## Finding 2 Student Preferences to Learning in Science

**A3:** Do you think you learn more/better by figuring things out on your own, or by having your teacher tell you?

*Table 4-10 Preferences to Learning*

Units	Cluster 1 Learn better	Cluster 2 Think I learn	Cluster 3 Learning	Cluster 4 People	Cluster 5 Ways
Unit_Algae	28.57%	19.64%	12.5%	16.07%	23.21%
Unit_Environments	42.59%	7.41%	12.96%	20.37%	16.67%
Unit_Landforms	16%	16%	32%	16%	20%
Unit_Mixsol	15.79%	15.79%	18.42%	31.58%	18.42%
Unit_Msrc	36.07%	18.03%	8.2%	22.95%	14.75%
Unit_Polsol	30.23%	16.28%	25.58%	16.28%	11.63%
Total	29.14%	15.56%	17.55%	20.2%	17.55%

The first cluster – ‘Learn better’ is in 88 Elementary Contexts (E.C.) out of a total of 302 classified, making up 29% of the corpus. Students expressed ‘work’ (73%) as objects or things functioning poorly, differently, or successfully – “*you might think, ‘oh there's more than one way’*. *But if no, ‘no, oh this works and this works’*” (CJ63 CO2 UNIT\_LANDFORMS, SCORE ( 175.683 )); or as solving or “*figuring it out*” (JB56 CO1 UNIT\_MSRC, Sore (124.014)).

Solving an answer without the help of the teacher accounts for 47% of the cluster, suggesting both the Agency and Inquiry groups prefer to figure things out on their own because it mediates learning. For example, “*Well there's a different type of learning I guess, like cos if you look at the teacher is working is helping you with it then it's like umm it's like learning it with her, but when you learn it on your own, it's like learning how to do like umm I don't know how to say it... it's like you're figuring it out on your own* (MC62 CO1 Unit\_Environments, Score 51.374)”. These reoccurring perceptions account for 21% of the corpus.

The second cluster – ‘Think I Learn’ is in 47 E.C. out of a total of 302 classified, making up 16% of the corpus, and it mostly represents the Agency group. Students prefer to figure things out on their own because they learn from their mistakes (84%) - *“Well you can make mistakes but you can learn from those mistakes. Where if the teacher's doing it for you, the mistakes are what help you learn, and so if you, if the teacher has it already and it's perfect, no mistakes, you're not gonna be, you won't learn as much where if you have those mistakes (AK59 CO1 Unit\_MSRC, Score 105.473).”* Although the second cluster is the smallest, students consistently prefer solving things in science on their own so that they may benefit by learning efficiently (better 61%).

By the same token, the third cluster – ‘Learning’ is in 53 E.C. out of a total of 302 classified, making up 18% of the corpus, relates ‘learning’ to remembering (58% and ‘stick’ 23%). For example, *“Mostly I figure it out on my own cos I when the teacher tells me something, it's like once and then you have to remember it for like the whole unit but when you find something, you learn something, you could always remember it because when you do a presentation, you can like write it down so you so you can like add information to it and you can remember more stuff (AW57 CO1 Unit\_Algae, Score 70.294).”* This suggests that students perceive successful learning as a resource, having the ability to remember ‘stuff’ (34%) for future events.

The fourth cluster – ‘People’ is in 61 E.C. out of a total of 302 classified, making up 20% of the corpus, thus representing predominantly the Inquiry group. Statements such as the following represents students’ preference for working in groups: *“Mm, I think personally it's better to, like, do it in a group, like, we did in this, last unit 'cause, like, with more people you would have, like, better ideas 'cause you could have different people thinking of a different ways*

*about it* (AH45 CO1 Unit\_MixSol, Score 40.006).” Working in ‘groups’ (46% and ‘people’ 31%) is beneficial and fun (23%) but having the ‘teacher’ set-up (teacher tell: 24%) is perceived ‘helpful’ (37%) when they encounter difficulties (‘hard’ 19%).

Figuring things out individually or collaboratively is perceived as an additional benefit because students get to try things in ways that differ from how the teacher demonstrates things. Thus, the fifth cluster—‘Ways’ is in 53 E.C. out of a total of 302 classified—making up 18% of the corpus. The element of suspense during experiments and students’ natural curiosity for testing out their own ideas sets the theme for this cluster. For example, *“If the teacher gives us a hint, like to tell us, like, what material, that's okay but, um, I like figuring things out on my own because I think that gives us a better chance to learn what happens. Because then you get to experiment with different varieties of things and you get a chance to know more.* (MC54 CO1 Unit\_MixSol, Score: 13.27). For both groups, students preferred ways to try various methods (experiment 20%) in anticipation of an outcome (happen 19%), which suggests a process that is valued.

Both the Agency and Inquiry groups think they learn better by figuring things out on their own. For the Agency group, students learn from their mistakes and it is perceived as an efficient way of learning. Both groups stated that by figuring things out on their own helped their learning by remembering things, thus successful learning is perceived as a resource for future learning. Working in ‘groups’ is beneficial and ‘fun’ but having the teacher guide their learning is perceived ‘helpful’ when students encounter difficulties. Finally, students thought they learn more by figuring things out on their own because they can test out their own ideas and try various ways to figure something out.

### Finding 3 How Learner Choice Is Framed and Taken Up

The Inquiry and Agency groups both stated they made choices, although ‘choice’ is construed differently for each group. In the first cluster, ‘Choosing’, for the Agency group entails selecting a ‘pollutant’ (8%) for an experiment in the PolSol unit, however, the Inquiry group construe ‘choosing’ as choosing a role – *“Um, well I mean, like, small ones, like, ‘do you want to hold the water today?’ or, like, stuff like that (AY62 CO1 Unit\_Landforms, Score: 20.386).”* Fulfilling a particular role, like *“to track the time of the deltas” (CJ60 CO1 Unit\_Landforms, Score: 41.176)*, as it relates to regulative processes in epistemic agency, enables students to refine their skills when coordinating object-related activities. For the Agency group, choosing what to study for their experiments or as a student, JB40, expressed, *“Yeah, our group made choices by, like, choosing, like, choosing what to do, um, choosing how are we, how are we gonna word the, um, conclusion, the procedure, materials list, that stuff (CO1 Unit\_MSRC, Score: 54.222)*, deciding how to formulate their writing suggests their epistemic and regulative dimensions of agency are enacted.

Another difference in the Agency group is illustrated in the second cluster, which has ‘power point’ in 79 E.C. out of a total of 284 classified contexts, making up 28% of the corpus. This also included posters (16%) and presenting to the public (18%). For example, from the Agency group the following student, AD41, stated, *“Uh, I would say so because we definitely had to decide, like, we had to learn about HABs and we had to decide, well what are we gonna do and we had to think about that and it was fun because of the Go Public, we got to tell other people and my friend, we were just at the dock the other day, she’s like, ‘algae’ and I’m like, ‘yes algae’. So that was fun (CO1 Unit\_Algae, Score: 20.827).”*

The ‘Go Public’ represented in cluster 2 in Power Point, as a mode, is a feature of the Agency units (see Appendix 3 for unit outlines). In addition to the ‘Go Public’, cluster 3 represents other features in the units that students regarded as choices they made. For example, ‘fertilizer’ (24%) from the Algae unit is a common product available in youth’s lives, which they identified with strongly.

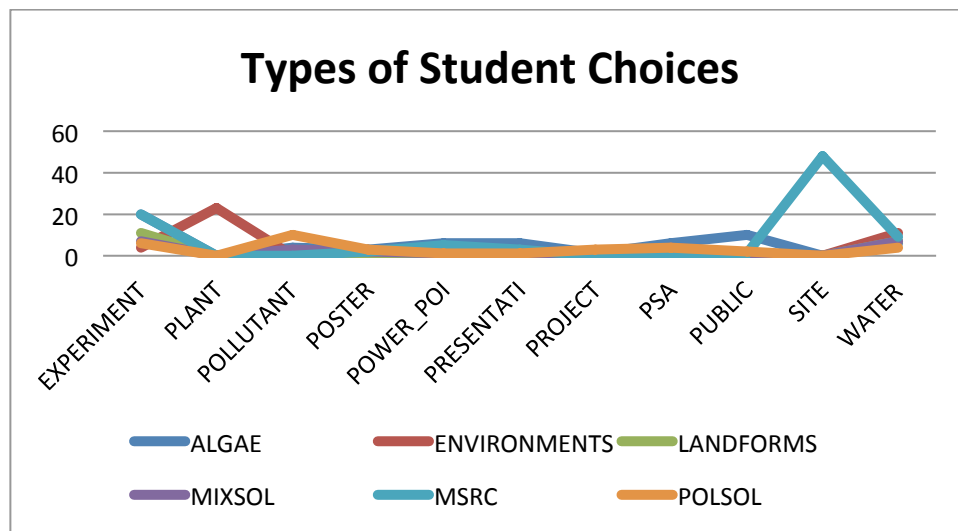
Responses related to the Algae unit constitute cluster 4 ‘Algae’ that makes up 27% of the 284 classified E.C. Unit elements identified in the third cluster are more defined in the ‘Algae’ cluster as changed variables, thus representing the choices students made in the Agency group. These include materials such as the amount of ‘water’ (94%), the ‘cups’ (25%), ‘filters’ (24%), and ‘algae’ (20%). In addition, both groups identified making choices in the PolSol unit and MixSol unit, recalling processes such as “separating” (20%) – *“Yeah umm when we tested, we would have a funnel cup, filters and water and we got to figure out how we can separate umm salt from water and we got to do that how we wanted to with our groups (PB70 CO2 Unit\_Algae, Score: 80.858).”* Concomitant with cluster 4, the fifth cluster, ‘People’ shows the majority of responses from the Agency group also identified making choices with members in their groups (team 28%), particularly in the MSRC unit where students needed to ‘pick’ (36%) a site (26%) as a team.

The different types of choices available for the Inquiry and Agency groups are a result of the curriculum activities and ideologies. In other words, the Inquiry units provide students with choices that are identified as roles and choices made in experiments are construed as contrast, suggesting only two options are made available. This theme is illustrated in the following student statement from the Inquiry group, *“Um, yeah with my team and not myself because we had to pick what kind of experiment we wanted to do like, um, like, [inaudible] soil versus wet soil, like,*

*soil, no, it was soil versus soil with grass and, like, dry soil versus, like, wet soil, that kind of thing like we decided as a group and we all agreed on it* (JB43 CO1 Unit\_Environments, Score: 51589).” The Agency group also identified their role in the group as a choice but they had more options available when deciding as a group what to investigate in relation to the challenge presented in the unit. As a result, this has implications for how students are able to actualize their intentional goals.

Self-control is defined as imagining a desirable end and it is inherently cognitive. Agency enables one to achieve a desirable goal because as an inherent resource one uses it to achieve an inherent goal or desire. Through sustained practice, attention management and emotion regulation one’s ability to exercise one’s agency improves (Paglieri, 2012). When students have limited opportunities to exercise their agency, it disables their capacities. One’s ability to invoke agency to achieve a desired goal is bounded by our capacities, which Castelfranchi (2012) states is a measure of “internalized authoritarianism”. The resources used to facilitate change stems from weighing the benefits and drawbacks, rewards and sanctions, commitment, material arrangements, and emotions. Through reflection, making choices based on one’s interests, concerns and subjective perceptions of a situation in context as well as assigning value to an alternative position or action projects goal-driven possibilities. These possibilities are contingent on the kind of goal one wishes to achieve. In other words, the capacity of doing, accomplishing, and achieving a goal and the capacity to persuade, reward, incentivize or sanction a person are motivating factors for harnessing social capital.

The different types of choices available for the Inquiry and Agency groups are a result of the curriculum activities and ideologies.



*Figure 4-19 Types of Student Choices*

From *Figure 4-19* the Inquiry group perceives choice as a regulative process where object-related activities are coordinated. The Agency group perceives choice in the available multimodal genres: power point, posters, and presenting to the public. Both groups felt they had choices in taking up a role for handling materials and deciding on processes, such as ‘separating’. The Agency group also identified making choices with members in their groups, thus opening up their options for choices and actualizing their intentional goals. The Inquiry units provide students with choices that are identified as roles and choices made in experiments are construed as contrast, suggesting only two options are made available that are constrained by the classroom socio-material arrangements.

#### **Finding 4 Resources Facilitating Student Learning**

**A5:** What did you do in this unit that helped you learn?

Table 4-11 Factors Facilitating Student Learning

Units	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
	HABs	Experiments	Hands-on	Erosion	Algae	Control
		helped				
Unit_Algae	18.42%	2.63%	15.79%	7.89%	42.11%	13.16%
Unit_Environments	12.12%	21.21%	27.27%	12.12%	18.18%	9.09%
Unit_Landforms	14.81%	7.41%	18.52%	44.44%	11.11%	3.7%
Unit_MixSol	4%	4%	32%	16%	24%	20%
Unit_MSRC	16.67%	7.14%	14.29%	28.57%	11.9%	21.43%
Unit_PolSol	16.67%	0%	26.67%	13.33%	20%	23.33%
Total	14.36%	7.18%	21.54%	20%	21.54%	15.38%

The first clusters, HABs, entails figuring things out (52%) and doing activities that are ‘hands-on’ (35%). For the Agency group, the Algae unit helped students learn the most because of research time – “*Uh, figuring it out on our own and doing research. Like, research about HABs and, like, how, and what good HABs, good algae is instead of, like, everything's just all bad in the world*” (AD48 CO1 Unit\_Algae, Score: 34.669).

For the Inquiry group, the Environments unit helped students learn about plants (83%) and the conditions in which they grow (29%), encompassing the experiments (47%). While the second cluster is the smallest (7%), the third cluster, ‘Hands-on’ highlights how material arrangements helps students learn. For example, “*Well you got to experiment and, um, test different things out and see which of these chemicals bubbled and stuff and if your teacher just said write all this stuff down, this does this, this does this, I wouldn't really learn from it because it would just be, like, ‘blah blah blah blah blah’ and some of it, like, taking Cornell notes, um, also helped because I could study before a test and if I forgot what a word meant I could just go*

*back in and look* (MC45, CO1 Unit\_MixSol, Score: 37.536).” Doing science and using the materials of school science, such as the ‘Cornell notes’, were perceived as useful resources for their learning.

The fourth cluster represents predominantly responses from the Inquiry group where the Landforms unit establishes an understanding on processes such as ‘erosion’ (64%), ‘deltas’ (40%), ‘deposition’ (30%) and scientific practices such as ‘record’ (35%) data and information. The Agency group refers to the Algae unit as helpful to their learning in the fifth cluster. For example, “*We, we did the, we got the algae and we, we saw the effects of algae on actual people, well we didn’t, like, ‘here eat some algae’, but we, we kinda, um, did experiments, experiments on what, on what type of algae does to another type of water and then if that was, and then we learned that the darker the green algae is, the healthier it is, so my group, we did fertilizer and fertilizer kills algae so that means that the algae could be bad, like, worse, so you wouldn’t want to go swimming in that water with, like, [ inaudible ] algae* (AD57 CO1 Unit\_Algae, Score: 390.642).” In this representative example, students make connections to what they learnt in the unit to their everyday lives, suggesting deeper learning. Materials such as ‘fertilizer’ (50%) that are familiar to students helped them learn because they could connect with what they know about fertilizer and conduct ‘research’ (34%) to gain a deeper understanding. Having students engage with multimodal genres also is perceived as a precursor to learning, for example the fifth cluster also includes themes such as ‘interviews’ (25%), watching ‘videos’ (15%), and researching ‘online’ (13%).

The final cluster ‘Control’ represents both the Agency and Inquiry group responses to collaborating in groups in fostering learning. Group collaboration and self-regulation enabled students to cooperate with each other and learn about how they are positioned in groups. For

example, “*Um, it helped me learn again learning about myself and with others but not, like, a big group, just like a small one but still I learned with them and I learned how to cooperate with different type of people, um, yeah* (PB55 CO2 Unit\_PolSol, Score: 148.503).” For the Inquiry group, groups were perceived as a type of resource; for example, “*I... well... working with our group because like sometimes I don’t know some stuff and then my group sometimes they help me* (EB59 CO1 Unit\_Environments, Score: 8.716).”

For the Agency group, the Algae unit helped students learn the most because of research; figuring things out; and doing activities that are ‘hands-on.’ In the Inquiry group, the Environments unit helped students learn about plants and the conditions in which they grow, encompassing the experiments. Thus for both groups the material arrangements helped students learn. Furthermore, the Inquiry group perceived the Landforms unit as beneficial for establishing an understanding on processes such as ‘erosion’, ‘deltas’, ‘deposition’, and scientific practices. In the Agency group, students stated they learnt more about pollutants and engaging with multimodal genres, such as the interviews, videos, and doing research online. Finally, group collaboration engendered self-regulation for both groups yet for the Inquiry group, groups were perceived as a type of resource.

## **Assessing Students’ Developing Understanding of Scientific Inquiry**

### **Finding 1 Hierarchical Learning Modeling of Inquiry Assessment**

In order to understand the effects of the redesigned learning environments, which are designed for agency, next I briefly discuss the results of students’ learning outcomes based on scientific

inquiry assessments (see Shutt, Morozov, Thummaphan & Abbott (2015) for in-depth results and analyses).

The data from the inquiry assessments come from seventeen 5<sup>th</sup> grade classrooms across seven schools (n=403). Ten classes participated in the Agency group (n=235, 19% free/reduced lunch, 18% ELL). Seven classes participated in the Inquiry group (n=158, 25% free/reduced lunch, 20% ELL). Hierarchical Linear Modeling (HLM) was used to determine whether the Agency units versus the Inquiry units predicted students' learning outcomes based on the inquiry assessment, while taking into account the clustering of students in classrooms (classroom effect) as well as students' prior performance on math and reading standardized tests (covariate STAR math and reading standard test scores) (cf. Shutt, Morozov, Thummaphan & Abbott, 2015).

Overall across all three units (MSRC vs. Landforms, PolSol vs. MixSol, and Algae vs. Environments), students in the Agency group scored significantly higher on the science inquiry assessments compared to the Inquiry group (see Appendix 15 for Descriptive Statistics, Model Design, and Results). In MSRC, scores in Agency groups (mean=15.27, SD=4.22) were significantly higher than the scores in Inquiry groups (mean=10.43, SD=4.44,  $t=5.15$ ,  $df=12$ ,  $p<.001$ ) (see Figure 4-20 Fall to Winter Scores). Results show Cluster 1, students generate their own investigative question, and Cluster 3 where students identify variables, yielded the most differences across the Agency and Inquiry groups.



Figure 4-20 Fall to Winter Results for Landforms (Inquiry) and MSRC (Agency)

The first cluster shows little change from fall to winter across both groups in relation to refining the structure and content of student-generated investigative questions, although the Agency group scored higher after controlling for classroom effect and the baseline test scores. The third cluster, where students recall their same, changed, and measured variables, shows the Agency group improved from fall to winter by 1.6% (5.01 to 5.08) whereas the Inquiry group regressed -9.3% (3.99 to 3.62). Finally, although results in the fourth cluster show little variance between the Agency (2.88 to 2.92 with 1.3% gain) and Inquiry groups (2.68 to 1.87 with -30.3% decline) in terms of writing conclusions, this supports students' negative sentiments towards writing in science.

In PolSol, Agency scores (mean=6.47, SD=2.45) were higher than the Inquiry groups' MixSol scores (mean=5.58, SD=2.68,  $t=1.80$ ,  $df=13$ ,  $p<.033$  one-tailed).

The results as seen in Figure 4-21 from both groups show minimal differences, yet findings for the baseline test scores significantly predicted total scores. Moreover, higher scores are related to Cohort 1 in winter and the PolSol (Agency) unit, after controlling for classroom differences and baseline test scores. Thus cohort and treatment (one-tailed) were significant predictors. A difference in scores is shown in the third cluster for conclusive statements, where the Agency group scored slightly higher than the Inquiry group when providing supporting data (Agency 1.77 vs. Inquiry 1.52). Similar results are shown by cohort: Cohort 1 Winter 2013 Agency, value=1.85 vs. Cohort 2 Spring 2013 Agency, value=1.70; and Cohort 1 Winter 2013 Inquiry, value=1.68 vs. Cohort 2 Spring 2013 Inquiry, value=1.31.

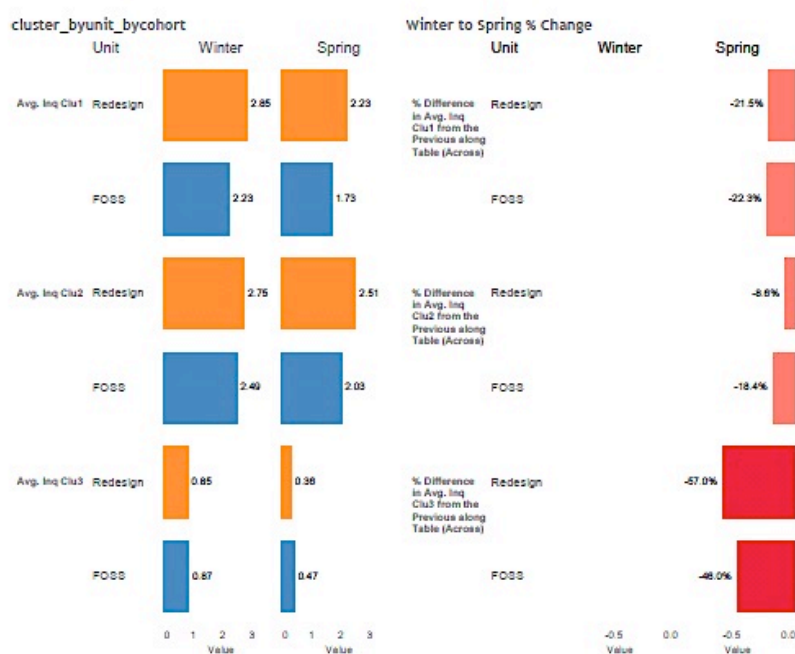


Figure 4-21 Winter to Spring Results for MixSol (Inquiry) and PolSol (Agency)

Finally in the Algae unit (see Figure 4-22 Fall to Spring Scores), Agency scores (mean=12.46, SD=3.80) were also higher than the Inquiry groups scores in the Environments unit (mean=7.41, SD=3.38,  $t=6.71$ ,  $df=11$ ,  $p<.001$ ). Level 1 model shows math and reading scores as significant predictors ( $\gamma_{10} = .006$ ,  $p=.002$ ;  $\gamma_{20} = .004$ ,  $p<.001$  respectively) when testing whether inquiry scores are effected by baseline math and reading scores, after classroom level differences are controlled for. The level 2 model includes group-level covariates, which entails treatment, cohort, and treatment-cohort interaction term.

The total scores in the Agency group are higher than the Inquiry group total scores as well as in the spring, among the higher-SES cohort (1); whereas total scores in the fall, among the lower-SES cohort (2) were reduced. Student-led investigation question scores in the Agency group, cluster 1, were higher than the Inquiry group, especially in the spring when compared to the scores for fall and among the higher (1)- and lower (2)-SES cohorts.

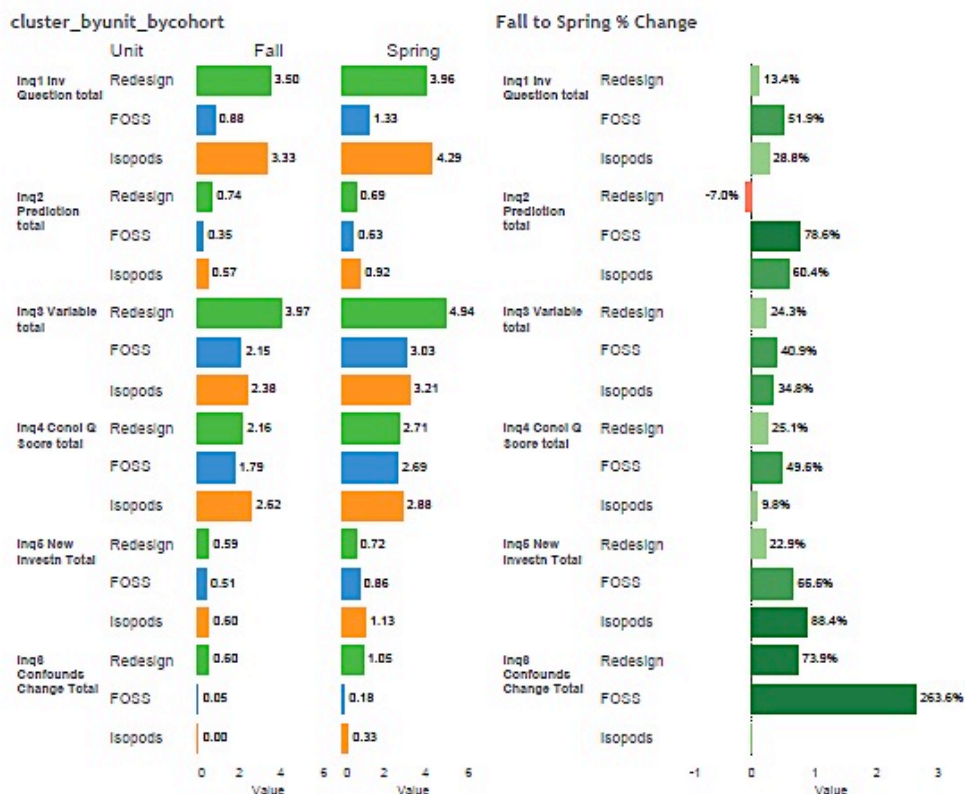


Figure 4-22 Fall to Spring Results for Environments (Inquiry) and Algae (Agency)

Student scores on Prediction showed a significant effect among the Agency group and for treatment-trimester interaction ( $\gamma_{03} = -.37, p < .05$ ). Changes from fall to spring for the Inquiry group was significantly different compared to changes from fall to spring within the Agency group. (The mean Agency group score was higher than the Inquiry group but decreased in spring, while the mean Inquiry group score in spring was almost twice as large compared to fall.) In the fourth cluster, conclusion writing, the baseline reading test score was a significant predictor ( $\gamma_{10} = .001, p < .001$ ); however, the treatment (Inquiry vs. Agency) was not a significant predictor. For the Inquiry group, there was a 50% improvement from fall to spring. Finally, the fifth cluster results show that neither the treatment, trimester/cohort, nor the baseline reading score were significant predictors; only the baseline math test score was a significant predictor ( $\gamma_{20} = .001, p < .05$ ).

In Summary, across all three units (MSRC vs. Landforms, PolSol vs. MixSol, and Algae vs. Environments), students in the Agency group scored significantly higher on the science inquiry assessments compared to the Inquiry group. In MSRC versus Landforms, the Agency group showed learning gains in refining the structure and content of student-generated investigative questions and recalling their same, changed, and measured variables. Providing youth with opportunities to design their own investigations in open inquiry (Hodson, 2014) suggests students establish linguistic resources that enable them to engage in the methods of investigations used by scientists. However, both groups initially show no improvement in writing conclusions, which supports students' negative sentiments towards writing in science.

Results from winter to spring for MixSol (Inquiry) and PolSol (Agency) show the Agency group scoring higher for conclusive statements when providing supporting data. Thus indicating that exposing students to multimodal genres and giving them the choice to select what is relevant impacts students' evidence-based reasoning in positive ways.

Finally, the fall to spring results for Environments (Inquiry) and Algae (Agency) where the Agency group, in the spring among the higher-SES cohort, show significant learning gains in student-led investigation question scores suggests a deeper understanding in how variables in an investigation facilitate what counts as data.

## **Chapter 5 Conclusions and Implications**

This dissertation examined how youth develop practice-linked identities in science as a consequence of their fleeting identity performances and language choices made for and by them in the science classroom. Central to this notion of identity is agency where positionality as well as material and symbolic, interactional and situational resources constrain or enable identity development. In a learning context, these choices and values inherent in language use are relational to learner agency outside of language, but ensouled in performative curating where solidarity, intention, creativity, emotion, accountability, anticipation, cognition, and rewards enable the capacity to transform the self, others, and communities. Conceptually, learner agency and developing identities in science are understood by taking a semiotic approach. This means social and material arrangements in performativity and language are essential resources in semiosis.

In semiotically acting, a learner may enable or constrain the capacities for themselves and others to semiotically act. Kockelman (2013:84) explains that in doing so, the learner should be accountable to themselves and others for these actions. Therefore, a semiotic approach enables one to understand how language is a system of meaning that embodies human experience; it has potential for intersubjectivity in everyday interactions as well as meaning creating (semogenic). Viewed from a trinocular perspective, language is metafunctional ideationally, interpersonally, and textually. Thus, language as the root for meaning making is actuated by and actuates consciousness. The linguistic choices a learner or teacher makes stem from the metafunctions in particular contexts; temporal dimensions as in the phylogenetic (cultural), the ontogenetic (individual) and the logogenetic (discursive). Consequently, Bednarek (2010) shows that identity

construction is fostered through discourse phylogenetically by establishing a system of identity in culture – that is, identities within the scientific enterprise, thus scientists, ontogenetically with discourse engendering a perceived interior coherent self, and logogenetically by generating a particular construal of identity in a given text – that is, students’ identities in science.

In Systemic Functional Linguistics, the frequencies observed in text (spoken and written structures, frequencies, etc.) both reflect the language system at a given point in time as well as shape the system over time (Plum and Cowling, 1987: 284 as cited in Bednarek, 2010). Matthiessen (2006: 104) explains that texts are located at the instance pole of the cline of instantiation and so by identifying patterns at different points along the cline of instantiation reveals the systemic profiles of particular texts, of text types, and of the overall system potential. Bednarek (2010) asserts that patterns repeated across texts contribute both to the phylogenetic and ontogenetic development of identity, impacting both on the cultural and the individual system. Thus, an image of the performative nature of students’ identities in science is represented in the repeated discursive patterns examined, which show the actual (performance) and the typical (the repeated), so inferences about likelihood and typicality are determined.

The findings illustrated in this dissertation demonstrate how youth participation in science in relation to their developing science identities emerges in a paradox. Wanting certainty and stability, as well as having the opportunity, the possibility, expectation and/or obligation to fulfill particular roles, youth identities shift when confronted with the unfolding of social situations, needs, and conditions. Caldas-Coulthard and Iedema (2008) argue that social life, characterized as “liquid modernity” (Bauman (2000), is implicated in identity development as youth “brand” themselves (Machin & van Leeuwen, 2008) as consumers, kids, scientists,

debaters, etc. Identity multiplicity (Lemke, 2008) emerges through dynamic positioning where opportunities and risks yield wants, accomplishments, and a dislocation of self.

Acknowledging that identities develop and change, the continued and consistent constructions students establish about themselves are oftentimes mandated by the socio-cultural norms. Consequently, tension emerges between students' subjective identities – who they are to themselves, and their projected identities – who they want to seem to be to others (Lemke, 2008). As a result, Lemke (2008: 20) defines one's identity as a "product of life in a community" where students accrue a repertoire of roles and assume identities to get a feel for "their texture and fit." This notion of identity mediates the moment-to-moment experiences and the established socio-structural category relations of power, values, beliefs, expectations and meaning-making practices. Central to this notion of identity is agency where positionality as well as material and symbolic, interactional and situational resources constrain or enable identity development. Thus at short timescales – as shown in this dissertation through momentary events, students enact different identities in different social settings, assume different roles. At longer timescales, students may continue to develop for themselves identities in science that are useful to them, or required of them, through sustained participation in science at school, in communities of practice. The implication made by Lemke (2008) regarding the subjective and projected identities of youth in science is that students mix and match identities to fulfill their needs or to navigate the compromises demanded by conflicting social pressures. Thus, we get images of youths stereotypical identities.

From the findings, youths agency and developing identities are represented by the three metafunctions as they relate to a cultural learning pathway across constellations of situated events (Bell et al., 2012) and so identities can be: categorized and segmented (labels and

taxonomies) as they are connected to places, thus establishing expectations as a result of the sociomaterial arrangement; positioned in relation to the kinds of persons and one another (evaluations); and organized by actions and discursive stances as meaningfully linked concepts (lexical/reference/semantic chains) . The co-articulation between the different systems allows expectations to project moral obligations and positions to bundle as collections of attributes around expectations or categories. The interactions between these two aspects are managed through the constant foregrounding and backgrounding of information. Identities, from this perspective, are an emergent feature of a text resulting from collaborating systems. ‘Couplings’ (Martin, 2000) between meanings across metafunctions are expressed as “slippery” because expectations and positions fluctuate with the other changing identities, thus producing texts. The implications are that the way expectations or categories are formulated facilitates positioning. Positions relate those expectations or categories, and actions seen as a semiotic organization of the text relates expectations or categories and positions in specific ways.

Consequently, identities are continually construed, enacted and organized in discourse to represent a coherent framework of identities against the background of other changing identities. To this end, texts in science provide the semiotic basis around which students can bond or affiliate with in terms of past experiences or supposed properties in science that must paradoxically be ‘re-presented’ (Anderson, 2006: 25) – that is, established norms and standards are simultaneously enacted in the here-now and meaning-making is established through semiotic organization. In other words, Tann (2010) asserts that student affiliations or bonds in science are enhanced or reduced as students are positioned to recognize the text as their own forming ‘a conceptual repertoire and a location for persons within the structure of rights for those that use that repertoire (Davies and Harre, 1990: 46).’ Having demonstrated how youths’ agency and

developing identities are represented by the three metafunctions, next I discuss the conclusions and implications of the findings illustrating how identities and learner agency are construed as process (Harre & van Langanhve, 1991; Tann, 2010).

**Conclusion 1: The social and material divisions of labor in teacher instructional framing differentiates between sociomaterial arrangements and participation in relation to the degrees of power and status as authority, thus impacting student participation in science by sequestering or affording agency and apprenticeship in science.**

From Finding 1, Teachers' use of the regulative and instructional registers differentiates between what and whom as well as establishes differential access to goods. For the Agency group, the teacher operates under parameters that constitute elements of epistemic agency. For example, when she creates awareness by identifying a problem within the context of the unit through joint construction thus creating a shared understanding. Moreover, in the agency group *doing science* entails engagement with a range of genres to fulfill particular instructional goals and is performative and threaded into materiality for the production of knowledge, thus opening up opportunities for becoming. With the Inquiry curriculum, the teacher positions youth to follow a more set of prescribed procedures. Student accounts encompass a regularized, routinized, standardized way of doing school science. The relationships the teacher develops with her class in relation to degrees of power and status as authority impacts student participation often by dominating discussions and providing minimal opportunities for student-led discussions – sequestering student agency and apprenticeship in science.

While teacher pedagogic discourse influences how youth come to know and engage with science, the curriculum macro-genres also impact student learning and identity in science. The Agency units account for a relational epistemology of science (Bang et al., 2012), thus the

Agency group adopts a change-agent stance towards science as they engage with various multimodal genres, particularly public interviews, during challenge cycle phases. By placing emphasis on *how* genres are used to accomplish specific goals, demonstrates how they may mediate learning and establish credibility among peers. This suggests that through sustained practice students develop flexible and transferable communicative competences in science as well as a repertoire of texts elements, which then become resources serving the needs of the learners and school science. Bransford and Schwartz (1999) Preparing for Future Learning (PFL) perspective where emphasis on learning that is perceptual entails “knowing with” thus provide learning opportunities that enable students to apply what they know so that they may refine and expand on their knowledge.

As students develop control over their own actions in local situations as evaluated from practical, performative, and moral stances, Duranti projects that it also refers to one’s interest in problem solving and accomplishing things individually or collaboratively because one “cares” about the affect of doing and saying things (Heidegger, 1962 as cited in Duranti, 2011: 158). Hence, individuals with a degree of control over their own actions (i.e., in the context of science investigations) invoke practical agency, and student stances in practical, performative, and moral evaluations characterize agency as shared and epistemic. Thus curriculum content, practices, goals and activities aimed at intentional learning position students as trusted, respected and valued community members that have as much capacity and intellect as adults to make valuable contributions in their classrooms and community.

Finally, youth positioning across conditions in Finding 3 reveal that in the case study showing the relation of the curriculum genre to science learning with agency there are particular

strategies teachers may use when providing learning opportunities that enable students to apply what they know so that they may refine and expand on their knowledge; namely:

1. *Positioning youth as trusted community members: Curriculum content, practices, goals and activities aimed at intentional learning position students as trusted, respected and valued community members that have as much capacity and intellect as adults to make valuable contributions in their classrooms and community.*
2. *Using multi-modal genres: Multi-modal genres during challenge cycle phases mediate learner participation, identity and agency over time, particularly when teachers explicitly model how the relations of form and functional properties of genres encourage and embody thought, emotion, and action.*
3. *Raising consciousness: Raising student consciousness to the variegated ways scientists practice science inducts students into how scientists intentionally and purposefully employ these genres to engage in scientific ways of communicating.*
4. *Sustained Practice: Through sustained practice students develop flexible and transferable communicative competences in science as well as a repertoire of texts elements, which then become resources serving the needs of the learners and school science.*
5. *Preparing for future learning: Marshaling student's developing flexible and transferable competencies in science adopting a Preparing for Future Learning (PFL) perspective where emphasis on learning that is perceptual entails "knowing with" (Bransford and Schwartz, 1999).*

Therefore, the Agency group perceives science as a mental process, which stems from an explicit, subjective orientation, and accompanied with an interested disposition shows a

developing consciousness about science that is fueled with emotional investment.

#### Positioning in Pedagogic Science Discourse as Regimenting Student Apprenticeship

The teacher in the Inquiry group uses regulative and instructional registers to regiment student apprenticed science interactions. Thus the Inquiry group construes science from an objective perspective where participation in science is circumstantial where material and cognitive “*know how*” are obligations. Thus students’ developing consciousness is grounded in institutionalized feelings, which includes emotional investment.

Lemke (2008) construes belief systems as features of communities, whereas one’s identities-by-belief are positional and individual – individual because we are all to some extent unique given the varying degrees of access one has under varying circumstances. Institutions, such as schools, offer “pseudo-identities” (Lemke, 2008:32) because the social-material arrangements enable or disable opportunities for action and interaction, and the norms and practices as embodied in others, monitor, evaluate, control, and steer students by threats and rewards to become acculturated – “the scientist during science”. Pseudo-identities are a result of the product of interests and dominating interests. In other words, they are governed by ideology that serves interests. Side-effects or features’ roles and functions, known as “slippages” (Lemke, 2008: 35) enable one to distance oneself from identities that are used to control students to suit the social interests of the teacher/authority.

These findings can be seen as parameters for construing ideational meaning in constructing identities as categories where experiences of the world are segmented into sequences and entities. Language as a linguistic resource is used to interpret entities into categories and then into taxonomies, thus establishing a way to explain human experience (Halliday & Matthiessen, 2004: 29). The socio-material arrangements and practices in the school

science classroom categorize students based on their social acts where identities emerge as a related social phenomenon. Membership categories are relational when “articulated within the values set up within such structures.” “Category-bound features” allow students and as evidenced with the teacher AY in the Inquiry group to establish categories and infer values associated with the categories. Thus, categorization, used as a positioning strategy establishes an implicit division between ‘us’ and ‘them’ (Tann, 2010).

The ideational resources construe identities as though they are natural realities. The interpersonal resources enact those identities as social realities. The textual resources organize identities as semiotic realities. Identities as semiotic reality are realized through social interaction in text, that is, the ideational and interpersonal aspects of text provide the discourse with the entities (knowledge) and the relationships between those entities. Thus the textual resources as semiotic realities repackage the natural and social realities by textual structuring producing a pedagogic discourse that functions rhetorically. Consequently, the production of texts, a facilitating function, establish discourse sequences, organize the flow of discourse, and function to foreground or background identities through prominence. In other words, the teacher may direct students to assume particular identities by foregrounding the Theme to specify a position on the subject matter (Tann, 2010).

Student identities are also organized textually where introducing people and things into a discourse and keeping track of them trace participant roles. Identities can then be tracked through chains emerging from the cohesive ties provided by the link between presupposing and presupposed information. Martin (1992:126) states that attaining a coherent text entails making inferences about identities. Viewed as a normative requirement, identities are constructed as

continuous and students participate in organizing the categories, rendering them complicit in construing the social world and positioning themselves in specific ways.

**Conclusion 2: Developing a critical consciousness is essential for developing science identities and knowing one's possibilities, so students may not only navigate the social structures in ways that supports their ways of knowing and learning, but also have the capacity to distinguish between opportunities and needs with an understanding of the uncertainties and the possibilities inherent in scientific practice.**

**Conclusion 3: Mental and material processes construed as a means to achieve goals in science impact students' way of knowing.**

The results in Finding 4 on students' affective engagement in science using Appraisal analysis reveal how students affiliate with feelings about scientists, places and things related to the scientific enterprise, and the science activities students participate in. Martin (2008: 57) explains that evaluating things, actions, and natural phenomena can be understood as 'appreciations', where 'reaction', 'composition', and 'valuation' are differentiated by positive or negative evaluations. In relation to mental processes, reactions to things construe the level of interest as it relates to affection (emotive and desiderative), thus establishing interpersonal implications. Compositions reveal the perceived level of complexity in terms of textual organization. Finally, valuation interprets relevancy as it relates to cognition, thus establishing ideational worth. Therefore, in Finding 4 two evaluations emerge in terms of students' affective engagement in science: The agency group display emotional investments whereas the Inquiry group reveal institutionalized feelings. Student emotional investments can be characterized as having a subjective orientation and high valuation, therefore embodying solidarity, power, and

agency. Institutionalized feelings are characterized as having a subjective orientations and low valuation, therefore the Inquiry group hold institutionalized feelings because of the socioeconomic values attributed to science for its role in innovation and consumption.

The results from the keyword concordances show that developing cognition and interest in science also entails having fun. The Agency group shows positive cognitive dispositions towards science, as students feel rewarded and construe science as experiential and mental processes, which stem from an explicit, subjective orientation, and accompanied with an interested disposition. Their participation in terms of their capacity and tenacity is evaluated as a social value, and their reactions to science have an engaging impact which are qualified as “fun”. The challenging and innovative aspects of science are construed as a positive valuation. The implication here shows a developing consciousness about science that is fueled with emotional investment, thus developing awareness for cognitive know-how.

For the Inquiry group participating in science means having the ability or ‘know how’ where scientific practices embedded in the scientific method are valued as a way of knowing, which is limiting to their creativity, identity and agency. Knowing from material processes provides a partial truth that is construed as useful and valid and so the dispositions towards science in the Inquiry group are indexed by the functions of science where students self-identify as a “user of science”, a consumer. The Inquiry group also construes science from an objective perspective where participation in science is circumstantial and material and cognitive “*know how*” are obligations, thus their developing consciousness in science is grounded in institutionalized feelings, which includes emotional investment, but with only partial cognitive know-how awareness. Thus the implication is that their identity and agency, at a median degree, are contingent and can potentially result in a discontinuous relationship to science.

The findings suggest that the Agency group show a developing awareness of the material and mental processes of science as well as the nature of science. The performative aspects of science as they relate to present and future activities show how students are expanding on their capacities through mental processes. The Inquiry group construes science as a material process where affect and valuation are outcomes based on the unexpectedness of an experiment. Products or results in science are also perceived as commodities where science is reduced to its products or results, thus possessing an exchange value. The Inquiry group position themselves as ‘users’ of science, thereby taking an objective stance and as a result constraining their agency in terms of problem solving and creativity as well as identification.

The implication from Finding 4 is that student’s developing identities in science have interpersonal meaning (Tann, 2010) and so student’s identities are seen as subject positions. Martin and White (2005) assert that as language enacts personal and social relationships with others, evaluative language or appraisal functions as an interpersonal resource for presenting the self as answering, questioning, accommodating potential participants and the value positions they represent. The choices students make in their evaluations of science produce relational or subject positions.

Tann (2010) explains that the meaning making metafunctions produce and manage identities in texts collaboratively by providing the context of the moral order set up in the discourse. When students ascribe different categories to science (as an entity), science is placed in a different normative context against which its actions are interpreted. Categories generalize situated actions by individuals as general attributes of people in the category – ‘scientists research things’, which then can be used to project further expectations of the categorized persons, including activities, obligations, rights and knowledge. Positioning entails culturally

established bundles of attributes, for example – “*and it's being able to explain yourself in a reasonable way and an intelligible way and I really like science (AD41, PolSol)*”. In other words, when students use categories as a means to express their moral valuations or moral expectations, they position themselves relationally to interpret their engagement in science to the associated activities within the science enterprise, which spurs further categorization. Categories may also be reformulated by changing the predicates normatively bound to them. For example, student identities expressed as ‘I am a scientist’ versus ‘I am kid scientist.’ Thus categorizing a person ideationally puts a moral expectation on the actions of that person that anticipates or requires further positioning with regards to those actions, which then generate more categories (Tann, 2010).

**Conclusion 4: Students see themselves in science and in relation to others during enabling and constraining modes of participation, particularly during moments of difference of opinion. Contributions made by participants can be understood as an obligation, an expectation, or an act of entitlement.**

The findings in Part II showed that students from the Agency and Inquiry group perceive science from different perspectives: socio-scientific and stereotypical. From Finding 1 in Part II of the Findings, the Agency group holds a socio-scientific view of science and people doing science have creator, inventor roles. Students’ initial representations of science are embedded in topics where concepts and processes realize “how things work”. Subsequently, science is perceived as performative and scientific practices are foregrounded in the context of improving the quality of life. Finally, scientific practices are associated with the ways in which science is experienced where experiences are expressed as ontologically subjective phenomena. Therefore,

students' perceptions of science become increasingly sophisticated over time as sense-making, having fun in science, engaging in the scientific practices mediate learning of new phenomena. The Inquiry groups held a stereotypical view of school science, as related to the typical school science practices. Students characterize science as playful and it functions as a way to figure out things about their surroundings. Finally, school science experiences represent student science experiences as obligations. The implication drawn is that student's expectations, emotional investments, and ways of knowing in scientific inquiry influences their perceptions of science. This implication can be seen from the results in Finding 2, particularly with the Inquiry group failed experiment episode where activities and events are initially appropriated, then objectified, and finally communicated.

**Conclusion 5: The agency units give students the capacity to act intentionally as well as design and manage their learning because they account for intentional reflection. The Inquiry group perceives science as a commodity that is disconnected from the self-as-scientist, thus having an external perspective of the self-as-consumer.**

The results in Finding 3, which traced the inclination and obligation of doing science show how control and power in student and teacher discourses regiment behavior. Results related to the degree of authority in 'shouldness' illustrate how "depersonalized orders" embody "shouldness" and, as a result, create institutional distance. The *Landforms* institutional discourse is imposed and realized through modals of moral necessity, which set the conditions for duties, obligations and responsibilities for the teacher. When teachers act according to a moral logic of what is necessary because of the relevant scientific norms, they establish expectations through images of scientists so students conform to the particular scientific norms. Consequently,

teachers are positioned to operate with high degrees of authority as the curriculum ideologies are realized through directives and explanations, thus experientializing shouldness.

Capacities realize the causes for a learner to know or possess a skill or ability. The potential for knowing, getting to know, learning, ability and permission are subject to judgments. For the Agency group, proposed actions are evaluated in terms of their possible future grounding and predictability. This suggests students are motivated and rationally assess certainties and risks when realizing their goals.

Students learn expectations about the behavior and responses of scientists as well as imitate, stereotype, or parody them. Lemke (2007) asserts that by acting and being like a scientist, students acquiring some attribute that enables them to be scientists of particular kinds. Students may not identify with attributes of a scientist, but they acquire them. Also, students may not have full, active competence in the full active sense of being a scientist, but they passively acquire it by being able to interpret the behaviors of scientists for their purposes.

Emotional factors and expectations lead students to identify only with one or a few of the available scientific practices and science identities in their communities. To this end, I strongly advocate Lemke's position regarding silenced identities that are disruptive or incompatible where he states, "*there is a great deal of covert identity transgression in people's private and fantasy lives which is itself part of the work of resolving the lack of fit between our unique feelings and dispositions and the ready-to-wear identities that are useful to social institutions with which we share only limited interests.*" (Lemke, 2007: 38)

Student perceptions of who does science influences how they identify and talk about who does science from an affective and categorical perspective. The Agency group has a broader view of science, they initially identify with science from a social perspective, which

encompasses a global perspective, where scientists and kids in school do science and people could do science whereas the Inquiry group identify with science from a local, restrictive perspective where ‘scientists’ and ‘kids in school’ do science.

The findings reveal how identities can be construed ideationally where ‘continuity of the self’ and ‘discontinuity from others’ is managed in text. The focus on the content of a discourse entails the kinds of activities undertaken, and how participants in these activities are described, how they are classified and what they are composed of. Taxonomic relations also function as identification by providing indirect reference known as ‘bridging’ (Martin, 1992: 124). Thus making meaning in how students experience ‘reality’, material and symbolic, is construed in discourse (Martin & Rose: 2003:66). The sub-classifications and subdivisions of categories collectively construe taxonomies of similarities and differences through which identities are produced differently.

**Conclusion 6: Material arrangements become embedded in student situational experiences and mediate student affect in science.**

Findings from the co-word analysis regarding students’ images of science show that from the identity-related thematic analyses, the Inquiry group shows that material arrangements mediate students’ positive emotional investments in science and learning. Students find these material experiences enjoyable because they are challenging and they invoke interest. This suggests students attribute science a typifying role that is part of a circumstantial context dependent on materiality and embedded in situational experiences. Moreover, aspects such as challenging science problems yield interested dispositions, which indexes emotional investment.

**Conclusion 7: Students establish practical experience through practical action. As students relate the contents and mode of the unit to science, they attribute value.**

**Values underlying youth identities are essential for guiding actions, thus enabling or constraining their agency and science identities.**

Findings from the co-word analysis regarding students' images of science show that for the Agency group materials and practices are an index of the students' representations about science, thus orienting to past experiences in science. These past experiences are subsequently oriented to the future where students infer that materials and practices not only invoke a positive experience but also have affordances in everyday life because of their functions.

Similarly, student preferences doing science from the agency-related interview questions reveal that the Agency group's felt affect, motivation, and interest assumes how they understand and regulate their learning, thereby demonstrating how consciousness empowers students to take a stance by orienting and attending to relevant activities as phenomena of experience. Student's developing consciousness capacitates them to modify and regulate their learning both from the perspective of the self and in responding to events by projecting actions during science activities that reshape the situation in context to accommodate student's 'wants', 'needs' and stances (Thibault, 2004). Consequently, learning is decontextualized and recontextualized as students primarily invest in their emotional commitments. Student's capacities for explicit reflection, as illustrated in student's utterances expressing felt emotions and interests to learning in science, develops as they realize their affective commitments through participation roles and science practices particular to their 'as-if' realms. The Agency and Inquiry groups prefer to figure things out on their own or with other students because they are obligated and capable of fulfilling institutional and personal expectations. *Institutional expectations* include (a) extra credit on

report cards, (b) scientific definitions for assessments, (c) follow teacher instructions.

*Personal expectations* defined as working cooperatively and ‘seriously’ with others includes: self-assessment, to remember, to motivate and think harder, to regulate activities, sense of adventure, be creative and, to learn.

These institutional and personal expectations differ between the Inquiry and Agency groups in terms of identifying personal gains. The Inquiry group identifies personal gains in figuring things out on their own or with other students as *Benefits*. These include (a) remembering by doing, (b) collaborative problem solving, (c) self-assessment, (d) thinking to understand, and (e) interest. The Agency group warrants these benefits as *Opportunities* for (1) enhancing productivity, (2) peer-tutoring, (3) regulating learning, (4) engaging emotionally, and (5) challenging capabilities.

Findings related to student preferences to learning in science reveal that for the Agency group, students learn from their mistakes and it is perceived as an efficient way of learning. Both groups stated that by figuring things out on their own helped their learning by remembering things, thus successful learning is perceived as a resource for future learning. Working in ‘groups’ is beneficial and ‘fun’ but having the teacher guide their learning is perceived ‘helpful’ when students encounter difficulties. Finally, students thought they learn more by figuring things out on their own because they can test out their own ideas and try various ways to figure something out.

The different types of choices available for the Inquiry and Agency groups are a result of the curriculum activities and ideologies. The Inquiry group perceives choice as a regulative process where object-related activities are coordinated. The Agency group perceives choice in the available multimodal genres: power point, posters, and presenting to the public. Both groups

felt they had choices in taking up a role for handling materials and deciding on processes, such as ‘separating’. The Agency group also identified making choices with members in their groups, thus opening up their options for choices and actualizing their intentional goals. The Inquiry units provide students with choices that are identified as roles and choices made in experiments are construed as contrast, suggesting only two options are made available.

For both groups the material arrangements helped students learn. Furthermore, the Inquiry group perceived the Landforms unit as beneficial for establishing an understanding on processes and concepts and scientific practices. In the Agency group, students stated they learnt more about pollutants and engaging with multimodal genres, such as the interviews, videos, and doing research online. Finally, group collaboration engendered self-regulation for both groups yet for the Inquiry group, groups were perceived as a type of resource.

In assessing students’ developing understanding of scientific inquiry using Hierarchical Learning Modeling of the Inquiry Assessment findings show that across all three units (MSRC vs. Landforms, PolSol vs. MixSol, and Algae vs. Environments), students in the Agency group scored significantly higher on the science inquiry assessments compared to the Inquiry group. In MSRC versus Landforms, the Agency group showed learning gains in refining the structure and content of student-generated investigative questions and recalling their same, changed, and measured variables. Providing youth with opportunities to design their own investigations in open inquiry (Hodson, 2014) suggests students establish linguistic resources that enable them to engage in the methods of investigations used by scientists. However, both groups initially show no improvement in writing conclusions, which supports students’ negative sentiments towards writing in science.

Results from winter to spring for MixSol (Inquiry) and PolSol (Agency) show the Agency group scoring higher for conclusive statements when providing supporting data. Thus indicating that exposing students to multimodal genres and giving them the choice to select what is relevant impacts students' evidence-based reasoning in positive ways.

Finally, the fall to spring results for Environments (Inquiry) and Algae (Agency) where the Agency group, in the spring among the higher-SES cohort, show significant learning gains in student-led investigation question scores suggests a deeper understanding in how variables in an investigation facilitate what counts as data.

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## Chapter 6 Appendices

### Appendix 1

*Table 6-1 Summary of Semiotic Process in SFL (Adapted from Halliday & Matthiessen, 2014)*

rank	class	complexes	Context	<b>Icon Field</b> (the social action: what is actually taking place?)	<b>Index Tenor</b> (the role structure: who is participating? What are their statuses and roles?)	<b>Symbolic Mode</b> (the symbolic organization: what role (e.g. function, channel-spoken/written/both is language playing?)
				<b>Ideational</b> (interpretation and representation of world in and around us) <b>Logical</b> (realized serially by iteration) <b>Experiential</b> (realized segmentally by constituency)	<b>Interpersonal</b> (realized prosodically-interaction between speaker and listener; speech roles; attitudinal comments)	<b>Textual</b> (realized periodically by oscillation)
				<b>Transitivity</b> (process type)	<b>Mood</b>	<b>Theme</b> (Rheme; Information Structure)
				AGENCY (Voice - middle (no active or passive agent)/effective (Subject is agent & Process realized by verbal group) AGENT-MEDIUM-RANGE	MOOD TYPE (indicative – interrogative   (wh- and yes/no) /imperative)	THEME (unmarked/marked)
				PROCESS TYPE (material/mental/verbal/relational)	POLARITY (positive/negative)	THEME PREDICATION (non-/predicated)

phrase	prepositional	phrase complexes	CIRCUMSTANCE	Mood (adjunct type)	Conjunction
group	verbal	group complexes	Interdependency (parataxis/hypotaxis) Event Type Aspect (non-finite)	Finiteness	Voice
nominal	group complexes	group complexes	Logical-semantic relation (expansion/projection) Thing Type Classification Epithesis Qualification	Vocative; Modality: Person Attitude	Determination
			Episodic patterns	Exchange patterns	Information flow patterns
			Figure/Representation	Proposition/Pro- posal/Exchange	Message
			Configuration	Speech Function	Contextualization

## Appendix 2

### 6.1 Study Context

*Table 6-2 2012-2013 School Demographics*

Elementary School	2012-2013 enrollment	F/R	Afr Am	Asian/Pacific Islander	Hispanic	Multi	White	ELL
Ardmore	419	44%	5%	28%	32%	6%	30%	36%
Phantom Lake	324	36%	3%	21%	15%	6%	56%	22%
Sherwood Forest	411	47%	8%	26%	27%	5%	34%	31%
Enatai	513	18%	4%	25%	8%	7%	56%	14%
Medina	522	6%	1%	32%	3%	6%	53%	7%

## Appendix 3

### 6.2 Unit Descriptions

#### 6.2.1 *Inquiry Landforms Unit and Agency My Skokomish River Challenge Unit*



*Figure 6-1 My Skokomish River Challenge Cycle*

The Inquiry *Landforms* module introduces students to fundamental concepts in earth science. Students are shown ways to represent the features of the Earth's surface at a small scale. Maps and models are used to represent landforms and students learn about the similarities and differences between the representations. Then students run investigations where they learn that running water causes erosion and deposition and it defines the features of landforms. They also learn that humans make changes that affect the amount of erosion and deposition in stream channels. Finally, students learn about some of the tools and techniques used by cartographers and use them to depict landforms.

*My Skokomish River Challenge* (MSRC) is a 12-week long earth science unit, which is a redesign of the FOSS *Landforms* module ([Delta Education \(Firm\), Lawrence Hall of Science, & University of California Berkeley, 2000](#)). Students learn about erosion and deposition while

investigating a challenge involving a real-world scenario – erosion in the Skokomish area – where they need to choose one site out of three that will accommodate the construction of low-income housing, but not contribute to the ongoing erosion in the area. Subsequently, students explore the concepts of erosion and deposition, the context, and then run their class-led and own investigations. Next, students look at ways to mitigate erosion. Finally, students present their chosen site in the form of a presentation (Go Public), using evidence they have gathered from research and investigations.

### 6.2.2 *Inquiry Environments Unit and Agency Algae Invasion Unit*



Figure 6-2 *My Algae Invasion Challenge Cycle*

*Algae Invasion* is a 12-week long environments science unit, which is a redesign of the *Inquiry Environments* module ([Delta Education \(Firm\), Lawrence Hall of Science, & University of California Berkeley, 2000](#)). The *Inquiry Environments* module focuses on how living things depend on conditions in their environment. Students study the relationships between an organism and its environment. Changes in an environment may impact an organism, especially when

humans change environments. Through controlled experiments, students determine ranges of tolerance and optimum conditions as well as environmental preferences.

In the redesigned unit, *Algae Invasion*, students are introduced to a challenge where scientists are concerned about the number of algal blooms in Puget Sound. As students are introduced to algae and algal blooms in Puget Sound, their challenge is to find out what is causing harmful algal blooms in Puget Sound, what organisms are at risk because of these harmful algal blooms and why, and what are some important things the public need to know about harmful algal blooms. Students conduct investigations using algae to understand the effect of various environmental factors on the growth of algae. Next, they are introduced to ecosystems and what makes up the Puget Sound ecosystem. At this point in the unit students look at what organisms in Puget Sound are at risk because of harmful algal blooms and how are they at risk. Students use what they have learnt from their designed experiments about environmental factors to address how a harmful algal bloom can affect an organism. Then students learn about the ways that their communities deal with harmful algal blooms by listening to interviews of different stakeholders who talk about how harmful algal blooms affect ecosystems, human health, tourism, recreation and the economy. Students begin to address the third part of their challenge where they need to educate the public about what they need to know about harmful algal blooms in their local area. As students gather information from their designed investigations, web research, and stakeholder interviews, they then conduct a community survey to find out what the public knows about harmful algal blooms. All the information students have gathered up until this point informs the culminating part of the unit, the Go Public. Students are expected to frame their Go Public around things the public does not know about harmful algal blooms.

### 6.2.3 Inquiry Mixtures and Solutions Unit and Agency My Solution to Pollution Unit



Figure 6-3 My Solution to Pollution Challenge Cycle

The Inquiry *Mixtures and Solution* Module ([Delta Education \(Firm\), Lawrence Hall of Science, & University of California Berkeley, 2000](#)) is a chemistry unit that studies the structure of matter and the changes that take place in it. Students learn the concepts of mixture and solution, concentration and saturation. The investigations introduce students to the fundamental ideas in chemistry using tools and materials to 1) make and separate mixtures, 2) measure and compare the mass of a mixture to the mass of its parts, 3) determine density (concentration), 4) compare the solubility of substances in water and, 5) observe and compare reactants. Learning about the properties and behaviors of substances gives students knowledge about how things go together and how they can be taken apart. Finally, learning about changes in substances may lead to the development of new materials and ways to produce energy (<http://www.fossweb.com/web/foss-fossweb/modulesummary>).

*My Solution to Pollution* is also a 12-week long science unit where students study what is in their local waters and about water quality. First, students begin to understand that their everyday practices affect the water in their rivers, creeks, lakes and oceans.

Students are then introduced to their challenge. The challenge is divided up into three sections where students, first, understand how scientists test water samples for possible pollution. Second, how Water Quality Inspectors find the source of pollution in a stream or river, and what do they do. Finally, students take action to prevent pollutants from entering our local waterways by creating a Public service Announcement that educates the local community about the problem of pollution in their waterways.

Students then conduct investigations where they examine a water sample and find ways to separate the mixture and the solution. Next, students use a model, *Enviroscape* (<http://www.enviroscapes.com/>), to investigate water flow and dispersion of pollutants through the watershed. Finally, students select and research a common pollutant in their community by conducting community interviews and creating a Public Service Announcement that educates the public.

## Appendix 4

### 6.3 Agency and Inquiry Unit Enactments

*Table 6-3 Agency and Inquiry Unit Enactments - Teacher (unit) [School]*

	Fall 2012	Winter 2013	Spring 2013
<b>Cohort 1</b>	SK (MSRC) [Medina]	SK (PolSol)	SK (Algae)
	AY (Landforms) [Enatai]	AH (MixSol) [Medina]	AH (Environments)
<b>Cohort 2</b>	PB (Algae) [Ardmore]	PB (MSRC)	PB (PolSol)
	JV (Environments) [Phantom]	GL (Landforms) [Sherwood Forest]	GL (MixSol)

## Appendix 5

### 6.4 Curriculum Designs

The redesigned units draw on the STAR (Software Technology for Action and Reflection) Legacy Inquiry Cycle (NRC, 2000), which is made up of five components (in italics) of learning (Schwartz, Lin, Brophy, & Bransford, 1999). The redesigned units are organized around case-based scenarios in the form of a *Challenge*. Providing students with an engaging challenge to introduce the topic and invite inquiry. *Initial Thoughts* makes space for students to articulate their own ideas so that can assess what they currently know about the proposed challenge. Cobb (2001 as cited in NRC, 2000) maintains that eliciting students' prior knowledge and experiences regarding the proposed challenge and building on what they know enhances learning, especially for students from culturally diverse background. *Perspectives and Multimodal Resources* relevant to the proposed challenge are then presented as bits of information. These resources allow students to discover what they initially did not consider thus building on what they know. Applying what they know takes place in the *Assessment* stage where students can go back to the *Perspectives and Multimodal Resources* stage and fill in gaps if needed. Finally, the *Wrap Up* stage encompasses a summary and another opportunity for students to review their final thoughts in relation to their *Initial Thoughts*. Learning occurs when there are differences between initial and final thoughts (Schwartz & Bransford, 1998). In Appendix 3 I show our adaptation of the STAR Legacy Inquiry Cycle. This STAR legacy inquiry cycle is specifically used for the redesign of the inquiry units, which are explained later.

#### 6.4.1 *Design Principles*

The redesigned units draw on the following design principles. In addition to outlining the design principles I highlight, when relevant, the activities designed for agency that are applicable for the *My Skokomish River Challenge* unit – a redesign of the Inquiry unit, *Landforms*:

1. *The overlapping area between science (concepts and practices) and the everyday lives of students is central to curriculum design. A culturally responsive and socially-centered design approach was implemented in order to increase the overlap of the curriculum with the everyday lives of students and worked from an educational capital perspective with respect to ethnic, linguistic, and class diversity (Nasir et al, 2006; Gutiérrez & Rogoff, 2003).*

*Activity in Investigation:* Students are introduced to the challenge and they generate initial ideas and questions about why the Skokomish river floods. Students identify questions they feel are important to address before responding to the challenge and they conduct basic research.

*Agency Indicator:* Students know what they do not yet understand and articulate questions to help them access this knowledge.

2. *The redesigned units situate students as knowledgeable about science and capable of taking action in relation to science. To these ends the curriculum: promotes a sense of purpose and meaningful learning by creating an overarching problem/driving question/consequential task/public performance; supports learning of connected and in-depth science concepts/skills through sustained learning with opportunities for feedback and revision; and, promotes social learning through purposeful student-to-student interaction and sharing.*

*Activities in Investigations:* (a) The class reviews factors in flooding (erosion and deposition) and they decide which of these to study. A whole-class investigation experiments on one factor that affects erosion and deposition. After reviewing the findings from the whole-class investigation, students are asked what do they know now? (b) Students in small groups decide, define and run their own investigation. In sifting through the evidence from the stream table investigations, the videos from the stakeholder interviews in the Skokomish river area, other background materials, and the field study students have to decide what they believe; which evidence is strongest, etc. for selecting a site. (c) Students are shown the tools and strategies used to mitigate for erosion where in small groups they select a strategy to mitigate flooding for their site. They then model their site in the stream table to test their chosen strategy. (d) Students design their own presentations on their selected site. Students choose which medium they would like to use to communicate their site selection to an audience they select. (e) Students present their presentation to an audience.

*Agency Indicator:* Purposeful choices are made about consequential aspects of scientific inquiry at the individual, small group, and whole class levels. Resources such as tools and materials are used in ways that support scientific investigation and sharing scientific understanding. Consequently, students and teachers see and experience learning as an iterative process of developing and revising ideas through dialogue and action. As a result, students see themselves as capable and confident to reason through a situation; problem solving occurs through purposeful social interaction with peers and teachers as resources; and students take action in the world using scientific understanding, at 5<sup>th</sup> grade level at least.

3. *The redesigned units prepare students for future learning by: supporting sustained investigations within the classroom and presenting compelling future engagements with*

*science; and, engaging students in science-rich social networks: credentialed experts and “more expert others” (e.g., hobbyists, interested peers and family members).*

*Activity:* Students do a field study exploring erosion and/or deposition outside of school and they share their findings with the class.

*Agency Indicator:* Formal and informal connections are forged as students navigate between practices in the everyday world and practices embedded in scientific investigations.

4. *The redesigned units operate cleanly within relevant infrastructural and political realities of school systems.*
5. *The redesigned units provide clear guidance to teachers. Materials include guidance, tools, resources for teachers to support their work and learning, in particular where practices are novel.*
6. *The redesigned units leverage from disciplinary/professional expertise.*

*Activity:* Students watch a video on erosion and deposition, showing how scientists study these processes in the world. Stakeholder interviews provide information about the flooding impacts in the Skokomish River area from the perspective of an engineer working in the area.

*Agency Indicator:* Subjective perspectives provide accessible information and a means for social action.

## Appendix 6

### 6.5 Interview Data Sources

*Table 6-4 Student Interviews Data Source*

Cohort	School[Teacher]	Quarter	Unit	Students	≈h:mm
1	Medina[EB], [AH];	Fall 2012	Landforms	n=29	≈9:52
1	Enatai[AY], [MC]				
	Medina[AK], [SK];	Fall 2012	MRSC	n=37	≈11:13
	Enatai [JB];				
	ClydeHill[AD], [AW]				
1	Medina[EB], [AH];	Winter	M&S	n=29	≈8:09
	Enatai[AY], [MC]	2013			
1	Medina[AK], [SK];	Winter	PolSol	n=34	≈9:16
	Enatai[JB];	2013			
	ClydeHill[AD], [AW]				
1	Medina[EB], [AH];	Spring	Env	n=32	≈9:42
	Enatai[AY], [MC]	2013			
1	Medina[AK], [SK];	Spring	Algae	n=32	≈7:12
	ClydeHill[AD], [AW]	2013			
2	Ardmore[PB];	Fall 2012	Algae	n=17	≈5:13
	Woodridge[ASA]				
2	Phantom[JV], [CJ]	Fall 2012	Env	n=16	≈5:36
2	Ardmore[PB];	Winter	MSRC	n=15	≈4:13
	Woodridge[ASA]	2013			
2	Phantom[JV], [CJ];	Winter	Landforms	n=20	≈5:59
	Sherwood Forest[GL]	2013			
2	Ardmore[PB];	Spring	PolSol	n=17	≈5:02
	Woodridge[ASA]	2013			
2	Phantom[JV], [CJ];	Spring	M&S	n=24	≈7:26
	Sherwood Forest[GL]	2013			

### 6.6 Identity-related Interview Questions

*Table 6-5 Identity-related Interview Questions*

<b>I1</b>	If you had to explain what science is to somebody who had never heard of it, how would you explain it?
<b>I2</b>	Who does science?
<b>I3</b>	What does a scientist do?
<b>I4S</b>	How was your work in this unit like the work of Scientists?
<b>I4D</b>	How was your work in this unit different from what a scientist would do?
<b>I5</b>	Do you consider yourself a scientist? Why or why not?
<b>I6</b>	Do you like science? Why or why not?

The interview responses from the identity-related questions were analyzed using two methodologies: paper-and-pencil and software analysis, T-Lab (Lancia, 2012). Results from the two methods show similar results. Differences in themes were detected where the T-Lab analyses produced additional themes, thus strengthening the validity of the results from the paper-and-pencil analysis.

### 6.7 Agency-related Interview Questions

*Table 6-6 Agency-related Interview Questions*

<b>A2</b>	Some students like it when the teacher tells how to do things in science. Other students prefer to figure things out on their own or with other students. Which do you prefer and why?
<b>A3</b>	Do you think you learn more/better by figuring things out on your own, or by having your teacher tell you?
<b>A4</b>	Did you make choices? Examples of choices
<b>A5</b>	What did you do in this unit that helped you learn?

## Appendix 7

### 6.8 Identity-related Interview Questions Categories for Coding of Data

6.8.1 *I1: If you had to explain what science is to somebody who had never heard of it, how would you explain it?*

*Table 6-7 I1 Key Code Descriptions and Examples*

Code	Description	Example
I1_crosscutting concept	Students recall a concept, such as interdependence in ecosystems, to explain what science is.	“What effects, you have to find out the effects of something on something else. That's it. Algae affect the ecosystem and the ecosystem, like, backlash on algae or something... 'Cause the ecosystem dies out 'cause of algae and the ecosystem will crash and then once it crashes, algae will ... that's feeding off of it, it will overpopulate.”
I1_doing science	Science is about doing things like experiments, one is actively doing something with an object - doers of science.	“I would say that mainly science is part of your every day life and you're always doing science, um, there's always things that puzzle you or confuse you and, um, that's science basically, you just have to solve, try and experiment and solve the problem.”
I1_disciplinary core idea	Student uses a core concept in science to explain what science is, for example Newtonian laws of force and motion, matter.	I would explain it like, we learned about, in class, about solutions and mixtures and so when certain things mixture, mix there's a chemical reaction and that makes it so the two or more materials that you mix make something else.
I1_discovery	Science enables one to make discoveries and inventions	“I think it would be the discovering and the study of pretty much everything on the entire earth ... seen or not seen. Like, there's electricity and there's trees, two very different things but science I think is a lot of studying and understanding and just getting a better knowledge of.”
I1_everything	Science is everything, part of every day life, the world around you, or anything.	“Well, I'd probably tell him that it's how everything fits together, why thing - things happen, why the Grand Canyon's here, why that mountain's there, why that island's over there.”
I1_experiment	Student states verbs related to “experiment”: “test”, “investigate”, “research”, and “inspect”	“Um, well math is where you learn, like, um, like, right now we're learning with fractions, so technically it's just with numbers and next year it's gonna be with letters but in science you do experiments and you get information from sources to help you learn about the main topic that you're trying to solve.”
I1_figure out	Science is about figuring things out.	“Uh, like, if this thing goes out of balance, you can figure it out, like, how to help by doing science because, um, science, like, helps you figure out things.”

I1_fun	Student's emotional investment indicated by 'fun', 'like', 'love'.	"Science is I think it's really fun and I've always really liked science"
I1_how things work	Science is about how things work or happen or why things happen or change.	"Well, it's fun and you get to, like, do interesting things and learn a lot about how things work and how stuff is formed and why things do what they're supposed to do."
I1_learn	Science mediates learning.	"I'd say, well science is about where you learn scientific, like, definitions and, like, where you observe a bunch of different things, like, the landforms and electricity and stuff like that."
I1_real life	Student relates science to everyday life, reality.	"I think, like, everything is kind of linked to science, like life is linked to science" / "Geography. Landform. Um, real life problems and you solve them"
I1_school practice	The student views science as made up of various scientific practices, commonly making predictions and conducting observations. Moreover, students see science as a way to collaborate and communicate to the public about results. Science and math are seen as complimentary.	"you observe and predict and you could tell them what those words mean" "you do a lot of, uh, experimenting and, you kinda do whatever you're supposed to do and then you just collect that data and share it with your class and then it's cool to see what other people got with the same, same materials, same stuff, same way."
I1_solve	Science is about solving something, reaching a solution, having questions answered.	"Um, I would tell them, it's a really fun subject, it's when you take sort of, like, a question that you have about, um, like, earth or anything that you really have a question on and you make an experiment but, um, if you keep doing your experiment then you get your, um, question solved or, um, like in our unit, like, making decisions on, like, things, like a site and, yeah. It's fun."
I1_WEN	Science is about the World, Nature, or Earth.	"I think science, it's, like, the study of something, like, it's, like, the study of the world from [inaudible] because you're, like, studying, like, you could study nature in science, or you could study, um, trees or something because biology's a part of science or something else or astronomy's part of science. Like, there's many parts of science. It's, like, I think, um, that anything that ends with 'ology' is something to do with science."

## 6.8.2 I2: Who does science?

Table 6-8 I2 Key Code Descriptions and Examples

Code	Description	Example
I2_Scientists I2_Particular scientist	Student states “scientist” or calls out a particular scientist, for example, aerospace engineer, astrologist	“Um, well there's lots of different kinds of scientists, there's scientists that study animals, or scientists that study, like, sea life, there's scientists that study medicine, I guess. Um, so kind of mostly scientists but it can, it can really be anybody if they want to.”
I2_Kids (or kids in school) I2_Students I2_Teachers	Student explicitly states “kids” or “kid” Student explicitly states “student” or “people in school”, “upper grades”, “we” (anyone in school), and “teacher”	“Well scientists do science and kids, they do science when they're in school and they learn how to do it.” “Um, scientists. Mad scientists. Everybody, basically. Well not everybody as in everybody but, like, kids at school, they do science, teachers do science to show the kids, and, um, builders do science kind of, like, to [inaudible] to get the electricity working or running water or something like that and people that work, like, with the tubes underground, they do science 'cause you have to, like, do investigations to see if the water actually works.”
I2_Everybody	Student states “everybody”, “anybody”, “anyone”	“Scientists, um, kids who do, or pretty much everybody because it's, um, during school you do science for grades and scientists do science to learn new things about the world.”
I2_People	Student states “people” are doing something related to science/have an interest/study things/figures things out/discover things	“People who are trying to discover things.”
Family	Student mentions a family member or friend	“Mm, sort of my cousin because she's an audiologist so she works with, like, science in a way with ears though.”

## Appendix 8

### 6.9 Inquiry Landforms Unit and My Skokomish River Challenge (MSRC) Unit Scope

Table 6-9 Landforms (Inquiry) and MSRC (Agency) Unit Scopes

<b>Inquiry Landforms Module</b>	<b>MSRC Module</b>
<p><b>1. Schoolyard Models</b>  <i>Schoolyard Models</i> and <i>View from Above</i>: Students create models of their school site and then transfer their model onto a grid. <i>Mapmaking</i>: They observe and compare features of the models and corresponding maps, focusing on a different scale.</p>	<p><b>1. Challenge</b>  <i>Challenge</i>: Introduction to the challenge scenario with a motivating problem context, real-world scenario involving erosion in the Skokomish Valley. <i>Initial Ideas</i>: Students independently record their initial ideas about the challenge. In a whole-class discussion, students pose and record questions they have about the Skokomish River area. <i>Conduct Basic Research</i>: Students explore a website designed by the research group that contains the challenge, the problem, the context/location, and ‘why worry?’</p>
<p><b>2. Stream Tables</b>  <i>Erosion</i> and <i>Deposition</i>: Students run teacher-led investigations where they observe the processes of erosion and deposition and become familiar with the landforms created.</p>	<p><b>2. Making Connections: Exploring Erosion</b>  <i>Erosion in stream tables</i>: Students reflect on what they already know about erosion and deposition. Next, students watch and discuss a video related to erosion, where connections are made to how scientists study erosion and deposition and do their work. Subsequently, a whole class discussion on factors that affect erosion and a discussion on experimental design lead to the first whole-class stream table investigation where the results are used as the control for student-led investigations. Finally, the class reviews the results and how they relate to the challenge; and students are shown images of erosion and deposition in the world and comparisons are made between the images and the stream tables. <i>Field Study</i>: Students are introduced to another method that scientists use to investigate landform changes – doing field studies. Students are introduced to field studies as a method of data collection, where the teacher models the activity first and then students individually do their own field study related to erosion and/or deposition, which is then shared in class.</p>
<p><b>3. Go with the Flow</b>            Students continue with their teacher-led investigations, exploring various variables that affect erosion and deposition.</p>	<p><b>3. Exploring the Context: Making Connections</b>            Students are provided with tools to help them with the challenge.  <i>Introduction to Topographic Maps: Foam</i></p>

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*Slope:* Students compare how slope affects erosion and deposition in the stream tables and the class discusses the formation of the Grand Canyon.

*Flood:* Students simulate a flood in their stream table investigation.

#### **4. Build a Mountain**

*Making a Topographic Map:* Students are introduced to topographic maps by building a model of a mountain.

*Drawing a Profile:* From their model students produce a profile of the mountain.

*Inquiry Creek Map:* Students are presented with a fictional topographic map of a creek where they provide interpretations.

#### **5. Bird's-eye View**

*Mt. Shasta Topographic Map:* Students learn to read USGS topographic maps and compare them to aerial photographs.

*Mt. Shasta Aerial Photos and Death Valley and Grand Canyon Maps:* Students compare aerial photos of Mt. Shasta to topographic maps and foam mountains; and they explore aerial photographs and topographic maps of Death Valley and the Grand Canyon.

*Mountains:* Students build a foam mountain while learning about elevation and connect the model to a topographic map of Mt. Shasta. The teacher highlights all the relevant key features of topographic maps.

*Topographic Maps:* Students learn more about the 3 sites by exploring simplified topographic maps of the Skokomish River valley; and they listen and take notes of interviews from stakeholders in the area. *Introducing the 3 Sites:* Finally, students explore the 3 sites using topographic maps.

#### **4. Student-led Investigations**

*Student-led Investigations:* Each small group investigates their own factors by designing their own investigation for two/three cycles. After each cycle findings are shared and compared with the class. Students revise their decision for selecting a site based on the information they have accrued.

*Site Selection:* Students are oriented to the Skokomish webpage where they review the information and they are reminded that their decision must be grounded in their work with maps, webpages that include stakeholder interviews, and the investigation. In small groups, students select a site to recommend justifying their decision.

#### **5. Mitigation**

Students are introduced to the term 'mitigation' and they review various mitigation strategies provided in a handout as well as stakeholder interviews. In small groups students design and test their own solutions to the problem. The class reviews and shares findings before they make their final decision.

#### **6. Go Public**

Planning, rehearsing, presentation and defense of proposals.

---

## Appendix 9

Table 6-10 Text Statistics

		Excerpt 2: Inquiry Group, Teacher AY, Landforms	Excerpt 1: Agency Group, Teacher SK, MSRC
Length	Words in text	206	306
	Sentences in text	22	18
Text Complexity	Average Word Length	3.76	4.17
	Average Sentence Length	9.36	17.0
Lexical Density	Lexemes per sentence	4.36	7.27
	Lexemes % of text	46.60	42.81
Reference Density: (% of tokens)	1 <sup>st</sup> person Reference	8.2524	5.2287
	2 <sup>nd</sup> person Reference	5.8252	4.5751
	3 <sup>rd</sup> person Reference	3.3980	1.3071

### 6.10 Excerpt 1: Agency Group, Teacher SK, MSRC

Teacher      Ok, um [Circumstance], we [Carrier]'re [Process] now [Attribute] to the part [Circumstance] where [Circumstance] you've done research, [Circumstance] you [Actor]'ve checked [Process] out the different sites with information and visual information [Circumstance], we [Actor]'ve run [Process] an experiment that [Recipient]'s based [Process] (on an elevation possibility) (Circumstance) that we [Goal] saw [Process] [Goal]. We [Actor] compared [Process] it [Goal] with a level platform, plateau [Circumstance]. And now [Circumstance] you [Possessor] have [Process] to take everything [Circumstance] that you [Sensor]'ve been seeing [Sensor], learning, thinking about and discussing [Sayer], and you [Sensor] have to decide what [Goal] experiment your team [Actor] can [Process] create that can (best answer a question) (Circumstance) you [Possessor] still [Circumstance] have, or will best [Attribute] give you [Recipient] the information [Circumstance] that need to help refine or make a decision[Goal]. And (if you [Actor]'ve already [Circumstance] got [Process] one or two sites [Beneficiary] that you [Carrier]'re [Process] pretty sure [Attribute][Goal])(Circumstance) you [Sensor] think [Process](are [Process] good ones [Attribute])(Element), or maybe one, (what kind of test information, what experiment)(Goal) could you [Actor] run [Process] (that would give [Process] you [Receipient] even more information?[Goal])(DObj) [Phenomenon] So basically [Circumstance], with your team [Circumstance], you [Possessor]'re going to have [Process] to think about and talk about and come up with an experiment [Goal], ok? What [Attribute] was [Process] the one that we, what [Carrier] was [process] the last experiment [Attribute] that we [Actor] ran [Process]? [Carrier] What [Goal] were we [Actor] testing [Process] for [Circumstance]? Student J [Goal], what were we [Actor] testing [Process] for [Circumstance]?

Student J      The effect of erosion and um, slope...

- Teacher So [Circumstance] if we [Actor] put [Process] our plateau [Goal] on a slope [Circumstance], how [Circumstance] did that [Goal] affect the erosion? And what [Phenomenon] did we [Senser] discover [Process], Student Ja? How [Circumstance] did it [Actor] affect [Process] the erosion [Goal]?
- Student Ja That it [Goal], that the plateau [Actor] does [Process] more erosion [Goal] on a 30 degrees slope [Circumstance] than it [Actor] does [Process] on a flat plateau [Circumstance].
- Teacher So [Circumstance] the same quantity of water running at the same rate across a plateau that [Carrier] was [Process] slightly [Attribute] (on a slope, a 30 degrees slope)(Circumstance) [Subject], did have [Process] a huge effect. And what [Goal] did we [Actor] measure [Process] our effect by [Circumstance]? How [Circumstance] did we [Senser] find [Process] out what our effect (Subject) was (Process)[Phenomenon]? Student S?
- Student S Uh, we [Actor] got [Process] the averages [Goal].

### 6.11 Excerpt 2: Inquiry Group, Teacher AY, Landforms

- Teacher: **All right**, at this time [Goal] we [Actor]'re going to, I [Sayer]'m going to explain the next step (Parataxis). We [Actor]'re going to push our dirt back [Circumstance]. **And** this time, we [Senser] really [Circumstance] want to see where the water flows, when *we watch the water go through our stream table* [Goal] [Circumstance {from to see = Phenomenon}]. **And in order to** [Goal] do that [Circumstance], we [Actor]'re going to put food coloring in the water [Circumstance]. **So [Circumstance]** I [Possessor] have red dye. **And** the way that I want you to get it - red food coloring, the way that I [Senser] want you [Assessed] to get it into your cup [Goal][Circumstance], is with a Q-tip [Attribute]. This stuff [Actor], don't get it [Goal] on your clothes [Circumstance]. Don't get it [Goal] on stuff [Circumstance]. It might not come out. Depending on what [Circumstance] you Actor]'re wearing. It [Actor] won't come out of the carpet [Circumstance]. We [Senser] don't want *a murder scene* [Phenomenon] around here [Circumstance]. **So [Circumstance]**, you [Actor] are going to take your Q-tip [Goal] and just leave it in your tub [Circumstance] [Goal]. Should [Goal] we [Actor] do standard or flood?
- Class: Flood.
- Teacher: Okay, we [Actor]'ll do *flood* [Goal], today [Circumstance]. **All right, so [Circumstance]**, I [Authority] need you [Authorized] to quietly go to your groups [Goal]. Quietly. Mail carriers, I need your help. I need Hugh, Ana, and Gabe. Will you pass these out? Will you pass *these out* [Goal]?

The following table traces the Instructional register where in some instances the Goal is signaled (→) before or after circumstantial elements.

Table 6-11 Circumstantial Information and Goal as Instructional Register

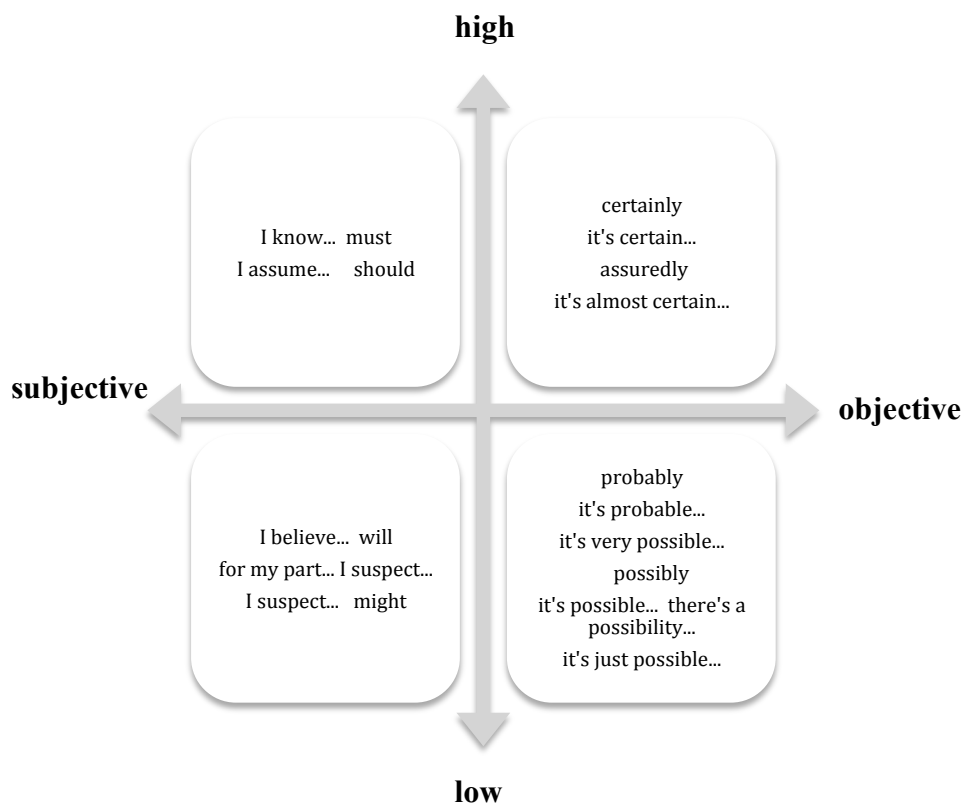
<b>Circumstantial Information and Goal as Instructional Register</b>	
<b>SK</b>	<b>AY</b>
<b>you've done research</b> [Circumstance: Extent] → on an elevation possibility that we saw [Process - Sensing] [Phenomenon]	<b>the dirt back</b> [Circumstance: Manner^means]
<b>out the different sites with information and visual information</b> [Circumstance: Manner^comparison]	→ we watch the water go through our stream table [Goal] <b>where the water flows, when we watch the water go through our stream table</b> [Circumstance: Location^place] <b>when we watch the water go through our stream table through our stream table</b>
<b>on an elevation possibility</b> [Circumstance: Manner^means] → We [Actor] compared [Process: Material] it [Goal] <b>with a level platform, plateau</b> [Circumstance: Manner^means]	<b>in the water</b> [Circumstance: Location^place] <b>into your cup</b> [Circumstance: Location^place] [Goal] → don't get it [Goal] <b>on your clothes</b> [Circumstance: Location^place]
→ you [Senser] have to decide what [Goal] experiment <b>best answer a question</b> [Circumstance: Manner^quality]	→ Don't get it [Goal] <b>on stuff</b> [Circumstance: Location^place] <b>on what</b>
<b>the information</b> [Circumstance: Extent] → that need to help refine or make a decision[Goal].	<b>out of the carpet</b> [Circumstance: Manner^means] → your Q-tip [Goal]
<b>if you got one or two sites that you're pretty sure</b> [Circumstance: Manner^quality] [Goal] → what kind of test information, what experiment [Goal] could you [Actor] run [Process: Material] that would give [Process: Material] you [Recipient] even more information? [Goal] <b>if we put our plateau on a slope on a slope</b> [Circumstance: Location^place]	→ <b>in your tub</b> [Circumstance: Location^place] [Goal] → Should [Goal] we [Actor] do standard or flood? → flood [Goal] → go to your groups [Goal] → Will you pass these out [Goal]?
→ you [Possessor]'re going to have [Process] to think about and talk about and come up with an experiment [Goal] → What [Goal] were we [Actor] testing [Process: Material] for? Student J, what [Goal] were we [Actor] testing [Process: Material] for? → if we [Actor] put [Process: Material] our plateau [Goal] on a slope, how did that [Goal] affect the erosion? → How did it [Actor] affect [Process: Material] the erosion [Goal]? → That it [Goal], that the plateau [Actor] does [Process: Material] more erosion [Goal] <b>on a 30 degrees slope that it does on a flat plateau on a flat plateau</b> [Circumstance: Location^place] <b>at the same rate</b>	
<b>Across a plateau that was slightly on a sloe, a 30 degrees slope on a slope, a 30 degrees slope</b> [Circumstance: Location^place]	

## Appendix 10

### 6.12 Student Affective Engagement in Science

#### 6.12.1 *Appraisal Analysis Resources (Martin & White, 2005)*

Appraisal is concerned with how evaluation in discourse is established, amplified, targeted, and sourced. In discourse semantics appraisal realizes attitudes, which are actualized across grammatical categories such as adjectives, “*It’s [Epithet] really interesting*” (MC45, *Environments*), verbs, “*I’m not interested [process] in all science, I’m interested in a few science stuff*” (CJ54, *Landforms*), adverbs, “*Actually I do consider myself as a scientist*” (PB42, *Algae*), grammatical metaphors where a process nominalizes an attitude, “*Anyone with an interest in certain things*” (JB60, *Environments*), and modality realized through modal adverbs and/or modal verbs, “*Actually a lot of people may do science*” (AD62, *Algae*) as well as the first person, present tense mental process of cognition to indicate degrees of certainty, “*I think anybody could do science*” (JB50, *MixSol*).



### A topological perspective on value and orientation:

Appraisal comprises attitude, engagement, and graduation (Martin & White, 2005).

APPRAISAL – an interpersonal resource relevant for understanding the discourse dynamics of solidarity (contact/involvement) and power (status)

1. ATTITUDE = AFFECT (resources for construing emotions and emotional reactions, text/process, phenomena)

- Reacting to behavior, text/process, phenomena

	Type of behavior	Disposition
[mood: 'in me'] Unhappy/happy	[low grading]Cry/chuckle – [median grading]laugh – [high grading]rejoice	Down – sad – miserable/cheerful – happy - overjoyed
[directed feeling: 'at you'] antipathy/affection	Criticize / shake hands – hug - embrace	Dislike – hate – abhor / fond/like – loving - adoring
Insecurity (concerns/worries) / security (confidence/trust)	Restless – shaking / shudder Declare – assert – proclaim /delegate – commit - entrust	Uneasy – anxious – scared / wary – fearful – terrorized / Together – confident – assured / comfortable with – confident in - trusting
Dissatisfaction (bored/displeasure) Satisfaction (engagement/admiration)	Fidget – yawn – tune out / caution – reprimand – criticize Attentive – busy – focused / Reward – compliment - commend	Bored – upset – annoyed / cross – angry – furious Interested – absorbed – engrossed

		/ satisfied – impressed - proud
affect as Quality	affect as Process	affect as Comment
Epithet: describing participants (a happy student) Attribute: attributed to participants (the student was sad) Circumstance: manner of process (the student left sadly)	Process (effective): affective mental (the results upset her) Process (middle): affective mental (she trusts them) Process: affective behavioral (the student laughed)	Modal adjunct: desiderative (surprisingly, she had to go)

2. ATTITUDE = JUDGEMENT (resources for judging behavior ethically/morally – proposals: rules and regulations “institutionalized feelings”)

Judgments of social esteem:

Social Value	+ Admire	- Criticize
Normality [fate] Is s/he special?	Lucky, normal, everyday	Odd, peculiar, dated
Capacity	Powerful, clever, balanced	Slow, insane, made
Tenacity [resolve]	Brave, reliable, persevering	Unreliable, distracted, despondent

Judgment of sanctions:

Social rights and responsibilities	Praise	Condemn
Veracity [truth]	Truthful, honest, real, authentic	Dishonest, fake, deceptive
Propriety/standards/norms [ethics]	Good, moral, fair, kind, caring	Bad, evil, corrupt, unfair, mean, cruel

3. ATTITUDE = APPRECIATION (resources for valuing objects aesthetically – propositions and awards)

Meta-function	Appreciation	Mental process type		
interpersonal	REACTION - impact	Affection: Engaging, exciting, fascinating	Boring, dull	“fun” (Occ. 169 – I1LM & MP; I5EA, LM, MP; I6) “it’s fun” (Occ. 47 – I6) “It’s really fun” (Occ. 22 – I6LM, MP, Inquiry)
	REACTION – quality (did I like it?)	Affection: Lovely, appealing,	Gross, ugly, plain	
textual	COMPOSITION – balanced (did it hang together?)	Perception: Unified, proportional	Unbalanced, distorted	
	COMPOSITION – complexity (hard to follow)	Perception: Simple, detailed	Embellished, simplistic	
Ideational (attitude)	VALUATION – (what did I get out of it?)	Cognition: Challenging, deep, innovative, original	Insignificant, conservative, unsupported, bizarre	
attitude	Inscribed attitude	Invoked attitude		
	“it was our lack of knowledge”	Provoke: “this year we get super scientist awards and they make you feel	Invite: Flag: “our team wasn’t working together”	

		like you actually are a scientist" (GL48, Environments)	Afford: "we finished late"	
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4. ATTITUDE = ENGAGEMENT (speaker's commitment to what they are saying – I think)
5. ATTITUDE =AMPLIFICATION (resources for grading –‘really fun’, at least')

## Appendix 11

### 6.13 Appraisal Analysis Key-Term Occurrence Results

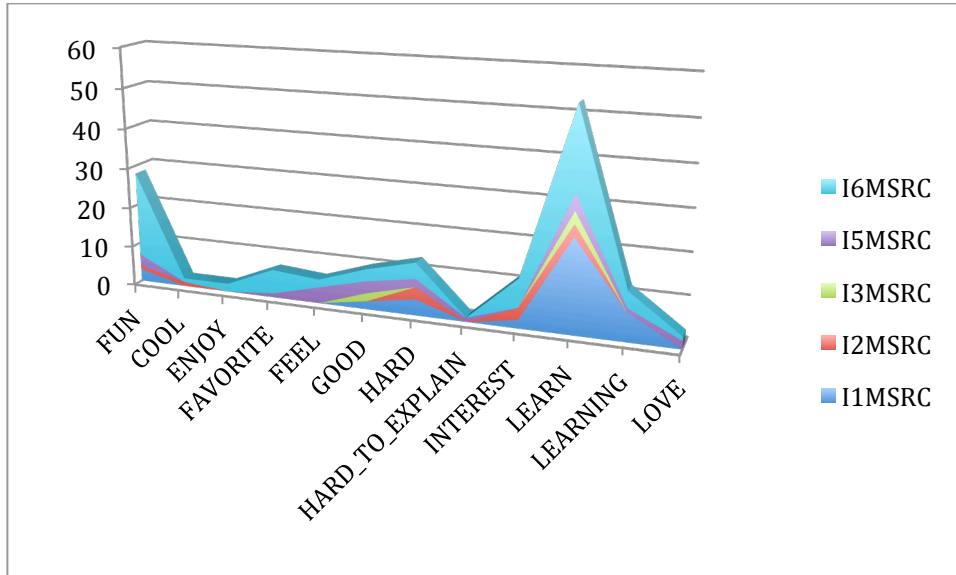


Figure 6-4 Agency: My Skokomish River Challenge, Cohort 1 (Fall 2012) and Cohort 2 (Winter 2013)

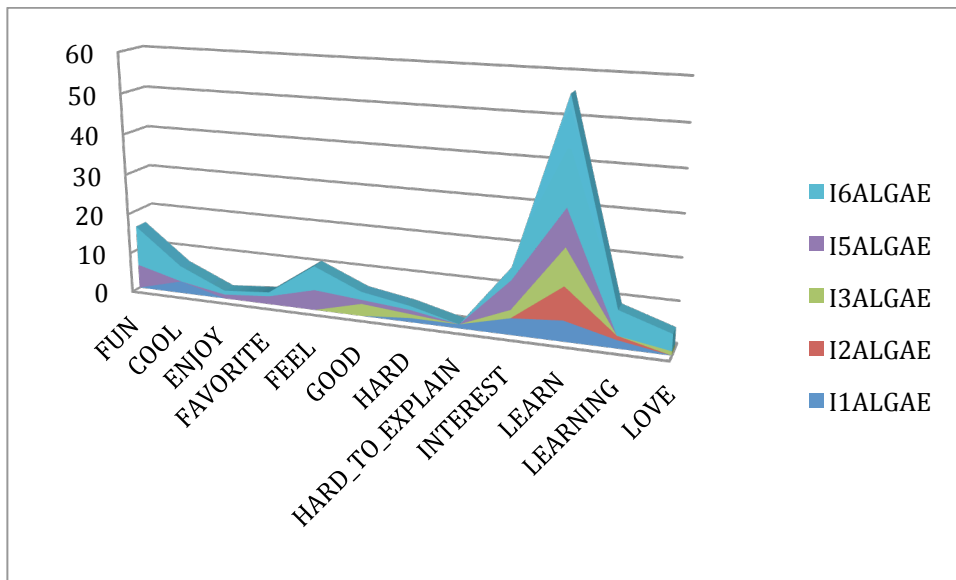


Figure 6-5 Agency: Algae Invasion, Cohort 1 (Spring 2013) and Cohort 2 (Fall 2012)

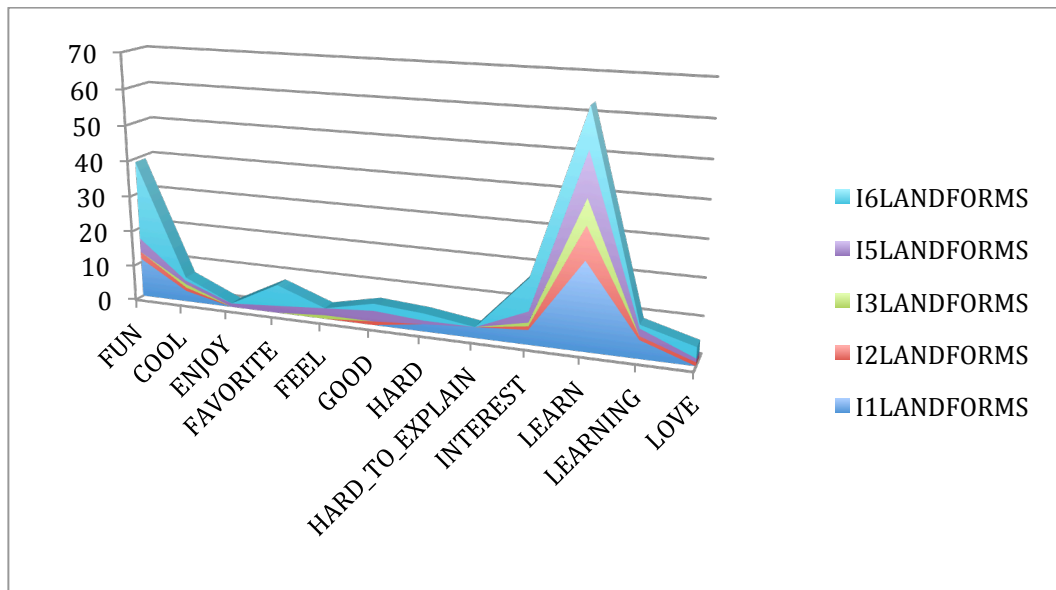


Figure 6-6 Inquiry: Landforms, Cohort 1 (Fall 2012) and Cohort 2 (Winter 2013)

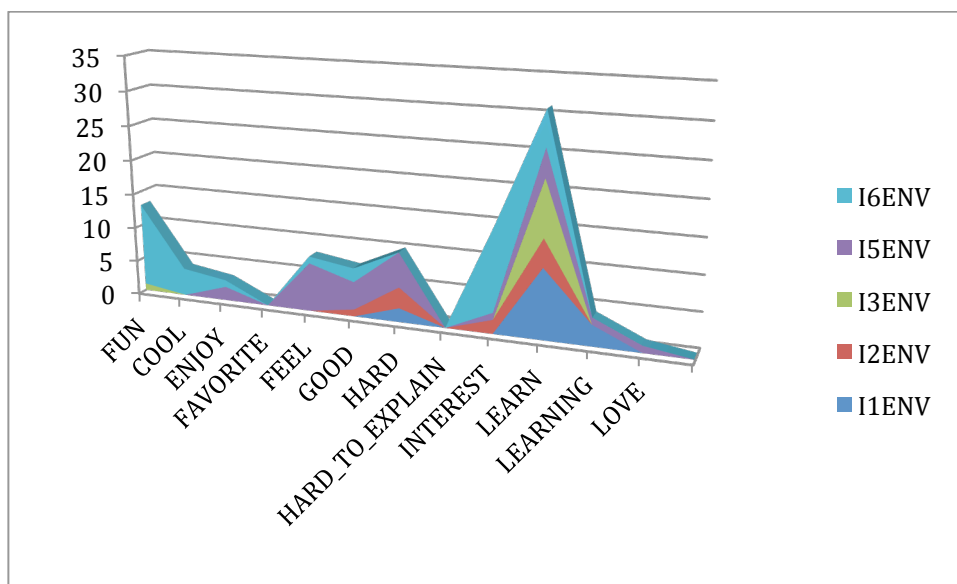


Figure 6-7 Inquiry: Environments, Cohort 1 (Spring 2013) and Cohort 2 (Fall 2012)

## Appendix 12

### 6.14 Students Talking about their Images of Science

Table 6-12 Images of Science

Science is...		Cohort 1				Cohort 2			
		Fall 2012 MSRC (n=35) Landforms (n=30)		Winter 2013 MSRC (n=16) Landforms (n=21)		Winter 2013 MSRC (n=16) Landforms (n=21)			
Category	Theme	F*	%**	F	%	F	%	F	%
Function	How things work			8	28	4	25		
	Experiment	13	37	12	40	7	41	9	43
	Figure out	8	23					5	24
	Practices	7	20	9	30				
Purpose	DCI <sup>1</sup>	11	31	8	28	5	33	6	29
	Everything	9	26			5	33		
	Learn	8	23					6	29
	World, Nature, Earth	7	20	8	27	4	25		
	Cross-cutting concept	6	17	7	24	4	25	6	29
	Fun			9	30				
Function		Winter 2013 PolSol (n=27) MixSol (n=18)				Spring 2013 PolSol (n=16) MixSol (n=16)			
	Experiment	5	19						
	Figure out	4	15	3	17				
	Discovery	4	15						
	Collaboration	4	15						
	Prediction					2	13		
	Solve							4	25
	Doing science Practices							3	19
Purpose	World, Nature, Earth	4	15			3	19		
	Cross-cutting concept			5	28				
	Everything			3	17				
Function		Spring 2013 Algae (n=36) Env (n=25)				Fall 2012 Algae (n=15) Env (n=23)			
	Practices	10	28					9	39
	Prediction	8	22						
	Experiment	7	19	4	16	4	27	11	48
	How things work					5	33		

Purpose	Figure out					7	30	
	Discovery					5	22	
	Human safety	8	22					
	World, Nature, Earth				9	60	4	17
	Cross-cutting concept				3	20	6	26
	Learn				3	20	6	26
	Everything			7	28			
	DCI			4	16			13
Fun							4	17

\* Frequency

\*\* Percentage of Cases

## Appendix 13

### 6.15 The Inclination and Obligation of Doing Science

Table 6-13 Text Statistics for GL (Inquiry) and SK (Agency)

		130503_GL_MIXSOL INQUIRY	121022_SK_MRSC AGENCY
Length	Words in text	8595	4039
	Sentences in text	1003	362
Text Complexity	Av. Word Length	4.16	4.33
	Av. Sentence Length	8.56	11.1
Lexical Density	Lexemes per sentence	4.19	5.39
	Lexemes % of text	48.90	48.37
Reference Density: (% of tokens)	1 <sup>st</sup> person Reference	4.76	4.46

#### 6.15.1 'Who does science?'

Table 6-14 Who does science?

Who does science?		Cohort 1				Cohort 2			
		Fall 2012		Landforms		Winter 2013		Landforms	
Category	Theme	MSRC (n=32)	(n=30)	F	%	MSRC (n=15)	(n=20)	F	%
... do	Scientists	20	63	21	69	11	73	19	93
	Kids (in school)	13	41	8	28	13	87	4	20
... does	Everybody	16	50	7	24	10	67	12	60
... could	People	28	88	5	18	4	27	7	35
		Winter 2013				Spring 2013			
		PolSol (n=27)		MixSol		PolSol (n=16)		MixSol	
		(n=18)				(n=16)			
... do	Scientists	8	30	4	22	6	38	2	25
	Kids (in school)	13	48			4	25	2	25
... does	Everybody	11	41	2	11	7	44		
... could	People	5	19	5	28			2	25
		Spring 2013				Fall 2012			
		Algae (n=31)		Env (n=29)		Algae (n=17)		Env (n=24)	
		(n=31)		(n=29)		(n=17)		(n=24)	
... do	Scientists	17	55	9	31	6	35	19	79
	Kids (in school)	6	19						
... does	I							8	33
... does	Everybody	10	32	6	21	7	41	7	41
... could	People	8	26						

\* Frequency \*\* Percentage of Cases

## Appendix 14

### 6.16 Agency-related Interview Questions T-Lab Descriptive Statistics

Table 6-15 Agency-related Interview Questions Descriptive Statistics

Corpus	A2 (N)	A3 (N)	A4 (N)	A5 (N)
<b>Context</b>				
Texts	244	243	226	225
<b>Variables</b>				
Cohort 1	172 (67%)	165 (67%)	157 (69%)	153 (64%)
Cohort 2	72 (33%)	78 (33%)	69 (31%)	72 (36%)
<b>Units</b>				
Algae	48	45	47	48
Environments	37	49	30	36
Landforms	41	40	34	34
MSRC	48	47	48	48
PolSol	35	33	34	33
MixSol	36	29	33	26
<b>Words</b>				
Tokens	14972	13274	14305	9759
Lemmas	916	860	1028	919
Hapax (occ=1) <sup>ii</sup>	437	428	476	417
Threshold Frequency <sup>iii</sup>	5	5	4	4
<b>Method</b>	TF-IDF <sup>18</sup>			
<b>Key-term selection</b>	1000			

### 6.17 Thematic Analysis of Elementary Contexts

#### 6.17.1 Preprocessing:

The preprocessing phase of the student interview responses were segmented in Elementary Contexts (ECs) where either textual ‘chunks’ or the short texts were selected. The corpus was then preprocessed with automatic lemmatization, with stop-word and multi-word lists, which were further refined.

#### 6.17.2 Procedure (Lancia, 2012):

1. Construction of a data table context units x lexical units, with presence/absence values;

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<sup>18</sup> The TF-IDF measure (Salton, 1989) evaluates the weight of a term (lexical unit) within a document (context unit).

2. TF-IDF normalization and scaling of row vectors to unit length (Euclidean norm). The formula is the following:

$$w_{i,j} = tf_{i,j} \times idf_i \text{ (Term Frequency} \times \text{Inverse Document Frequency)}$$

$$w_{i,j} = tf_{i,j} \times \left( \frac{N}{df_i} \right)$$

Where:

$tf_{i,j}$  = number of occurrences of  $i$  (term) in  $j$  (document)

$df_i$  = number of documents containing  $i$

$N$  = total number of documents

*Term Frequency* ( $tf_{i,j}$ ) value can be normalized as follows:

$$tf_{i,j} = tf_{i,j} / \text{Max}(f_{i,j})$$

where  $\text{Max}(f_{i,j})$  is the maximum frequency of  $i$  (any term) in the  $j$  (document).

3. Clustering of the context units
  - a. Measure: cosine coefficient;
  - b. Method: bisecting K-means
4. Filing of the obtained partitions and, for each of them:
5. Construction of a contingency table lexical units x clusters ( $n \times k$ );
6. Chi square test applied to all the intersections of the contingency table, where the formula is as follows:

$$X^2 = \sum \frac{(O-E)^2}{E}$$

Where:

“O” and “E” represent Observed and Expected frequencies, respectively. For each cell, the expected (E) occurrences are calculated as follows:

$$(N_i \times N_j) / N_{ij}$$

7. Correspondence analysis of the contingency table lexical units x clusters

## 6.18 Thematic Analysis of Elementary Contexts Descriptive Statistics

Table 6-16 Theme Analysis Descriptive Statistics

Corpus	A2	A3	A4	A5
<b>Text Segmentation</b>	Texts	Chunks	Chunks	Texts
<b>Elementary Contexts (ECs)</b>	244	323	325	225
<b>Key-Terms</b>	136	117	208	150
<b>Method</b>	Unsupervised clustering (bisecting K-means)	Unsupervised clustering (bisecting K-means)	Unsupervised clustering (bisecting K-means)	Unsupervised clustering (bisecting K-means)
<b>Thematic Clusters Obtained</b>	Max. 10	Max. 10	Max. 10	Max. 10
<b>Co-Occurrences within the Context Units</b>	Min. 2	Min. 2	Min. 2	Min. 2
<b>Classified Contexts</b>	237 (97% of ECs)	309 (96% of ECs)	314 (97% of ECs)	195 (87% of ECs)
<b>Partitions</b>	6 Clusters	4 Clusters	5 Clusters	6 Clusters

## 6.19 Agency-related Interview Question Responses

### 6.19.1 Thematic Analyses Cluster Theme Example in Context

**A2:** Some students like it when the teacher tells how to do things in science. Other students prefer to figure things out on their own or with other students. Which do you prefer and why?

**Cluster 1 Learning:** “I think learning on my own 'cause then I don’t get, like, um, 'cause if you, if the teacher tells you what to do, you’re gonna probably learn, like, nothing but if you figure it out on your own you’re gonna get it more and, like, so if the teacher tells you what to do with the experiments, like okay so you gotta do this and this, okay this is what you gotta write, this is your conclusion and everything. But if you do it on your own, um, you can, like, learn more and, um, work harder and not be all, like, lazy so I prefer doing it, learning on my own or with, like, my teammates. (ASA41).”

**Cluster 2 Interest:** “I would prefer, um, figuring it out on your own because, um, it’s not as interesting when everything is just told to you, when you figure it out it’s a lot more, um, um, uh, uh, how should I say it, um, exciting when you figure it out (AK52).”

**Cluster 3 Student:** “I would prefer to do it, um, with a group, figure it out with other students (AK62).”

**Cluster 4 Figure out:** “Figuring stuff out on my own (MC45).”

**Cluster 5 Table group:** “What the teacher tells me because, like, we were in, like, a table group, I was in a table group and there was, like, this one, there's either, like, always in one table group there is, like, a person that, like, likes to not pay attention to the teacher during science and I don’t really like that (AH60).”

**Cluster 5 Direction:** “Um, I like if the teacher gives a basic layout directions but doesn’t go in-depth so the students can figure out the in-depth things (CJ49).”

**A3:** Do you think you learn more/better by figuring things out on your own, or by having your teacher tell you?

**Cluster 1 Learn Better:** "Uh, when I figure it out. Well I'm still learning when the teacher tells me, because, well I'm still figuring out, like, how it, like, works I guess but, um, but she's just telling us how it works, but I'm learning the same thing when I'm doing it on my own, so. Uh, I would want to figure it out on my own (AK45)."

**Cluster 2 Think I learn:** “I think you learn better when you figure things out on your own 'cause then if you make mistakes you learn not to do, make that mistake so you don’t make it in the future (SK50).”

**Cluster 3 Learning:** “When you learn on your own it tends to just stick in your head. When you learn it by tea - when a teacher tells you, you have to be drilled, you have to be rev - you have to review it to remember it because just learning it on your own just gives you a sense of discovery that you’ll usually remember. Learning it by a teacher doesn’t have that effect (JB40).”

**Cluster 4 People:** “Um... well if, if I’m in a group, some people in that, in the group maybe work better with instructions, but for me I work better without them telling me because then I, I can, like, help those people out and so they understand, like, what we think and then I get them to, like, share their opinion (SK47).”

**Cluster 5 Ways:** “If the teacher gives us a hint, like to tell us, like, what material, that's okay but, um, I like figuring things out on my own because I think that gives us a better chance to learn what happens. Because then you get to experiment with different varieties of things and you get a chance to know more (MC54)”.

**A4:** Did you make choices? Examples of choices.

**Cluster 1 Choosing:** “Yeah well sometimes, like, we got to choose, we got to study an animal in my group, we got to choose one, so and then we also got...we choose, we chose the orca and then, so we also got to choose what we wanted to do our, um, presentation, our Go Public presentation about, so we chose what organisms it affects so we did get choice (AK62).

**Cluster 2 Power Point:** “Like, we decided what we were gonna do for our stream tables, except for one, just to practice them. Um, we decided, like, the site, which site we would do if we would do a site. We, and we decided on, um... how the Skokomish River, you think it’s flooding and how to do our posters. Yeah (AW48).”

**Cluster 3 Unit Elements:** “Well we had to choose what site we were gonna do. What we would have to do for our experiments, and I feel like it made it, would have been a little easier I guess if we had directed experiments and if we knew what kind of earth material was at each site,' cause I wasn't 100% sure (SK41)”.

**Cluster 4 Algae:** “I think I, I think we all did, I mean, choosing especially for, um, like, when we did the algae, do we want to do more water, less water, more algae and less algae, more space, less space? There were many different options and so considering all those options, we probably had to make choices (AK59).”

**Cluster 5 People:** “Picking the site. Um, picking, like, um, what, like, different things to say to my team, like, we should pick this site when we were discussing which site we'd pick because two other people picked site one in our group but we ended up just picking site three (AW61).

**A5:** What did you do in this unit that helped you learn?

**Cluster 1 HABs:** “Uh, figuring it out on our own and doing research. Like, research about HABs and, like, how, and what good HABs, good algae is instead of like everything's just all bad in the world (AD48).”

**Cluster 2 Experiments Helped:** “Umm what really helped me learn was umm it was working with a small group of kids I think it was four of us and umm we just we sort of like we figured out and we kind of worked with the same seats umm all through the unit, so when we kind of figured out that uhh that some plants grow faster and slower. Just like all throughout the unit (EB49).”

**Cluster 3 Hands-on:** “Um, I think the experiments helped me learn 'cause it's, like, a hands-on thing and I know most people like to do hands-on things than just learn it by them being told (SK43).”

**Cluster 4 Erosion:** “Well I think the experiments and actually watching erosion happen helped me, helped me, um, see what erosion was and the deltas helped me see what deposition was (AK57).”

**Cluster 5 Algae:** “Um, probably, um... hmm, probably the experiments, especially the fertilizer one 'cause when I did my interviews, everyone said, almost everyone said that fertilizer, um, helps algae but it actually, well maybe some fertilizers do but the fertilizer that we used actually killed algae, like, completely wiped it out (AD62).”

**Cluster 6 Control:** “Um, it helped me learn again learning about myself and with others but not, like, a big group, just like a small one, but still I learned with them and I learned how to cooperate with different type of people [...] because there's always someone who wants to take control and I like to take control of myself not people taking control of me or taking control of others, it's just better to for me...(PB55).”

## Appendix 15

### 6.20 Hierarchical Linear Modeling Results for Inquiry Assessments

#### 6.20.1 Landforms and MSRC

Table 6-17 Landforms (Inquiry) and MSRC (Agency) Descriptive Statistics

Unit	Total Score		Cluster 1 Inv. Q total		Cluster 2 Prediction total		Cluster 3 Variable total		Cluster 4 Conclusion Q Score total		Cluster 5 New Inv. total		Cluster 6 Confounds Change total		STAR Math 2012		STAR Reading 2012	
	L*	M**	L	M	L	M	L	M	L	M	L	M	L	M	L	M	L	M
Mean	10.43	15.27	2.40	4.34	.40	.70	3.79	5.02	2.28	2.89	.60	1.29	1.38	1.41	736.04	739.14	705.66	716.27
Std. Dev.	4.44	4.22	1.55	1.02	.49	.46	1.90	1.29	1.24	1.10	.92	.99	1.10	1.19	91.51	98.68	221.05	237.12
Range	20	20	5	5	1	1	6	6	5	4	3	3	4	4	510	794	1148	1256
Valid N	163	215	159	214	159	214	159	211	159	210	137	189	156	209	137	192	137	194

\*L (Landforms)

\*\*M (MSRC)

Table 6-18 Model Design

Individual-level variables:

DV: (parallel analyses run)

Landforms and MSRC Assessment Questions

Inquiry total scores (inquiry\_total)

cluster 1- Investigation Question (Q. frame/manip/resp var)

Write your investigative question in the box below:

cluster 2- Prediction (single item only)

Write a prediction for what you think will happen in your investigation and then explain why you think this: "I predict...because..."

cluster 3- Variables (q.1-3 same/changed/measured)

1) Identify at least 2 variables that were kept the same.

cluster 4- Conclusion (q.4 conclusive statement, supporting data and comparison)

2) Identify the variable that was changed.  
3) What is your measured variable? Be specific.  
4) Write a conclusion for the investigation.  
Be sure to:

- Answer the investigative question.
- Include **supporting** data.
- Explain how this data **supports** your conclusion.

cluster 5- New Investigation (q.5-6 changes and explanation)

5) If you could re-do your investigation to improve it, what changes would you make?

cluster 6- Nancy's Investigation (confound and explanation)

6) Why would you make these changes?  
Nancy is a student who has been studying erosion in stream tables. She did an investigation to study how slope affects the length of the delta in a stream table.

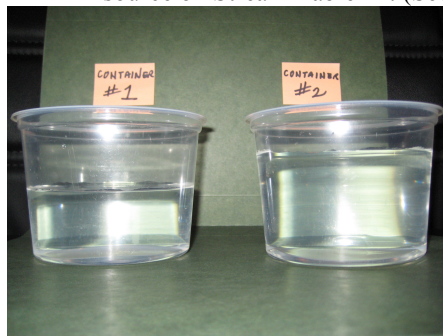
Here's what she wrote for her study procedure:

In Stream Table #1:

1. Put earth material at one end of Stream Table #1.
2. Spread earth material to cover 20 cm from end.
3. Prop up the stream table on a wood angle so that it is sloped not horizontal.
4. Pour water from Container #1 into the water source on Stream Table #1. (See picture)

In Stream Table #2:

- i. Put potting soil at one end of Stream Table #2.
- ii. Spread potting soil to cover 20 cm from end.
- iii. Put Stream Table #2 on a flat surface.
- iv. Pour water from Container #2 into the water source on Stream Table #2. (See picture)



Nancy measures the length of the delta in Stream Table #1 and #2 and concludes that slope has no effect on the length of the delta.

Give Nancy feedback on her investigation. What should she change? Why?

IV:

- STAR 2012 math score (STAR\_math\_12) – *group-centered*
- STAR 2012 reading score (STAR\_reading\_12) – *group-centered*

Group-level variables:

- Unit Treatment (group\_id)
- Cohort (cohort\_id)
- unit/cohort interaction (interact)

Clustering:

- Classroom (class\_id\_orig)

Variables not in model: positive affect construct, negative affect construct, and school.

## Results Overview

The Level 2 model includes group-level covariates: treatment, cohort, and treatment-cohort interaction term. The model tests whether the Dependent Variable is predicted by

classroom and baseline math and reading scores, but also varies by treatment condition and cohort.

*Table 6-19 Level 2 Model Summaries of Landforms and MSRC Inquiry Results*

Predictors / DVs	Inquiry Total	cluster 1 Inv. Q.	cluster 2 Prediction <sup>1</sup>	cluster 3 Variables	cluster 4 Conclusion	cluster 5 New Inv.	cluster 6 Nancy's Inv.
<b>Cohort (cohort_id)</b>	NS	NS	$\gamma_{01} = -.49$ , p=.013 two-tailed; p<.01 one-tailed	NS	NS	approached sig. $\gamma_{01} = -.11$ , p=.11 two-tailed; p=.055 one-tailed	NS
<b>Unit Treatment (group_id)</b>	$\gamma_{02} = 2.56$ , p<.001	$\gamma_{02} = .98$ , p<.001	$\gamma_{02} = .78$ , p<.001	$\gamma_{02} = .65$ , p<.01	$\gamma_{02} = .32$ , p=.02 two-tailed, p=.01 one-tailed	$\gamma_{02} = .4$ , p<.001	NS
<b>STAR 2012 math (STAR_math_12)</b>	$\gamma_{10} = .013$ , p<.001	$\gamma_{10} = .003$ , p<.001	approached sig. ( $\gamma_{20} = .0026$ , p=.055, one-tailed).	$\gamma_{10} = .003$ , p<.001	$\gamma_{10} = .003$ , p<.001	NS	$\gamma_{10} = .003$ , p<.001
<b>STAR 2012 read (STAR_reading_12)</b>	$\gamma_{20} = .005$ , p<.001	approached sig. ( $\gamma_{20} = .0005$ , p=.053, one-tailed).	$\gamma_{10} = .0015$ , p<.05	$\gamma_{20} = .001$ , p<.01	$\gamma_{20} = .001$ , p<.001	$\gamma_{20} = .0009$ , p<.001	$\gamma_{20} = .001$ , p<.001

## Setup

Data excluded non-consented participants; participants identified as serious IEP and ELL; unidentified students; and incomplete data. Data included the Agency and Inquiry groups combined of two cohorts (fall 2012 and winter 2013). HLM used inquiry total scores and cluster scores as outcome variables to check whether those scores are depending on classroom/teacher, treatment, cohort, and affected by covariates (2012 STAR math and reading). The positive affect construct was not used as covariate as it could be affected by treatment/control condition.

## Overview of Results

The Level 2 model includes group-level covariates: treatment, cohort, and treatment-cohort interaction term. The model tests whether the Dependent Variable is predicted by classroom and baseline math and reading scores, but also varies by treatment condition and cohort.

Results show the baseline math and reading test scores were significant predictors ( $\gamma_{10} = .013$ , p<.001;  $\gamma_{20} = .005$ , p<.001 respectively). The treatment, Inquiry vs. Agency, ( $\gamma_{02} = 2.56$ , p<.001) was a significant predictor after controlling for classroom effect and baseline math an

reading test scores. Inquiry total scores in the Agency classrooms were higher than the scores in Inquiry classrooms.

Cluster 1: Investigation Question (question. frame/manipulated/responding variable) results reveal that the baseline math score was a significant predictor ( $\gamma_{10} = .003$ ,  $p < .001$ ); the reading score approached significance ( $\gamma_{20} = .0005$ ,  $p = .053$ , one-tailed). The treatment, Inquiry vs. Agency, ( $\gamma_{02} = .98$ ,  $p < .001$ ) was a significant predictor after controlling for classroom effect and baseline test scores. Cluster 1 scores in Redesign classrooms were higher than the scores in FOSS classrooms.

Cluster 2: Prediction (single item only) was run with Bernoulli outcome distribution (0,1) since the outcome variable is a single item scored 0/1. The baseline reading score was a significant predictor ( $\gamma_{10} = .0015$ ,  $p < .05$ ); the math score approached significance ( $\gamma_{20} = .0026$ ,  $p = .055$ , one-tailed). The cohort ( $\gamma_{01} = -.49$ ,  $p = .013$  two-tailed;  $p < .01$  one-tailed) was a significant predictor. Cluster 2 scores in fall (Cohort 1, higher SES) classrooms were higher than the scores in winter (Cohort 2, lower SES) classrooms.

Cluster 3: Variables (q.1-3 same/changed/measured) for this treatment, Inquiry vs. Agency, was a significant predictor ( $\gamma_{02} = .78$ ,  $p < .001$ ) after controlling for classroom effect and baseline test scores. Scores on the Prediction item in the Agency classrooms were higher than the scores in the Inquiry classrooms.

Cluster 4: Conclusion (q.4 conclusive statement, supporting data and comparison) writing scores show that the baseline math and reading test scores were significant predictors ( $\gamma_{10} = .003$ ,  $p < .001$ ;  $\gamma_{20} = .001$ ,  $p < .01$  respectively). The treatment was a significant predictor ( $\gamma_{02} = .32$ ,  $p = .02$  two-tailed,  $p = .01$  one-tailed) after controlling for classroom effect and baseline test scores. Cluster 4 scores in the Agency classrooms were higher than the scores in the Inquiry classrooms.

Cluster 5: New Investigation (q.5-6 changes and explanation). The baseline reading test score was a significant predictor ( $\gamma_{20} = .0009$ ,  $p < .001$ ); math score was not a significant predictor. The cohort effect approached significance ( $\gamma_{01} = -.11$ ,  $p = .11$  two-tailed;  $p = .055$  one-tailed). The treatment (FOSS vs. Redesign) was a significant predictor ( $\gamma_{02} = .4$ ,  $p < .001$ ) after controlling for classroom effect and baseline test scores. Cluster 5 scores in the Agency classrooms were higher than the scores in the Inquiry classrooms.

Cluster 6: Nancy's Investigation (confound and explanation) - The baseline math and reading test scores were significant predictors ( $\gamma_{10} = .003$ ,  $p < .001$ ;  $\gamma_{20} = .001$ ,  $p < .001$  respectively). However, the treatment and Cohort were not significant predictors.

## 6.21 Mixtures and Solutions (Inquiry\_MixSol) and Pollution Solution (Agency\_PolSol)

Table 6-20 Mixtures and Solutions (Inquiry\_MixSol) and Pollution Solution (Agency\_PolSol) Descriptive Statistic

Unit	Total Score		Cluster 1		Cluster 2		Cluster 3		STAR Math 2012		STAR Reading 2012	
	MixSol	PolSol	MixSol	PolSol	MixSol	PolSol	MixSol	PolSol	MixSol	PolSol	MixSol	PolSol
Mean	5.58	6.47	2.01	2.54	2.29	2.63	.70	.60	730.44	746.92	692.06	726.16
Std. Dev.	2.68	2.45	1.46	1.46	1.12	.82	.98	.99	98.35	92.58	226.90	228.84
Range	12.00	11.00	5.00	5.00	3.00	3.00	3.00	3.00	564.00	516.00	1148.00	1193.00
Valid N	158	218	155	217	155	213	151	212	140	205	140	207

## Model Design

Table 6-21 Individual-level variables

DV: (parallel analyses run)	Mixtures & Solutions (Inquiry) and Pollution Solution (Agency) Assessment Questions
<b>Inquiry total scores (inquiry_total)</b>	
<b>cluster 1- Questions 1-3 (variables)</b>	<ol style="list-style-type: none"> <li>1) Identify one variable that was kept the same (controlled).</li> <li>2) Identify the variable that was changed (manipulated).</li> <li>3) Identify the measured (responding) variable.</li> <li>4) Write a conclusion for the investigation.</li> </ol>
<b>cluster 2- Question 4 (conclusive statement and supporting data)</b>	<p>Be sure to:</p> <ul style="list-style-type: none"> <li>• Answer the investigative question.</li> <li>• Include <b>supporting</b> data from the Substance vs. Mass of Solute Dissolved data table.</li> <li>• Explain how this data <b>supports</b> your conclusion.</li> </ul> <p>[Prediction: (More, less, the same amount of) citric acid compared to salt dissolves in 50 ml of water to form a saturated solution]</p>

**cluster 3- Chris' issue (confound and explanation)**

Like you, Chris is a student who has been studying saturated solutions.

He also investigated the question: “How does the **temperature of the water** affect the **mass (weight) of citric acid that dissolves** to form a saturated solution?”

*Here's what he wrote for his study procedure:*

1. Using a syringe, measure 30 ml of water into a container.
2. Heat container of water in microwave for 2 minutes.
3. Using a funnel, add citric acid to the bottle as shown in the picture.



4. Place lid on bottle and shake well.
5. Repeat steps 3-4 until the solution is saturated. Some un-dissolved citric acid will remain.
6. Using the funnel with wet filter paper, filter the solution so that the un-dissolved citric acid is captured by the filter and the saturated solution is in a cup.
7. Place the cup of solution on one side of a two-pan balance and a cup with 50 ml of plain water on the other side. Add gram weights to the plain water to achieve balance.
8. Record the number of grams of citric acid it takes to saturate the water.
9. Collect data from other groups in the class.
10. Find and record the average for the trials.
11. Compare the average grams for the heated solution to the average grams for the un-heated citric acid solution from yesterday's investigation.

***Here are the results of Chris' investigation:*** He found the same mass (weight) of citric acid solute in the heated and unheated solutions. He concluded that the water temperature had no effect on the mass of the solute that dissolves to form a saturated solution.

Give Chris feedback on his procedure. What should he change? Why should he make this change?

**IV**

- STAR 2012 math score (STAR\_math\_12) – *group-centered*

- STAR 2012 reading score (STAR\_reading\_12) – *group-centered*

Group-level variables:

- Unit (group\_id)
- Cohort (cohort\_id)
- unit/cohort interaction (interact)

Clustering: Classroom (class\_id\_orig)

Variables excluded from model: positive affect construct; negative affect construct; and school.

### Setup

Data includes both the Agency and Inquiry groups of two cohorts (Winter and Spring 2013). HLM used **inquiry total scores and cluster scores** as an outcome variable to check whether those scores are depending on classroom/teacher, treatment, and cohort, and affected by covariates (2012 STAR math and reading). The positive affect construct was not used as covariate as it could be affected by treatment/control condition.

### Level 2 Model Summaries of MixSol and PolSol Inquiry Results

Table 6-22 Level 2 Model Summaries of MixSol and PolSol Inquiry Results

Predictors / DVs	Inquiry Total	cluster 1 Inv. Q.	cluster 2 Prediction	cluster 3 Variables
<b>Cohort</b> (cohort_id)	$\gamma_{01} = -.79, p < .01$	$\gamma_{01} = -.27, p < .05$	$\gamma_{01} = -.20, p = .051$ two-tailed; $p < .05$ one-tailed*	$\gamma_{01} = -.23, p < .01$
<b>Unit Treatment</b> (group_id)	$\gamma_{02} = .46, p < .05$ one-tailed	$\gamma_{02} = .28, p < .05$	$\gamma_{02} = .16, p = .107$ two-tailed; $p = .054$ one-tailed (NS)	$\gamma_{02} = -.02, p = .73$ (NS)
<b>STAR 2012 math</b> (STAR_math_12)	$\gamma_{10} = .006, p < .001$	$\gamma_{10} = .004, p < .001$	$\gamma_{10} = .001, p < .05$	$\gamma_{10} = .0007, p = .264$ (NS)
<b>STAR 2012 read</b> (STAR_reading_12)	$\gamma_{20} = .002, p < .001$	$\gamma_{20} = .001, p < .01$	$\gamma_{20} = .001, p < .001$	$\gamma_{20} = .005, p = .069$ two-tailed; $p < .05$ one-tailed

\* Significant predictor

## 6.22 Environments (Inquiry) and Algae Invasion (Agency)

Table 6-23 Environments (Inquiry) and Algae Invasion (Agency) Descriptive Statistics

	Total Score		Cluster 1 Inv. Q total		Cluster 2 Prediction total		Cluster 3 Variable total		Cluster 4 Conclusion total		Cluster 5 New Inv. total		Cluster 6 Confounds Change total	
	*Env	Algae	Env	Algae	Env	Algae	Env	Algae	Env	Algae	Env	Algae	Env	Algae
<b>Unit</b>														
<b>Mean</b>	7.41	12.46	1.14	3.64	.54	.72	2.66	4.36	2.32	2.38	.74	.65	.14	.79
<b>Std. Dev.</b>	3.38	3.80	1.09	1.29	.50	.45	1.68	1.53	1.06	.99	.92	.96	.43	.95
<b>Range</b>	14.00	20.00	5.00	5.00	1.00	1.00	6.00	6.00	3.00	3.00	3.00	3.00	2.00	4.00
<b>Valid N</b>	133	193	133	193	128	190	133	193	133	193	113	171	128	192

\*Env (Environments\_Inquiry)

### Model Design

Table 6-24 Individual-level variables

DV: (parallel analyses run)	Environments (Inquiry) and Algae Invasion (Agency) Assessment Questions
<b>Inquiry total scores (inquiry_total)</b>	
<b>cluster 1- Investigation Question (q. frame/manipulated/responding variable)</b>	Algae: Write your investigative question in the box below. Environments: If you could do another investigation with isopods in a runway, what would you do? Write a new investigative question and plan an investigation that could answer your new question. Be sure to include: <ul style="list-style-type: none"> <li>· Prediction (hypothesis) of the investigation results</li> <li>· Materials needed to do the investigation</li> <li>· Procedure</li> </ul>
<b>cluster 2- Prediction (single item only)</b>	Write a prediction for what you think will happen in your investigation and then explain why you think this: “I predict...because...”
<b>cluster 3- Variables (q.1-3 same/changed/measured)</b>	1) Identify at least 2 variables that were kept the same. 2) Identify the variable that was changed. 3) What is your measured variable? Be specific.
<b>cluster 4- Conclusion (q.4 conclusive statement and supporting data)</b>	4) Write a conclusion for the investigation. Be sure to: <ul style="list-style-type: none"> <li>• Answer the investigative question.</li> <li>• Include <b>supporting</b> data.</li> </ul>
<b>cluster 5- New Inv (q.5-6 changes and explanation)</b>	Explain how this data <b>supports</b> your conclusion. 5) If you could re-do your investigation to improve it, what changes would you make? 6) Why would you make these changes?

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**cluster 6- Confounds/Change (confound and explanation)****Algae (Agency):**

Andy is a student who has been studying environmental factors that affect algae growth. He did an investigation to study how water temperature affects algae growth.

Here's what he wrote for his study procedure:

1. Put water in 2 cups.



2. Add 20 drops of algae to each cup.
3. Put Cup #1 in a window in the classroom where the sun will warm the water.
4. Put Cup #2 in a place in the classroom that doesn't get warm sun.
5. After 3 days, measure the amount of algae in each cup by comparing the color of the algae to a Color Scale.

After 3 days, Andy measured the color of the algae in each cup using the Color Scale. The algae color was the same in both cups.

Based on his results, Andy concluded that water temperature has no effect on algae growth.

9) Give Andy feedback on his investigation. What should he change? Why?

**Environments (Inquiry):**

Carrie is a student who has been studying isopods and their habitats. She did an investigation to study how light affects the location of isopods in a runway.

Here's what she wrote for her study procedure:

1. Put 100 ml of soil at each side of the runway.
  2. Add water to the soil. (See Picture)
-



3. Put 8 isopods in the middle of the runway.
4. Put runway on windowsill where Side #1 is in the sun and Side #2 is in the shade.
5. After 30 minutes, record the location of the isopods in the runway.

Based on her results, Carrie concluded that light has no effect on the location of isopods in a runway.

Give Carrie feedback on her investigation. What should she change? Why?

#### IV

- STAR 2012 math score (STAR\_math\_12) – *group-centered*
- STAR 2012 reading score (STAR\_reading\_12) – *group-centered*

Group-level variables:

- Unit Treatment (group\_id)
- Cohort (cohort\_id)
- Unit/cohort interaction (interact)

Clustering: Classroom (class\_id\_orig)

Variables not in model: positive affect construct; negative affect construct; and school

#### Setup

Data includes the Agency and Inquiry groups of two cohorts (fall 2012 and spring 2013). HLM used inquiry total scores and cluster scores as outcome variables to check whether those scores are depending on classroom/teacher, treatment, and cohort, and affected by covariates (2012 STAR math and reading). The positive affect construct was not used as covariate as it could be affected by treatment/control condition.

#### Level 2 Model Summaries of Environments and Algae Invasion Inquiry Results

Table 6-25 Level 2 Model Summaries of Environments and Algae Invasion Inquiry Results

Predictors / DVs	Inquiry Total	cluster 1 Inv. Q	cluster 2 Prediction *	cluster 3 Variables	cluster 4 Concl.	cluster 5 New Inv.	cluster 6
<b>Cohort (cohort_id)</b>	$\gamma_{01} = 1.47,$ p=.006	approached sig. ( $\gamma_{01} = -$	NS	$\gamma_{01} = .51,$ p=.007	$\gamma_{01} = .39,$ p=.011	NS	$\gamma_{01} = .15,$ p=.025

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		.11, p=.11 two-tailed; p=.055 one-tailed)					
<b>Unit Treatment (group_id)</b>	$\gamma_{02} = 2.89,$ p<.001	$\gamma_{02} = 1.32,$ p<.001	$\gamma_{02} = .5,$ p=.011	$\gamma_{02} = .97,$ p<.001	NS	NS	$\gamma_{02} = .35,$ p<.001
<b>Treatment (trimester/ cohort)</b>	NS	NS.	$\gamma_{03} = -.37,$ p<.05**	NS	NS	NS	NS
<b>interaction STAR 2012 math (STAR_ math_12)</b>	$\gamma_{10} = .006,$ p=.002;	NS.	NS	NS	NS	$\gamma_{20} = .001,$ p<.05	$\gamma_{10} = .001,$ p<.05
<b>STAR 2012 read (STAR_ reading_12)</b>	$\gamma_{20} = .004,$ p<.001	NS	$\gamma_{10} = .002,$ p<.001	$\gamma_{10} = .001,$ p<.001	$\gamma_{10} = .001,$ p<.001	NS	NS

---

\* Model was run with Bernoulli outcome distribution (0,1) since the outcome variable is a single item scored 0/1

\*\* The mean Redesign score was higher than FOSS but decreased slightly in spring, while the mean FOSS score in spring was almost twice as large compared to fall and approached the Redesign level.

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<sup>i</sup> Contiguity refers to sequential occurrences or series of things in proximity. Associations are made by similarities where a property of  $x$  primes the ideas or experiences of  $y$ . For example, 'experiments' and 'stream tables' are a property of 'science'.

<sup>ii</sup> A hapax legomenon refers to a word occurring or appearing once in a text or corpus.

<sup>iii</sup> A minimum frequency threshold of 4 to select words or lemmas for the key-word list during the pre-processing phase establishes reliability of statistical computations.