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The application of language-game theory to the analysis of science learning: developing an interpretive classroom-level learning framework

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THE APPLICATION OF LANGUAGE-GAME THEORY TO THE ANALYSIS OF SCIENCE LEARNING: DEVELOPING AN INTERPRETIVE CLASSROOM-LEVEL LEARNING FRAMEWORK

by

Mohammad Ahmadibasir

An Abstract

Of a thesis submitted in partial fulfillment
of the requirements for the Doctor of
Philosophy degree in Science Education
in the Graduate College of
The University of Iowa

July 2011

Thesis Supervisor: Professor Brian Hand

ABSTRACT

In this study an interpretive learning framework that aims to measure learning on the classroom level is introduced. In order to develop and evaluate the value of the framework, a theoretical/empirical study is designed. The researcher attempted to illustrate how the proposed framework provides insights on the problem of classroom-level learning. The framework is developed by construction of connections between the current literature on science learning and Wittgenstein's language-game theory. In this framework learning is defined as change of classroom language-game or discourse. In the proposed framework, learning is measured by analysis of classroom discourse. The empirical explanation power of the framework is evaluated by applying the framework in the analysis of learning in a fifth-grade science classroom. The researcher attempted to analyze how students' colloquial discourse changed to a discourse that bears more resemblance to science discourse. The results of the empirical part of the investigation are presented in three parts: first, the gap between what students did and what they were supposed to do was reported. The gap showed that students during the classroom inquiry wanted to do simple comparisons by direct observation, while they were supposed to do tool-assisted observation and procedural manipulation for a complete comparison. Second, it was illustrated that the first attempt to connect the colloquial to science discourse was done by what was immediately intelligible for students and then the teacher negotiated with students in order to help them to connect the old to the new language-game more purposefully. The researcher suggested that these two events in the science classroom are critical in discourse change. Third, it was illustrated that through the academic year, the way that students did the act of comparison was improved and by the end of the year more accurate causal inferences were observable in classroom communication. At the end of the study, the researcher illustrates that the application of the proposed framework resulted in an improved version of the framework. The improved version of the proposed framework is more connected to the topic of science learning, and is able to measure the change of discourse in higher resolution.

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CERTIFICATE OF APPROVAL

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PH.D. THESIS

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This is to certify that the Ph.D. thesis of

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TO NILOUFAR

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ABSTRACT

In this study an interpretive learning framework that aims to measure learning on the classroom level is introduced. In order to develop and evaluate the value of the framework, a theoretical/empirical study is designed. The researcher attempted to illustrate how the proposed framework provides insights on the problem of classroom-level learning. The framework is developed by construction of connections between the current literature on science learning and Wittgenstein's language-game theory. In this framework learning is defined as change of classroom language-game or discourse. In the proposed framework, learning is measured by analysis of classroom discourse. The empirical explanation power of the framework is evaluated by applying the framework in the analysis of learning in a fifth-grade science classroom. The researcher attempted to analyze how students' colloquial discourse changed to a discourse that bears more resemblance to science discourse. The results of the empirical part of the investigation are presented in three parts: first, the gap between what students did and what they were supposed to do was reported. The gap showed that students during the classroom inquiry wanted to do simple comparisons by direct observation, while they were supposed to do tool-assisted observation and procedural manipulation for a complete comparison. Second, it was illustrated that the first attempt to connect the colloquial to science discourse was done by what was immediately intelligible for students and then the teacher negotiated with students in order to help them to connect the old to the new language-game more purposefully. The researcher suggested that these two events in the science classroom are critical in discourse change. Third, it was illustrated that through the academic year, the way that students did the act of comparison was improved and by the end of the year more accurate causal inferences were observable in classroom communication. At the end of the study, the researcher illustrates that the application of the proposed framework resulted in an improved version of the framework. The

improved version of the proposed framework is more connected to the topic of science learning, and is able to measure the change of discourse in higher resolution.

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THE STUDY OVERVIEW

The problem of classroom-level learning in science classroom

Leaning is a change of "something", and thus the question becomes what is the "something" that changes? Different fields of study look at learning in different ways and measure it differently. For instance, a cognitive scientist would consider learning as change of neuron activity in the mind of the individual, while a sociologist would define learning as change in the social structure of a society. A Cognitive scientist would tend to associate learning with individual and argue that the fundamental is the change in individual and any social changes is the byproduct of changes at the individual level. By contrast, a cultural psychologist would associate learning with culture and society and argue that individuals change as a result of cultural and social changes. Thus which one is fundamental, and which one is byproduct of the other is remained a controversial issue.

Wittgenstein's theory about the relation of language and reality can provide a solution for this individual-social antinomy. Wittgenstein states that there is no such thing as an essential aspect of words (2009). He states that all the differences and similarities we observe are not essential and don't have roots to external reality, they are just categorial differences and similarities that are developed through usage in a community. In this way of looking at words and their meaning, as there is no fundamental aspect for both objects and words, it is possible to break down the attachment between learning and individual or culture. The change or learning in any levels from atomic to holistic would be important and researchable without considering any of those levels as essential or fundamental. As Lewontin (1991) argued, in order to know the topic of study, research studies in different levels from the holistic to the atomic level are required and they are

not reducible to each other. There is no fundamental level that can explain what occurs in the other levels.

Which level of change should be considered primary in science education? A pragmatist response to this question is that classroom is an important unit of analysis in science education. Teachers are assessed based on the changes in their classroom and Science Education initiatives are designed and assessed based on changes at the classroom level. Thus measuring the changes at the level of classroom has a pragmatic value in science education. Therefore learning as change at the classroom level should be the primary improvement due to the practical advantages of this kind of improvement in the field of science education. This classroom-level learning should be closely connected to the lower level change of individuals as well as to the higher level change of society and culture. Despite this pragmatic value of defining learning at the level of classroom, traditionally, science educators have drawn on Piaget's ideas of constructionism and Kuhn's ideas of paradigm shift and developed the conceptual change framework. In this model, learning is defined as change in schema or conceptual patterns in an individual's mind. The emphasis on the individual in this model may come from the fact that the model borrowed originally from psychology where the fundamental is the change at an individual level. In this model nothing, besides the average change observed in individuals, is considered as a hypothetical construct that shows the learning at the level of classroom. Thus detaching learning from individual and constructing a hypothetical construct that represent learning at the level of classroom has a pragmatic value in science education.

The main problem that was addressed in this study is that in science education, learning is considered a change either at the level of individual or society and culture, yet very few explicit attempts have been made in order to build a hypothetical construct that shows learning at the level of classroom (ref, Sfard, 2007, 2008; Wickman & Ostamn,

2003; Wickman, 2002). The proposed framework in this study can be a response to this problem.

Classroom-level science learning: learning as change of discourse

In this theoretical/empirical investigation, the researcher searched for an interpretive framework that can speak directly to the change at the classroom level, classroom-level learning. In the following I will discuss how learning at the level of the classroom can be articulated.

The ideas of learning as change of discourse have been proposed in both science and mathematics education (ref, Sfard, 2004, 2008; Wickman, 2003, & Wickman and Ostman, 2002). When searching for learning at the level of the classroom, focusing on how an individual thinks or believes will have a secondary importance, as the major focus of attention is on how the ways of communication between a group of students change. What becomes a priority to focus on is the "collective patterned activities" (Sfard, 2007). The change in classroom discourse is an appropriate choice for the mentioned hypothetical construct. The discourse belongs to the classroom community, so its changes can be a representative of classroom change, is not bonded to individual, is situated in the science classroom, has the essence of culture and history, and finally the aspects of discourse such as vocabulary, rules, and routines can be operationally measured.

Wickman and Ostman (2002) stated that "Learning is…viewed as encounters between individuals and the world in a social and historical context" (p.603). Sfard (2007) further stated that discourses are inherently social, and rules and objects of discourses have social origin s. But if learning is change of classroom discourse, how is this discourse pertinent to society and history? This connection is extendedly discussed in the cultural-historical approaches of learning that come from Vygostky's and his

followers' views of learning. A strong alternative perspective that proposes similar views about the relation between discourse, language, and society comes from Wittgenstein's ideas of language-games (Wittgenstein, 2009, 1969). Both Wickman's and Sfard's theoretical frameworks are inspired by the language-game theory proposed by Wittgenstein.

Wittgenstein investigated the relation of society, culture, language, ontology of objects, and reality. Through the lens of language-game theory, it is through the discourse that social conventions and human perception are connected to each other: the discourse change on the one hand is connected to the change in social conventions and on the other hand is connected to the change in human perception. Change of culture and society is accompanied by change of social conventions and equated with change of discourse which consequently changes the way we see the world. We look at the world, see the objects, call them with their name, and think that those names are mapped to the external existence of those objects. However language-game theory proposes that what we see is an internal matter and related to the discourses, or the language-games, we have already learned.

As soon as the claim of language-game theory about the social origin of discourse and the effect of language on human perception is accepted, the theoretical application of this theory on learning becomes meaningful. If the origin of language and discourse is society rather than objective external reality, if the words are not essentially and intrinsically connected to the external reality of the concrete objects in the world, and that connection is instead made by human culture and society, then the more someone communicates and uses language, the more she will be able to see the world as others see it. Science as language or discourse can be learned through communication with people who know it, not in a laboratory and isolation. Becoming a master in a discourse requires an individual to go through the continuous process of communication, apprenticeship, with a master who has already practiced and mastered the discourse (Gee, 1989). As the

way we see the world is influenced by discourse, and thinking is influenced by the way we see the world, then communication becomes critical for the act of thinking (ref, Sfard, 2008).

How was the investigation conducted?

The purpose of this study was focused on an attempt to build an interpretive learning framework that can contribute to the analysis of change in the level of classroom. The Wittgenstein language-game theory can be chosen as the basis of this interpretive learning framework and accordingly the chosen hypothetical construct that is the representative of learning in the level of science classroom is "language-game" or discourse.

The theoretical connection: the theoretical aspect of this investigation is about making a connection between Wittgenstein's language-game theory and the current literature related to science learning in the classroom. The theoretical value of the interpretive framework can be evaluated by discussing how the proposed framework can have a meaningful insight on related literature in science education.

The empirical aspect of the investigation is about applying the framework to a science classroom. The empirical value of the interpretive framework can be measured by its power for the analysis of science learning in the classroom. In order to do this, Sfard's proposal for testing the interpretive framework was applied (2007). The basis of this test is that if an interpretive framework works, then it should have the power to shed light on three major problems of learning in classroom: the gap between what students do and what they are supposed to do in the classroom, how the teacher and students worked toward decreasing the gap, and the result of classroom learning over the instruction period.

In order to employ this evaluation on testing the proposed interpretive framework, the data of one academic year from a fifth-grade science classroom were chosen. The

data were analyzed by applying the interpretive framework which is based on language-game theory and the ideas of learning as change of discourse. Throughout the empirical study, learning as change of classroom language-game, or discourse, was investigated focusing on three questions: First, the gap between student colloquial discourse and classroom science discourse was analyzed. Second, the process of learning toward that objective was investigated. The researcher analyzed how teacher's and students' participation in classroom inquiry can change the colloquial to science discourse. Third, the overall changes in the whole academic year were analyzed in order to determine whether the gap was decreased or not. The researcher would suggest that if the interpretive framework has the explanation power in all three mentioned investigations then the framework has pragmatic value for both educators and researchers.

Research questions

As the nature of this investigation is partially theoretical and partially empirical, the questions that lead the investigation have the essence of both.

In the theoretical aspect, as Wittgenstein' language-game theory is not a popular theory in science education, there is a need to build a theoretical connection between language-game theory and the current literature related to science education. Therefore the theoretical research questions are: How can language-game theory be connected to current literature related to science education? How does this connection hold theoretical value?

In the empirical aspect, the main question that leads the investigation is whether the interpretive framework has explanation power or not. In order to test the explanation power of the framework, the framework was applied to a science classroom discourse, in order to see whether the framework can produce the meaningful explanations about the changes at the classroom level or not. The major empirical question is broken down to three questions focusing on objects of learning, process of learning, and outcome of

learning as follows. Focus on objects of the learning: what is the gap between colloquial and science discourse in the act of comparison in a fifth-grade science classroom? Focus on process of learning: how can teacher's and student's participation in the science inquiry classroom (SWH) decrease the gap? Focus on outcome: did the gap decrease or not?

Chapter organization

Chapter II is divided into three parts: the first part introduces the language-game theory as the building block of the framework, while in the second part there is an attempt to connect the language-game theory to the current literature related to science education with two purposes: First to strengthen the framework and make the framework meaningful to use in science education research, second to test the theoretical value of the framework by checking whether the framework can provide some explanations about the learning in science classroom beyond the current literature or not, and third to introduce the framework based on the built connection between language-game theory and science education-related literature.

Chapter III presents how the investigation was conducted. First the researcher's background and its influence on the study is discussed. Second, it is explained how the theoretical part of the investigation was done. In the third part, after the discussion on how the proposed framework was empirically evaluated, the way that data was analyzed through two parallel coding systems were discussed. And at the end, the criteria for evaluating the rigor and quality of the study are described.

Chapter IV presents the results of the empirical analysis of discourse changes in the fifth-grade classroom. The chapter is divided into three main sections providing the discussion of the three empirical research questions. In the first section, the researcher describes how the colloquial discourse of comparison conducted by students is different from the science discourse proposed by the teacher. In the second section, it will be

presented how the students brought their previous experiences into classroom and how through the negotiation by teacher and themselves they were able to change classroom discourse. The researcher will describe how the quality and quantity of causal inferences increased over the academic year as a sign of change in the classroom discourse.

Finally, Chapter V presents how the result of the theoretical and empirical investigation can strengthen the initial ideas of the proposed interpretive learning framework. At first the three empirical research questions are discussed. Second the theoretical and practical implications and limitations of the investigation is discussed. In the last part, the proposed interpretive framework is reevaluated in order to discuss how the framework transformed throughout the investigation.

CHAPTER II

THE INTREPRETIVE LEANRING FRAMEWORK

The purpose of this chapter is in twofold: developing the interpretive learning framework by connecting it to the literature of science learning and assessing the theoretical value of the framework by illustrating how language-game theory can provide different but pragmatic insight on the topic of science learning. The chapter is presented in three main sections. The first section is the introduction to language-game theory. This section starts by introducing the early Wittgenstein theory of language, his picture theory. Then his latter theory, language-game theory is introduced. The section ends with a discussion on whether the language-theory should be classified as a relativist or pragmatist theory of language. The second section discusses the possible connections between the language-game theory and the field of science learning. In this section, the language-game theory is compared with the four theoretical areas that are connected to science learning. In each area, the dialogue between language-game theory and the literature can advance the framework. Furthermore, the provided pragmatic and different insight about science learning by language-game theory is considered as the theoretical value of the framework. In the third section, the proposed framework is presented by six theoretical assertions about science learning.

Wittgenstein: a man with two theories of language

During World-War I, while Wittgenstein was a prisoner of war, he wrote *Tractatus-logico-philosophicus* (1923)—also known simply as *Tractatus*. In this book he examined the relation of language and the external reality of the world. By following the discourse of positivism, he proposed that language is the representation of external reality and language is a formal picture of the world. He argued for the one-to-one connection between objects and names as well as propositions and state of affairs where language was assumed to be a logical and formal picture of external reality. His picture theory had

an influential effect on members of the Vienna Circle in developing the discourse of logical positivism (Wittgenstein & Waismann, 2003). Around thirty years later, Wittgenstein wrote *Philosophical Investigation* (1953) and introduced his second theory of language which was vastly different than the first one. In his latter discourse on language, Wittgenstein criticized his picture theory of language as a "grave mistake" (Wittgenstein, 2009, P.4). His latter theory argued that language is interwoven into activity. He argued that we can use a word or sentences in multitudes of ways and what makes us pick one way over another is related to our "form of life." That is the way that we have experienced the world. He argued that this is similar to the way that we may learn to play a game and throughout his explanation of language-game theory, he often uses the metaphor of "game". Wittgenstein introduced the hypothetical construct of "language-game" as a specific way by which a community learns to talk and act. My thesis is heavily based on his latter theory of language. However as he mentioned, understanding of his language-game theory is closely related to the understanding of the picture theory:

> "I should publish those old ideas and the new ones together: that the latter could be seen in the right light only by contrast with and against the background of my older way of thinking" (Wittgenstein, 2009, P.3).

Thus in this section, I start the discussion by reviewing the picture theory and then discussing the language-game theory.

Early Wittgenstein: language as a picture of external reality

In *Tractatus*, Wittgenstein tried to describe the relation of language to the world. By following the discourse of positivism, he argued that the world is represented to us by language. He delineated the world as having a fixed structure with language being a logical and formal picture of the world. He further argued for a mapping between the logical structure of language and the structure of the world. The book is organized in seven propositions. In the first proposition, "the world is all that is the case", he argued

that we may think of the world as a collection of objects such as trees, animals, people, etc. with all objects together producing the world. But this answer, he argued, is wrong, because there are many different combinations of the objects that could have made up the world with many different possibilities. What is essential here is what we know about the specific combinations that make our world, what we know about the relationship between the objects. In the second proposition, "what is the case is the existence of states of affairs", he argued that facts can occur only in combination. For instance, what is fact is the combination of chandelier and ceiling: the chandelier is attached to the ceiling; neither chandelier nor ceiling is the fact. What makes the world are states of affairs, combination of objects, but not objects alone. Any changes in the combination of objects cause changes in the state of affairs. To sum up, he described the world as the collection of states of affairs that is the relation of objects with each other.

Language, for early Wittgenstein is the totalities of propositions which can be divided into elementary propositions, for instance, chandelier is attached to the ceiling. These elementary propositions represent the state of affairs and in this way, language and world are connected to each other. The elementary propositions are the picture or the model of the state of affairs. How he came up with picture theory is anecdote in the following quote:

> "There is a story of how the idea of language as a picture of reality occurred to Wittgenstein. It was in the autumn of 1914, on the Eastern Front. Wittgenstein was reading in a magazine about a lawsuit in Paris concerning an automobile accident. At the trial a miniature model of the accident was presented before the court. The model here served as a proposition; that is, as a description of a possible state of affairs. It has this function owing to a correspondence between the parts of the model (the miniature-house, -car, -people) and things (houses, cars, people) in reality. It occurred to Wittgenstein that one might reverse the analogy and say that a proposition serves as a model or picture, by virtue of a similar correspondence between its parts and the world. The way in which the parts of the proposition are combined—the structure of the proposition—depicts a possible combination of elements in reality, a possible state of affairs" (Malcolm,Wright, & Wittgenstein, 2001, p.8).

Essential to his argument is the way of validating of propositions. He points out that there is no way to verify the truth of a picture unless comparing it with reality: "in order to tell whether a picture is true or false we must compare it with reality" (Wittgenstein, 1953, P.43). As all elementary propositions could be compared with reality and all complex propositions could be divided into the elementary propositions, it can be concluded that true or false can be assigned to all kinds of propositions based on comparison with reality. In this view, scientific knowledge is a set of propositions that consist of elementary propositions which have been compared with atomic state of affairs in order to be validated.

The latter Wittgenstein: language as constituent part of form of life

In his latter book, *philosophical investigation*, Wittgenstein (2009) starts the argument by referring Augustine's description of learning languages a description that Augustine mentioned about learning language:

> "When grown-ups named some object and at the same time turned towards it, I perceived this, and I grasped that the thing was signified by the sound they uttered, since they meant to point it out. This, however, I gathered from their gestures, the natural language of all peoples, the language that by means of facial expression and the play of eyes, of the movements of the limbs and the tone of voice, indicates the affections of the soul when it desires, or clings to, or rejects, or recoils from, something. In this way, little by little, I learnt to understand what things the words, which I heard uttered in their respective places in various sentences, signified. And once I got my tongue around these signs, I used them to express my wishes" (P.5).

Augustine's description of language sounds similar to Wittgenstein picture theory. Wittgenstein argued that the root of Augustine's description of language is that words have meaning and their meaning "is correlated with the world. It is the object for which the word stands." (Wittgenstein, 2009, p.5)

Wittgenstein argued that Agustine's model of language is an over simplification of language. Although Augustine's description may explain how babies learn the act of

naming and pointing, language does more than naming and pointing, specifically when we think of the relation of language and action. He continued by pointing out an example: you sent someone to the grocery and gave him a list of items you need. He gave the list to the retailer. The retailer looked at your list and saw: “five red apples.” Then he went to fruit department and selected five red apples and put them in the bag for you. We can assume that he acted as you have described in the list, but what was done by the retailer cannot be reduced and was beyond the simple sentence of “five red apple.” The retailer’s previous experiences with the use of language enabled him to do that. Another example he cited is the example of a builder, A, his assistant, B, from Augustine’s work. A and B made a specific way of communication with each other, the builder call for a “slab” or “pillar” and the assistant brought those to his master. How did the master and assistant learn to communicate in this way? Referring back to the description of Augustine about how babies learn language, we could assume that in the community that A and B live in, a teacher taught students to point to the objects and call their name, the teacher point to a slab and ask students what is this and students answered it is a “slab.” Alternatively, we can assume that the teacher repeated the word “slab” while looking at a slab and the students just repeated the word after her. These are just two examples of the “language-games” they can be played in order to make an association between words and objects. During these two language-games students learned how to associate the word “slab” with the actual object. But these language-games are quite different than the game of “ I call it, you fetch it.” We can assume that the teacher and students played a game similar to the language-game of A and B that is: the teacher said a word, a name of an object available in class, and a student goes, finds the object, and brings it to the teacher. These three different language-games for learning the same words will bring quite different understanding for the learners. The emphasis is that we don’t simply learn the language by developing an association of words with objects in the world as it was argued in the picture language theory. Rather the language and activity are indispensable to each other.

Wittgenstein calls the whole unity of language and activities, a "language-game. He states that "I shall also call the whole, consisting of language and the activities into which it is woven, a 'language-game'" (Wittgenstein, 2009, p. 8).

In *Tractatus*, Wittgenstein emphasized that the meaning of a word was deeply related to the correlation of the word and the reality of the object in the world, one-to-one relation of the word and the object. With the idea of language-game, the meaning of a word was introduced in a vastly different manner: "the meaning of a word is its use in the language" (Wittgenstein, 2009, p. 25). He argued that the meaning of a word is local to the language-game at play. For example, the meaning of the word, "slab" was different for children who played the game of "I call it, you point it" compared with the time that A and B played the game called "I call it, you fetch it." As different communities follow different language-games, the meaning of a word for members of the communities can be different. And as the language-game is not fixed and changes over time, a word does not have the same meaning over time. There is no correct use of a word for all language-games. The same word, thus, can be used differently with different meaning in different language-games such as religion, philosophy, science.

A box full of tools can be utilized in multitudes of ways in different situations. Metaphorically a bag of words can be utilized in the same fashion. What we understand about the function of a tool is highly related to our previous experiences working with that specific tool and other tools in the toolbox. Similarly, the meaning of a word is correlated with the usage of that word and its relation to other words. Consequently, how are we going to judge whether a meaning of a word or a proposition is true or false? There is no way to go outside of the language and check the validity of the meaning by comparing a word with an object or a proposition with a state of affairs, as described in *Tractatus*. What can be done is the verification of the word or the proposition according to the language-game. For instance, we can ask someone to check the action of the assistant with how other members of that community act when they hear the word "Slab."

Outside of our language, action, and the language-game there is nothing to be used for the justification.

The word language-game emphasizes that "speaking of language is part of an activity, or form of life" (Wittgenstein, 2009, p. 15). The word "form of life" refers to the big ideas of how humans live in a community. It refers to how human begins communicate and work with each other. It can includes the whole human begins or it can only include a small community who have a specific form of life. Sfard (2008) mentioned that the other concept that can similarly be used as the terms "form of life" is the terms "practice." However she adopted the terms "collective patterned activity" in her commognitive theory. The main idea originally is about the main difference between human and other creatures. Human biological characteristics enables human to communicate discursively with each other. In return, the discursive aspect of human action has influenced on all the aspects of humans' form of life, even on biological characteristics of human body—for example amongst the close primates to human, it is only human that have such a complex vocal cord system.

Language is woven into the activity and without knowing how people in a community complete the activities or without knowing the language-game of that community, we cannot realize the meaning of the words they use. Some of language-games related to the science discourse are as follows:

- Describing an object under observation
- Reporting the observation
- Speculating about an event
- Making a hypothesis
- Building a narrative about an investigation

It is quite normal if we consider that people in different stages of the history of science may have different kinds of language-game for each of the above examples. For instance, the first language-game: Aristotle looked at the sunrise and described the sun as an object moving around earth. However Galileo many years later, may describe it as

earth is moving around the sun. Each followed different language-games for describing an object. The Aristotelian language-game, which was popular at his era, started to lose its power and was substituted by the Galilean language-game. The Aristotelian language-game of how to look at nature started to change for a limited number of naturalists across Europe such as Copernic, Kepler, and Galileo; what was normal and logical became obsolete for that small community who communicated with the Copernicus language-game.

So far, I discussed the early and latter Wittgenstein theories of language. It has been emphasized that the meaning of a word or a sentence cannot be reduced to a closed system of language; their meanings are related to an interwoven system of language and activities that Wittgenstein calls a "language-game." Language-game is a hypothetical construct which is beyond the language system; it has a meta-language nature (Philips, 1977). Wittgenstein did not introduce any specific aspect to point out as essential to all of the language-games. He argues that language-games can be categorized in a family-resemblance category, and by which he means that while there may be many kinds of affinity between them to be in the same category, there is no single aspect in common between all of them—Kuhn (2009) by citing Wittgenstein, used the same strategy to talk about the concept of "paradigm."

The meaning of the Language-game in Philosophical Investigation is similar to the meaning of discourse as Sfard defined it:

> "Special type of communication made distinct by its repertoire of admissible actions and the way these actions are paired with re-actions; every discourse defines its own community of discourse" (Sfard, 2008, P.297).

To the purpose of my thesis, this meaning of discourse is close enough to what Wittgenstein called "language-game" and throughout the rest of the document, I will apply these two words interchangeably.

Language-game theory: a pragmatist rather than a relativist theory of language?

Here I would like to emphasize that the language-game theory can be classified as a pragmatist theory of language rather than a relativist theory. James argued that true is "what is good in the way of belief" (Smite, 1996, p.23).

By this statement, he is simply debunking all the Kantian epistemology in which philosophy is considered as the brain of the society by stating there is no way to philosophically prove what is true. This is so similar to the position of relativism. However, the experiential and social aspects of pragmatism distinguish it from relativism. Pragmatism does not have any theory of truth (Rorty, 1982) for assessing the opinions. However, it has a mechanism to choose what idea is more viable and practical. For Wittgenstein, as we discussed it before, it is possible to see and describe an event in multitudes of ways. The act of describing an event is a language-game that can change from one community to the other. It seems both James and Wittgenstein are like a relativist. However, two aspects of their theories distinguish them from relativism as follows.

Frist, both theories emphasize the role of background experiences in formation of new ways of talking and acting. Through an experience, we come up with new ideas, but our new ideas are confined by our cultural backgrounds. In explaining cultural confinement, Dewey (2005) suggests that during a new experience, relationships "recur in different contexts and with different consequences so that each recurrence is novel as well as a reminder" (Dewey, 2005, p.169). The "reminder' in this statement distinguishes Dewey's ideas from a relativist's ideas. For example, during a science inquiry, new ideas to some extent are novel as well as reminders of our common cultural background. This load any talk and action with novelty and conventionality at the same time. From a philosophical point of view, Longino (2002) explains the point in a different fashion, by arguing that the middle ground between relativism and idealism is contextualsim. She

stated that contextual knowledge, which is based on experiences, is the requirement to justify a claim. If we assume language as a dispensable part of activity or experience, language becomes part of the common context. It is through language that our common background, culture or "reminders" are mediated. For Wittgenstein prior experiences direct our understanding, as he highlights the point by an example. He mentioned that when we look at the picture that shows a man is standing on a steep with the help of a stick, we most probably infer that he is going up. However it is completely possible to infer from the picture that he is just standing on the steep or he is sliding down.

> "I see a picture; it represents an old man walking up a steep path leaning on a stick. How? Might it not have looked just the same if he had been sliding downhill in that position?" (Wittgenstein,2009, p.60).

He mentions that although we can see the picture in two different ways, perhaps more, we are forced to the first one, because of our prior experiences of the first one. He argues that meaning of words can be similarly come into our mind. And our talk and actions are mediated by the "form of life" and the language-game we have used to.

Second, both theories emphasize the role of social conventions on how we talk and act. Dewey (1984) argued that "all developments are welcome as long as they do not conflict with one another" (p.128). However, he also thought about social consensus as an evolutionary process for selection of ideas by suggesting "it may be compared with natural selection, which is a principle of elimination but not one controlling positive development." Dewey's ideas of pragmatism are based on Darwinian evolution. This explains how pragmatism managed to deal with multiple ideas and truth. It seems pragmatism simply states that the evolutionary mechanism in society, progressive social conventions will converge the ideas to a pragmatic one, if we liberate the development of ideas by not looking for a universal correspondence to external reality. Through the lens of language-game, it can be translated in this way: the formation of concepts, ideas, and facts about nature in a community are directed by the language-game or form of life in

that community. However those language-games or forms of life are dynamic and change over time as well as subsume concepts, ideas, and facts of nature. Wittgenstein discussed how social conventions can change the truth or falsehood of a proposition by saying that:

> "So you are saying that human agreement decides what is true and what is false?" What is true or false is what human beings *say*; and it is in their *language* that human beings agree. This is agreement not in opinions, but rather in form of life.(Wittgenstein, 2009,p.94).

Here I intended to discuss that language-game similar to pragmatism accept the possibility of seeing and interpreting the world in multitudes of ways, while both distinguish themselves from relativism by emphasizing the role of experience and social convention on the development of knowledge.

Revisiting science learning through the lens of language-game theory

About Nature of Science: the problem of paradigm shift in lower level of analysis

The link between early Wittgenstein theory and nature of science becomes clear when the relation of reality and language is discussed. The picture theory was strongly connected to logical positivism, presumably because of its emphasis on formal logic and the assumed relation between language and reality. Reality is out there as we see it, and language comes to represent by providing us a means of communicating with each other about "what we see." Neils Bohr, the great father of quantum mechanics, in response to those who would claim that reality must be prior to language in guiding us to know the world, stated that: " we are suspended in language in such a way that we cannot say what is up and what is down" (ref, French, 1985, p.305). Putting language before reality was an idiosyncratic thought at the time of positivism/logical positivism. Language-game theory was an effort to see how the use of language forms the way we see and imagine the world. The connection of this theory with the nature of science becomes clearer if the

similarities between this theory and Kuhn's paradigm theory is examined. Kuhn's paradigm theory argues for similar ideas in the level of historical changes of scientific discourses. He introduces paradigm as a specific way of practicing science and argues that "the Change of paradigm not only create changes in the way of scientists make predictions or develop evidence, it is also makes them see the world differently (Kuhn, 2003). In the same token, Wittgenstein argues that the aspect of an object is not intrinsic and essential part of the object rather it is attributed to the object. That aspect of an object is invented by a community of people who have put that object and the others similar ones in the same category and labeled the category with that aspect. For instance, when we say a "white" mug, White is not the aspect of the mug. It is attributed to the mug, because the white color is invented as a family resemblance category in society—the idea of family resemblance category will be discussed in detail later. Wittgenstein states that "what I perceive in the lighting up of an aspect is not a property of the object, but an internal relation between it and other objects" (Wittgenstein, 2009, P. 223), similarly Kuhn states that:

> "There is, I think, no theory-independent way to reconstruct phrases like 'really there'; the notion of a match between the ontology of a theory and its "real" counterpart in nature now seems to me illusive in principle"(Kuhn, 2003, P.).

Kuhn argued that what scientists see is influenced by their theories which are not purely produced based on scientific evidence; the common institutions and social conventions also influence the formation and acceptance of new theories (Kuhn,2003). In parallel, Wittgenstein argued that language is not the representative of reality, rather it is the representative of forms of life; as society changes, the social conventions change, the language changes, and the way we see the world changes (Wittgenstein, 2009).

The social aspect of science has been widely acknowledged in the sociology of science (Knorr-cetina& Mulkay, 1983; Kuhn, 2009; Latour & woolgar, 1986; Longino,

2002; Lemke, 1990; Lemke, 2004; Lynch, 1985; NRC, 2007). However these ideas have not been fully implemented in science education (Lemke, 2004; Sadler, 2004). For instance, the act of communication, as a social aspect of science, has not yet been considered a central aspect of science inquiry (NRC, 2007; Osborne & Dillon, 2008); the main perception of science inquiry is still about what scientists do in a laboratory (Ford, 2008). This could be related to the traditional perspective about language in positivist culture which is mostly based on Wittgenstein's picture theory and inherited from the Vienna Circle. It is hard to see the social aspects of science inquiry, if language is a representative of reality, because language is considered as a vehicle to represent and communicate about the reality (ref, Ford & peat, 1998).

What is suggested here is that emphasizing the language-game theory in the field of science education provides a possibility to loosen the positivist perception of language as representative of reality. This would move the paradigm shift argument to a lower level in which the whole human practice for knowing the world is conditional to the applied language-games rather than only the science practice. As the society changes, the applied language-games change, consequently the family resemblance categories and the categorial similarities and differences change and then the new objects and the new connection between objects emerge. This would result in the emergence of a new world in front of our eyes.

About Science practices: science practices is not reducible to a re-discoverable algorithm

Wittegnstein assumed a language-game in which the teacher asks students to follow a formation rule, n+2, and make a series of numbers. The teacher assumed that the students can follow the rule and do the activity similar to other rule-ordered activities like playing chess. Some students can easily write down 2, 4, 6… However when they go beyond 1000, some students would start to write down: 1000, 1004, 1008,…. When

asked why they did it, it was realized that they were under influences of previous activities where they were adding 2 for numbers less than 1000, adding 4 to numbers less than 2000, and adding 6 to numbers less than 3000. The problem is that students' understanding of the rule was congruent with their previous experiences and when they don't have enough practice, their interpretation can be followed by their understanding of the rule plus their imagination. It is completely natural if we see some students interpret the rule as adding 2 to the number as figure like: 6, 62, 622, 6222…, or some students make a series by adding 2 to the power of starting number like: 6, 6^2, 6^4, 6^6,… . Students can understand the rule of "n+2" in indefinite ways based on indefinite examples they encountered previously and can imagine a connection between those previous experiences and the current situation. This seems to be a relativistic position as Wittgenstein put it:

> "This was our paradox: no course of action could be determined by a rule, because every course of action can be brought into accord with the rule. The answer was: if every course of action can be brought into accord with the rule, then it can also be brought into conflict with it. And so there would be neither accord nor conflict here" (Wittgenstein, 2009, p.87).

However Wittgenstein did not mean such a relativistic account. Lynch (1997) argued that if someone assumes that the grasp of rules is based on private judgment, he can see Wittgenstein as a relativist. However, if we consider that our grasp of rules is based on both private judgment and common social practices, as Wittgenstein meant, we cannot consider the above statement as a relativist statement. Lynch continued by suggesting that regularities in our action develop a context for our understanding of rules. Imaginable varieties of interpretation of the counting rule in the previous example rarely, if ever, were utilized by mathematicians as people who have enough contextual practices and familiarity with the unwritten convention in mathematics communities.

Thus it can be argued that the rule itself cannot determine our action. Our understanding of the rule is based on our contextual and communal practices; we can

personally interpret a rule in a multitude of ways following our imagination, but the social conventions limit our interpretation in a certain way. For instance, when we do calculus, we follow certain rules for calculation not because these rules are intrinsic to mathematics; rather, they are just part of our "form of life" that we learned through practice. This means that we are familiar with the discourse of mathematics and that familiarity makes these rules compelling to us. However students who are communicating with the colloquial discourse are not familiar enough with the mathematical discourse and its rules. They may interpret the rules in different ways and those imaginable ways may be logically compelling to them. So, the way we calculate something depends on social conventions and predispositions that we learn through normative practices in the social world around us. In other words, the ways we calculate something follow some rules that are coming from the specific mathematical discourse we learned through communication with others. This is one of the main points of Wittgenstein's language-game theory. These rules are not intrinsic in mathematics that we can learn them through a precise logical analysis. They are applied in this way because the group of mathematicians, which practices math, has being using them in this way. This would suggest that change in a language-game is conditional upon communication with people who know how to do it. No matter to what degree of preciseness somebody can do the critical or logical analysis in order to learn the rules and words of a language-game, for learning those sets of rules, he needs to practice it with people who know how to do it.

What was described here about rules in mathematics can be extended to theories in natural sciences as non-positivist views of science contend that theories are not determined only by a series of facts but are affected by common institutions and social conventions (Longino, 2002; Lynch, 1997). This very aspect of construction of science confines the range of reasonable alternative theories. If scientific theories are not just coming from hard evidence resulting from replicable experiments and pure platonic

logical relations between objects, there is no universal answer to any scientific investigation. Although the alternative investigations may end up with different explanations of similar phenomena the survivor is the one which gathered more support in the community. Obviously, the chosen theory, law, or explanation of a phenomenon is more congruent with the discourse of science in that community at the time of its popularity. The rules of science, either those that are associated with the relation of objects in nature or the ones that are associated to how science should be done, cannot be reproduced or rediscovered in isolation by a group of people who know nothing about scientific culture, simply because the rules were not discovered, but invented through a social practice. For instance, consider the rule that is associated with the interaction of two masses, Newtown's law of gravity. Can we imagine a group of aliens who rediscover this law in isolation? If the answer is yes, then next question is why they would not come up with the Aristotelian law that was popular before gravitational theory, or why they would not come with the general relativity theory proposed by Einstein? Or why they would not come up with something new and unfamiliar to us? There is no reason to consider gravity as something intrinsic to nature such that we can rediscover it. It was invented and became popular to the community of scientists. Language-game theory suggests that to learn that rule, you need to experience "a form of life" similar to what the scientists experienced. This similar experience means to be with scientists and to act with scientists. In other words, in order to learn that rule, or in a larger scale in order to learn the language-game including that rule, it is required to practice it with people who know how to do it.

About Learning: Learning as change of language-game

The traditional instruction for learning science has been considered as learning a cook-book recipe and still is the dominant culture practiced in schools (Weiss, Banilower, McMahon, & Smith, 2001). In this view on instruction, as language is the representative

of the external reality, there is no room for negotiation of the meaning of something. If there is a room for negotiation, it presumably follows a discourse such as: I don't know something, you know it, and you will negotiate with me to show me that external connection. Ford and Peat (1988) argued that in the traditional view, language has a passive role, and a vehicle by which information or meaning is transported from one person to the other. This positivist teaching culture can change by infusing both Kuhn's and Wittgenstein's ideas. For Kuhn, scientists from two different paradigms incommensurably see the world differently. He stated that:

> "What differentiated these various schools was not one or another failure of method— they were all "scientific"—but what we shall come to call their incommensurable ways of seeing the world and of practicing science in it" (Kuhn, 2003, p.4).

By mentioning the gestalt's famous picture, Kuhn argued that conversion from one paradigm to the other is similar to the gestalt switch; it is unstructured and relatively sudden event. The conversion, to Kuhn, means rejection of the old paradigm and acceptance of the new one. When this occurs and the new paradigm is formed, neither the followers of the old nor new paradigm can understand the point of view of the other side. Wittgenstein mentioned the rabbit-dock picture, which is picture that looks like a dog and at the same time looks like a rabbit, and stated that people with two different language-games see the world differently. However, he argued that it is possible for someone to learn two language-games and see the world "this way" or as "that way", similar to someone who can see the dock and then see the dog in the picture. So, while Kuhn placed an emphasis on incommensurability of the paradigms, Wittgenstein emphasized the importance of training in order to be able to learn the new language-game.

From the practical point of view, both theories show a part of the problem of teaching and learning. Applying Kuhn's theory suggests that students and teachers may look at the same things and see it differently, because they live in different paradigms. This difference places an emphasis on the gap between what educationalists want

students to see and do in the classroom, and what students actually see and do. In other words, Kuhn's ideas of incommensurability of paradigms place emphasis on the serious differences between colloquial and science discourses. However, paradigm theory may be too general to have a practical recommendation for how to fill this gap. Based on the language-game theory, people can practice and participate in the new language-game, can learn the new language-game and see the world differently; with practice in the new language-game, people who previously saw the word "that way" can see the world "this way." Accordingly, teachers and students by learning the language-game of each other can learn how the other side sees the world.

Many metaphors can be assigned to the theories of learning such as learning as acquisition in cognitive science, learning as participation in socio-culturalism, learning as transfer in math education, learning as conceptual change in science education, learning as interaction, learning as conceptual construction in Piagetian perspective, learning as interaction in interactionism, etc. In the proposed interpretive learning framework learning is considered as change of language-game or discourse in the level of science classroom. This articulation of learning is inspired by studies in both math and science education that are closely connected to the language-game theory. In the following, I will discuss two interpretive learning frameworks.

Wikman and Ostman (2002) introduced an interpretive model for analysis of learning as "Discourse change" inspired by Wittgenstein's latter theory of language and sociocultural approaches. In their model learning is considered as:

> "a process where gaps are filled by construing new differences and similarities in relation to what is immediately intelligible."(P. 3).

The model has three key concepts: *encounter* which emphasizes the importance of interaction with both people and physical world; *standing fast* which highlights what is immediately intelligible; and *gap* which stresses the moments that people build a connection between what is *standing fast* and the new things. Based on this interpretative

model, during encounters with the physical world students compare the objects they already know and the new objects in relation with what is *standing fast* and this way they assign a *relation* between what is standing fast and the new objects so that the *gap* is fulfilled. Wickman and Ostman applied this model in the context of a university biology practical course. They analyzed how two students observed some pinned-insects and figured out the relation between bumblebees and beetles while they were able to talk with each other or consult with biology texts. Wickman and Ostman concluded that students who are trying to play a new language-game can make relations from other language-games and transform the way that they communicate about the topic of discussion. Therefore they argued language-games are not incommensurable. They stated that in construing new relations between the old and new language, what is *standing fast* is the bridge between the two language-games. However, those relations are not necessarily similar to the ones that are assumed to be made in the classroom science language-game. Therefore the transformation toward science language-game demands something more than encountering the physical world, group discussions and even reading the science content books. The question of how the language-game can transform further to bear more resemblance to science discourse and how the language-game change over an academic course rather than one session are left open in this investigation.

Building on their previously mentioned model, Wikman (2009) introduced a similar model of learning and this time the study was more focused on learning during the conversation in the practical context of a chemistry laboratory. The model, practical epistemology, was applied to a laboratory investigation in order to analyze how students can practically learn about the topic of investigation during interaction with the teacher and events. One of the differences between this model and the former one presented by Wickman and Ostman (2002) is related to placing more emphasis on conversation and especially the conversation with the teacher in the latter model. In the former model, when an individual encounters a new situation, the individuals by connecting what

standing fast to the new situation the gap is filled; the focus was more on the relation of individual and physical words, although the context of study was based on the conversation of two students. However, in the latter model, the gap is defined in a broader context of conversation. When two persons are talking with each other and the conversation continues without a request for clarification, it is considered that there is no gap to fill. But when they started to ask for explanation or clarification of what the other side meant, then it is considered that there is a gap in their conversation. The second aspect of this model is the role of the teacher, which was not mentioned in the former model. Here teacher as the third conversant intervene into students conversation and reshapes student conversation in order to:

> "Make sure that words stand fast in conversations with students. It is also necessary for developing a scientific understanding in the classroom that words stand fast in ways that make students' use of words and scientists' use of words approach each other, thereby advancing students' word uses and habits toward a more scientific language-game" (Wickman, 2002, p.329).

The context of study was a chemistry laboratory investigation in which university students were given 12 non-organic solutions and a list of names of solutions and they were asked to match the number on the tube with the names of solutions on the list. What they should have done to make a relation between the name of solutions on the list and the actual solutions in the tubes. The task was manageable if students were able to fill two gaps: the first was to assign a specific aspect about the quality of solution to the tube and the second step was to assign that aspect to the name of solutions on the list.

Wickman (2009) argued that students' views influenced the way that they acted. It was argued that although students tended to accept the material evidence, they also depended on the teacher authority to decide about the valid observation. He also further argued that students habits change gradually and this change can be recognized and described while students are in action in a specific language-game. So, as the change is

gradual and situated in a specific language-game, it presumably cannot be universally tested. He argued that:

> "If old ways of language use and of acting would simply be discarded on evidence of truth before new language uses were established, then we would not be able to act; nothing would stand fast and serve to build new relations" (Wickman, 2003, p.341).

Despite the previous model in which the importance of the role of teacher was not emphasized, here besides emphasizing on the role of previous experiences and the habit of old-language-game, it was argued that the transformation of language-game required students to interact and practice with an authority.

The other interpretive model that advocates the idea of learning as change of discourse and is heavily based on Wittgenstein language-game theory is the model presented by Sfard in the field of math education. She coined the word comognition for the learning theory she proposed. The comognition learning theory is inspired by vygotsky's and Wittgenstein's works (Sfard, 2008). The word comognition is defined by her as:

> "term that encompasses **thinking** (individual cognition) and (interpersonal) communicating; as a combination of the words **communication** and cognition, it stresses the fact that these two processes are different (intrapersonal and interpersonal) manifestations of the same phenomenon"(Sfard, 2008, p.296).

She has an emphasis to put communication prior to thinking and argues that the act of thinking is the individualization of the act of interpersonal communication. In this model communication is the requirement for learning. Teacher and students communicate and the way they talk, the discourse, gradually changes. Special kinds of discourse are distinguished by "its repertoire of admissible actions and the way these actions are paired with re-actions" (Sfard, 2008, p.297). Although discourse cannot be reduced to language, the flow of discourse in language can be distinguishable by looking at "vocabularies, visual mediators, routines, and endorsed narratives" (P. 297).

In the following, the two research studies that has been done based on commognition theory will be discussed. In this framework two kinds of rules are defined: first the object-level rules that "defines regularities in the behavior of objects of the discourse" and meta-discursive rules that defines "the patterns in the activity of discussants" or how the members of the community of discourse attend to the discourse (Sfard, 2008).

Sfard (2007) reported a study aimed to investigate about how a group of elementary students learn about negative numbers. The study focused on the necessary change in meta-rules of endorsement as a requirement for learning about negative numbers. She mentioned that before negative numbers, the colloquial and math discourse were in agreement on how to endorse a mathematical claim about numbers. For instance, the claim 2+2=4 is a kind of claim that students can observe directly in the concrete world around them. However, the claim like -(-2)= +2 can be endorsed by comprehensive focus on the inner coherence of the mathematical discourse rather than observations in concrete world. Then she described how teacher and students worked together to decrease the gap.

The teacher built her instruction based on the students' familiarity with negative numbers in colloquial discourse such as the negative numbers on thermometer. Then she introduced the line number and marking the zero and some positive numbers on the line in order to emphasize the other side of the line that can be filled by negative numbers that are smaller than zero. After introduction of the model students were asked to operate some calculations on the negative numbers. Similar to Wickman's study (2003) that reported how students brought what stood fast from the old-language game into the new language-game, Safrd reported that kids utilized the routines and rules of the old discourses on positive numbers to do the operation on negative numbers (2007).

Sfard (2007) described how students used the old discourse of positive numbers in order to talk about negative numbers. Students assumed negative numbers as positive

numbers that hold a minus, rather than negative numbers standing as an independent entity. One interesting observation that resembled Wittgestein's discussion about students who wrote a sequence of numbers following the rule of n+2, is that a conversation between students in which two different rules for calculating: -2*6 was introduced by two students during the class discussion and the one that was not accorded with mathematics discourse was chosen by other students. The teacher had to intervene into the discussion and tell them about the math rule that was not picked up by the class. Latter, when students presented with more difficult calculation rule: (-2*-5), there was no re-invention of this rule and all of the students solutions were not aligned with the math rules and the teacher's intervention did not seem to solve the problem. The analysis suggested that the way students continue to calculate with negative numbers did not effectively changed. Sfard(2007) suggested that what teacher did was "waiting to see students finally arrive at the rule that accorded with math rule." She argued that this is not an effective strategy to teach math. The teacher expected students to re-invent the rules of calculation on negative numbers and when students were not able to arrive at those rules, she intervened and showed students how she calculates. Sfard argued that the teacher should have made explicit how the calculation on negative numbers follows specific rules that are the meta-rules of calculation on negative numbers.

The second study presented by Sfard (2007) is about how children learn about geometric figures. Through analysis of how students reacted to the discussion on the shape of some triangles, she suggested that students recognized the triangle by direct observation. In math class students are supposed to recognize the triangle following a discursively mediated identification. The first way of recognition, the direct one, is a process in which the person makes an statement about the state of affairs and there is no room for negotiation, but in the second one, the person at first recognizes something, and then makes statement about what she decided and her decision can be changed through discussion, because her decision was made based on the rule of math that says any

geometric shape with three side is called a triangle. But in the second way of identification, the person makes a statement about her own decision. The teacher in this study played a different role comparing with the teacher in the first study, after she observed that students look at the shapes and have some problem recognizing which shape represents a triangle, she scaffold the activity by "exemplifying her own routine for identification over and over, again asking the girls to perform the procedure with her" (Sfard, 2007, P.601). Sfard concluded that the teacher's strategy to make the meta-rule of identification explicit for students was partially effective. Even though the teacher tried to help the children to act following the discursively mediated rule of recognition of triangle, which is that a triangle is a geometric shape with three sides. She did not make clear the difference between how students wanted to identify the triangle and how mathematics wants them to do so.

These four studies can be summarized in three points about the change of language-game theory.

First, about what *standing fast,* all four studies suggest that students should activate the old language-games in order to deal with the new language-game. It is through this phase that they can make a connection between the old- and new language game. The two first studies delineate this concept, by emphasizing the role of what *stands fast* (Wickman & Ostma, 2002; Wickman, 2003), and in the two following studies, it was emphasized that what is immediately intelligible is a requirement for breaking "inherent circularity of discourse" (Sfard, 2008).

Second, about the gap in both object-level and meta-level rules, the object-level rules of discourse are those rules associated with the connection or relation of the objects of the discourse. For instance, the Newton gravity law talks about how two gravitational masses, as objects of science discourse, attract each other. Wickman and Ostman (2002), and Wickman (2003) mainly focused on how students started with standing fast moments in which a weak connection between the old discourse and new one were made and then

through the classroom activities those weak connections become stronger. In both mentioned studies the formation of object-level rules of discourse was emphasized. By contrast, in Sfard's studies (2007) on the problem of how to recognize a triangle and how to calculate a multiplication or addition in negative numbers are related to how discussants are supposed to mathematize and thus related to the meta-level rules of math discourse. However Sfard placed an emphasis on the critical role of object-level rules as well (Sfard, 2008). Thus, changes of both object- and meta-level rules are parts of the change in classroom language-game.

Third, about the role of teacher, although Wickman and Ostman (2002) had little emphasis on the role of teacher in change of discourse, Wickman (2003) discussed this issue. He delineated that students may make different kinds of relations and this is the teacher and instruction that should lead those connection to the language-game of science. Sfard's comognition theory (2008) showed more detailed analysis of the role of teacher. She argued that although it is important to let students to make the initial relation with the activity and also help them to build the object-level rule of the discourse, the important role of the teacher is to recognize the gap between what students do and what they are supposed to mathematize and make this gap for students explicit through practice.

About the act of comparison: differences and likeness emerges as the outcome of the act of comparison are *categorial* rather than *essential* and *intrinsic*

The act of comparison is central to language-game theory. It is through the act of comparison that we figure out the similarities and differences and are able to see the world around us with more precision and differentiation. Miller (1982) stated that while in colloquial discourse "the human body" can be considered a "mass of meat", in anatomy through the process of naming, categorization and dissection the body becomes

a system of parts that have their own sub-parts. Then this new way of looking at the term body enables them to see the body as an integrated system of organs. A butcher who always has to cut the body of a cow has a greater discrimination about the different parts of a cow body than a consumer and at the same time he knows more about the names of those different parts. This emphasis on act of comparison as a way of knowing was the trigger to choose "the act of comparison" as the object of this study. The researcher intended to see how the act of comparison is chosen as an object of this study. Although in language-game theory, the act of comparison has a central role, what Wittgenstein means by comparison differs from the classical way of comparison in which there is one essential thing with which other things can be compared. The idea of comparison is interwoven with the idea of "family resemblance categorization." The idea of family resemblance category is described by comparing it with the traditional way of categorization.

The traditional categorization is based on finding an essential aspect common between all the objects that are considered under that category. For example: object A is tall, wide, and white; object B is tall, red, and heavy; and object C is tall, red, and white. This group of objects can go under a category of, say, tall objects. Thus, there was at least one aspect as an essential similarity between all the members of the category. This kind of categorization is called monothetic. The other kind of categorization is called polythetic where there is no essential aspect common between all the members of the category. This is what Wittgenstein calls the family resemblance category—Wittgenstein is associated with these kind of categorization, however, before him, Nietzsche used it for talking about language family (Glock, 1996). In the previous example if we have the member D which is short, white, heavy, and wide, then A,B,C, and D do not have any common single aspects so they cannot go under the same traditional monothetic category. Each member of that set of objects has something in common with other members and

therefore they can be categorized under a family resemblance category. Such categorization has consequences on the act of comparison.

The act of comparison becomes relational and contingent to what kinds of family-resemblance categories were developed between the members of that community. If A=B and B=C, then A=C, this rule of equating is based on monthetic categorization. If A, B, and C belong to a monothetic category then, at least, there is one essential aspect common between all of them and easily that rule of equating can be inferred. However, when the rule of equating is applied to the members of a family resemblance category, B and C may become equal with each other only because they are in the same family resemblance category rather than having an essential similarity between them—If somebody makes a different family resemblance, in a way that C would not be in the same category, then that equating inference is not valid anymore. We can consider the following example to examine the complexity inherent in the family resemblance categories: an adult is playing with some Legos, two persons are playing chess, and five persons are playing monopoly. We can put all of these activities in a family-resemblance of "gaming." However we can consider a small community who live in isolation and they don't have the concept of gaming in their culture. They look at these three activities and are not able to understand why they can be under the same category. So, the concept of family resemblance is a relational concept and contingent to the culture, and social convention of the group of people who developed such a category. Ford (1991) described similar examples of what may happen for a learner of a new language, when the family resemblance categories are different in the mother language and the newly learned language:

> "The family resemblance principle is also active when words are borrowed or transferred from one language to another. For example, a speaker of English learning French may learn at one stage that an object which in English he would refer to as "ball" is referred to as "balle" in that language. He immediately proceeds do refer to all objects called "ball" in English as "balle" in French, running into all the difficulty one can imagine when he is trying to

> refer to “boulette”(meat balls), “ballon”(Ballons and other inflatable balls), “coquille”(tesicle), and so on (Ford, 1991, p.363).

As could be seen in this example, the objects that are classified under the family resemblance category of “ball” in English, are not classified in the French under the same category. Here the similarity between all those things under the category of “ball” in English is a “categorial likeness.” In other examples we can also find the objects that are just different because of the “categorial differences.” For instance Wittgenstein (2009) gave an example of these kinds:

> “What is important is the categorial difference between the two ‘objects’ of sight. … The one man might make an accurate drawing of the two faces, and the other notice in the drawing the likeness which the former did not see… I observe a face, and then suddenly notice its likeness to another. I see that it has not changed; and yet I see it differently. I call this experience “noticing an aspect”” (P.203).

Here “noticing an aspect” is the key for comparison. We look at the face of someone and suddenly noticing an aspect make that face similar to the face of one of our friend. That face before and after “noticing the aspect” are not the same anymore. Those aspects that make two things similar or different are actually a label for the family resemblance categories, as Wittgenstein pointed out “what I perceive in the lighting up of an aspect is not a property of the object, but an internal relation between it and other objects” (Wittgenstein, 2009, P. 223). In language-game theory, there is no essential category or aspects that universally influence the act of comparison. Going back to the picture of the rabbit-duck, somebody cannot see a likeness between a rabbit and the picture if she has not seen any rabbit, picture of a rabbit, or video of a rabbit. There is no essential rabbit-aspect in that picture; it is the family-resemblance categories that make a difference or similarity and enable the person to see rabbit or duck.

This is how the nature of the act of comparison becomes different when it is mixed with the ideas of family resemblance categorization. The differences and similarities between objects of comparison are neither essential nor intrinsic; they are “categorial” and contingent to the availability of family resemblance categories. There is

nothing essential in family resemblance categories; they change from one community to the other. The things that we don't see consider as different in our community can become different in another community, and the thing that we consider as different, may be considered similar in another community. This pertinent to how the family resemblance categories have developed differently based on the needs and social conventions of that community.

Language-game theory introduces the family resemblance categories which are socially and culturally constructed. This makes all differences and similarities between the objects of the world categorial rather than essential and intrinsic. Consequently it can explain how whatever we see in the world and think are objective and concrete are actually conditional to the society and culture we breathe in.

Two research areas related to science learning, that are closely connected to the act of the act of comparison are research studies on the topic of multivariable causal inference and research studies about scientific reasoning. In the following section two studies on each of these topics are presented and at the end those studies are analyzed on the eyes of language-game theory. Both field of studies focus on the patterns of causal inferences which are closely related to the act of comparison.

Multivariable causal inference

How do we know that one thing is the cause of another? Many philosophers may have tried to provide an answer for this question; however, from the time that David Hume (2011) proposed this question, no answer has been provided for it. David Hume, who became skeptical about human power of inductive reasoning, argued that:

> "A man, finding a watch or any other machine in a desert island, would conclude that there had once been men in that island. All our reasonings concerning fact are of the same nature. And here it is constantly supposed, that there is a connexion between the present fact and that which is inferred from it. Were there nothing to bind them together, the inference would be entirely precarious" (Hume, 2011, P.11).

He even went further and made the similar argument for the existence of fact:

> "What is the nature of that evidence, which assures us of any real existence and matter of fact, beyond the present testimony of our senses, or the records of our memory?" (Hume, 2011, P.11)

Two traditional answers to this question have been provided. One is related to the idea of priori proposed by Kant, where it is assumed that we are coded in a way that we can understand the power of causation. For instance, we can go outside and we are warm, then conclude that the sun is the cause for feeling warm. The sun has causal power but feeling warm does not. The second one is the idea of covariation. In this model, if two things co-vary with each other, one of them assumed to be the cause of the other. For checking this covariation, whether A is cause of B, this calculation is done: the probability of A when B is available minus the probability of A when B is not available. If this difference is big, then A considered the cause of B. However, this covariation suffers a major problem. Not all A that varies with B is the cause of B. for instance, A is a fulltime early riser that regularly goes to the office in the early morning, and B always arrives to the office some minutes after him because he wants to sleep as much as possible and then goes to work. There are some holidays that A and B both do not work. In this situation the contingency model may conclude that A is the cause of B. The problem is that there is no further evidence from covariation to causation.

Building on this background, Cheng (1997) proposed a psychological theory about human causal inferences, the causal power theory. The theory claims that people have some priori about the causal relation of two things and then they run the covariation as further evidence for that relation specifically for the situations in which the causal relation is not observable. He argued that the relation of causal power, the innate Kantian notion of priori knowledge, and covariation of two variables, is analogically like the relation of theory and model. Causal power, the innate intuition, is like a theory that explains why two variables in the covariation model change together. Cheng (1997) by referring some other studies claims that people are intuitive scientists (ref, Kelley, 1973; Nisbett & Ross, 1980); "when ordinary folks induce the causes of events, they innately act like scientists" (p.369). The paper-pencil

test of the participants in an experimental design was given in order to test the extent to which people behave as causal power theory would predict. It was concluded that people's behaviors accord with the qualitative version of the causal power theory.

To advance the causal theory, Lien and Cheng (2000) proposed a revision to the casual theory by proposing the coherence hypothesis. In this study they classified the factor covariating with an effect in two different categories: those that are judged to be causal as genuine cause and those that are judged as non-causal as spurious. They stated that traditionally there are two views to explain how people distinguish genuine causes from spurious: the power view that considers innate or priori knowledge for distinguishing the genuine cause, and the covariational view that considers the simultaneous change as a criterion for distinguishing the causes. Explaining the shortcoming of power view they mentioned three main problems of the power view: first, in power view, it is assumed that the reasoners have the priori knowledge of causality, but it is not clear where this priori or innate knowledge comes from. The second problem is that the level of abstraction of a causal mechanism can change the judgment. For instance, if the cause of mechanical motion is narrowly introduced as "impact by *solids* with momentum" then people may not be able to see how wind, which is not solid, can be the cause of motion of a leaf. Or if it is broadly introduced as "impact by an entity" someone may believe that the light photons that collide with the surface of the leaf may be the cause of its movement in the wind. Third is the difference between the spurious causes. When people know that there is another cause for the effect, they are more confident to judge that the candidate factor is spurious. For instance, ants go inside their nest and the air pressure drops before a storm comes. Reasoners who know about the pressure drop may more confidently judge that "ants going inside the nest" is not the cause of storm and consider it as a spurious cause. However, if the reasoners just observe that ants are going inside their nest and then the storm comes for several times and they don't know about the air pressure drop, then it is more probable that they consider ants going inside as a cause of storm. In this study the researchers introduced some factors such as

plant food that may affect the growth of plants to the participants. But what they showed to the participants was the manipulated results holding some fake connection between variables. Then the participants were asked to make a prediction in a new situation. The results suggested that two groups of participants who received two different manipulated data implying two different growth theories, ended up with two different causal inferences. Overall, the outcome of the study suggests that theories affect how people make causal inferences.

The second line of research studies related to the act of comparison is centered on the research studies on scientific reasoning. Kuhn and Dean (2004) reported the result of the study in which they aimed to identify "universal patterns of adult performance." They tested how adults make a prediction about the cause of phenomena while many casual candidates, some causal and some non-causal, were available to choose. Participants were supposed to make a prediction about how the shape of a boat can affect its speed. During the test, ll participants were asked to read the instructions in which they could learn about all causal candidates. And at the end of the instruction as it was assumed that they have learned about the causal and non-causal variables, the participants were asked to make a prediction about the speed of three different boats. The results of the study suggested that participants made predictions in an inconsistent manner, each time they categorized some variables as causal and in other time as non-causal. It was concluded that this may be caused by immature mental models. Those who realized the causal variables in the instructional part of the experiment made more correct predictions in the last part of the experiment. In comparison between adults and preadolescents, while adults mentioned evidence as justification of their inferences, preadolescents tended to justify their claims on theoretical grounds. For instance, one of preadolescent participants mentioned that "if it's too deep in the water it might sink". Due to differences between different groups participating in this study, Kuhn suggests that:

> "an individual brings a set of varying inference strategies, or rules (of varying validity), to the task of interpreting the implications of evidence, with these likely to be drawn on selectively in the service of theory-evidence coordination"(P.287).

Two forms of inconsistency in pattern of reasoning were observed in the results. Intra- inconsistency which addresses the inconstant act of comparison of individual, inter-inconsistency that stressed on the differences between individuals when they do the reasoning.

Following this study, Kuhn (2007) elaborated on the difficulties that involve in the task of prediction in presence of multi-causal candidates. This study investigated whether students who learn about the multi-variables involved in a phenomenon can then make correct predictions about the instances of the same phenomenon. Students were first introduced to a computer program in which they could control five variables and see the effect of those variables as forecaster of earthquake—two variables were non-causal and three were causal. After this phase, they were introduced to a similar activity called Ocean Voyage. They learned to work with that computer-based activity. While students were learning to work with Ocean Voyage, they individually should have attended in a test in which they had to make some prediction about the instances of Ocean voyage problem—they were given the condition of all five variables and were asked to predict the result. The results of the study suggested that even students who successfully controlled the variables in the instruction sessions, did not successfully pass the prediction test. While the focus of the first task was on controlling variables one by one in the prediction phase, students were asked to integrate the effect of all those variables in order to come up with a prediction. Kuhn argued that although these two tasks are closely related, knowing the first one is not enough to do the second one.

The connection between language-game theory and the research studies on both multi-variables causal inference and scientific reasoning can be summarized as follows.

First, about the role of theory on making a causal inference, Cheng's power causal theory and the following model, the coherence hypothesis, both address a similar

problem: covariation between two variables is not enough to make causal inferences and there should be some priori knowledge to distinguish which one of those covariate variables is the cause and which one is the effect. However, they are not clear whether that knowledge is something like Kant's innate knowledge, or something that people can learn. They stated that: "How knowledge regarding its causal nature came about was left mysterious" (Lien & Cheng, 2000, p.90). The current view in scientific reasoning studies also emphasizes the role of theory on making inferences, Kuhn and Dean (2004) addressed how for preadolescents, justification was affected by their theories about boats. In the language-game theory, the objects lose their intrinsic differences and similarities with each other and all the likeness and differences become categorial. The differences and similarities are contingent to the family resemblance categories that change from one community to the other. Therefore if there is a priori knowledge for causal power, it should be searched somewhere in the language-games that people play rather than thought of as something that is coded in the mind of people.

Second, about the pattern of reasoning, the research studies on multi-variable casual reasoning search for a universal pattern of causal inference. This ambitious research objective is clear at the last paragraph of Cheng's (1997) article, as she mentioned that what she proposed is:

> "A theoretical solution to the problem of causal induction first posed by Hume more than two and a half centuries ago. Moreover, the fact that this theory provides a simple explanation for a diverse set of phenomena regarding human reasoning and Pavlovian conditioning suggests that it *is* the solution adopted biologically by humans and perhaps other animals"(Cheng, 1997, P.398).

Therefore, any inconsistency in intra- and inter-personal ways of reasoning may be considered as a deviation from the original and universal pattern of reasoning or just lack of information rather than as differences in the pattern of reasoning. However the scientific reasoning research studies (ref, Kuhn & Dean, 2004) proposed intra- and inter-inconsistency in pattern of reasoning. It was argued that the intra-inconsistency is

pertinent to the immaturity of mental model. In language-game theory, people, depends on their background, can play different language-games, therefore they may act differently each time, they can switch from one language-game to the other. When students do the act of comparison, depending on what *stands fast* and how they make a connection between the old language-game and the new language-game, they may see a specific similarity or difference at one moment and not see that one in another moment. Therefore, the inconsistency is a constituent part of the action; however, as they learn more and more about the act of comparison through interaction with adults, they become more and more familiar with the science language-game of comparison. This may explain why adults acted with more consistency compared with preadolescents and why university-associated participants were more consistent than other participants.

Third, how does the instruction can make a difference? The first line of research argued that training does not have any influence on how people make causal inference, and even argued for further claim that other creatures may act like humans:

> "Research indicating a close parallel between human causal inference and Pavlovian conditioning in species that do not receive any academic training (Lien & Cheng, 2000, P.115).

However the result from Kuhn's study does suggest that preadolescents, a random set of people, and university-associated people performed differently in terms of making causal inferences (2004). The language-game theory can explain the result of Kuhn's study by arguing that the more people become familiar with the rules and words of the language-game of making causal inferences, the more they become similar to how scientists do the act of comparison.

Introducing the interpretive learning framework in the level of science classroom

The objective of this chapter is to develop the raw ideas of the proposed interpretive learning framework and determined whether it holds any theoretical value. In

this section, the interpretive learning framework is presented through six assertions. These assertions are the results of an effort to build a dialogue between language-game theory and the related literature in science learning. Furthermore, these six theoretical assertions are criteria to evaluate the pragmatic and theoretical value of the proposed framework.

Classroom-level science learning

What mainly distinguishes this framework is the attempt for developing a hypothetical construct that shows the change in classroom-level science learning. This hypothetical construct was introduced as language-game and it was shown that this choice was made based on the current research in math and science education in which the term discourse serves for the same purpose.

Language-game is socially and culturally developed

Language-game is a weaving together of language and practice (Wittgenstein, 2009) and its root goes back through the history and culture. What we have learned as language-game has been built on culture, history and social conventions. Changes in culture and social conventions may result in changes in the language-game. The colloquial language-games that students bring to the classroom come from their daily-life practices and are rooted back to their culture and history. Furthermore, the language-game of science that is proposed by teacher, curriculum, school, etc. is rooted in the academic language-games of science. Thus, while a language-game may appear confined to the classroom practice, it has the essence of history and culture of people who use it.

The language-game should be operationally measurable

Language-games have some aspects that make them measurable. The main two components as delineated by Wittgenstein (2009) are word use and rules. The ways that words are used and the ways that they are connected to each other can describe a

language-game. This aspect of the language-game can be called the object-level rules (ref, Sfard, 2008) of the language-game. The other aspect of the language-game is the way that people apply and use the language-games. The ways that people practice a language-game can be called the meta-rules (ref, Sfard, 2008) of the language-game. Thus the word use, and rules as Wittgenstein delineated, or object- and meta-level rules as Sfard stated are the measurable aspects of language-games.

Language-games present a stronger argument than Kuhn's paradigm shift

Kuhn (2009) argued that scientific knowledge is not merely built on facts about the world but that is also influenced by the society. Language-game theory presents a similar argument in the lower level and more decontextualized domain. Language-game theory argues that the whole human knowing of the world depends on language-games that are socially constructed. Changes in the social conventions may result in changes to the way we see the world.

Language-game provides an explanation for the teaching and learning dilemma

A science teacher in the classroom always faces the dilemma of to what extent she should coach, direct, facilitate, and coordinate students' classroom activities and to what extent students should be free to develop their own ideas. Language-game can provide an explanation for this problem.

The role of prior knowledge or background experiences has been emphasized in science education. In situated learning argues further for the importance of the relational interaction of learner and environment in the process of learning. The idea of *standing fast* has the essence of both mentioned ideas. Language-game theory explains that a person through the interaction with the environment makes a comparison between what he has already experienced and the current event in order to generate a similarity or

differences between them. This results in the emergence of what is called *standing fast* which is a spontaneous connection between what occurs and what has already been experienced (Wittgenstein, 2009, 1969; Wickman and Ostman, 2002, Wickman, 2002). In language-game theory, this is the mechanism to connect the old to the new language-game.

Language-games are contingent to family resemblance categories and there is nothing essential in them. This prevents an inquiry from discovering or re-inventing a language-game in isolation. They are contingent to social conventions and they change from one community to the other. Therefore learning a new language-game depends on practicing it with people who know how to apply and use it. This is in contrast with the pedagogy of open inquiry that expects students to discover or re-invent the rules of science discourse. Science as language-game is not re-inventible in isolation; it is a human made language-game and should be learned by practice with people who know science (ref, Sfard, 2007; Wickman, 2003).

Thus, in science classroom, on the one hand students are required to generate the connection between the old and new language-games; on the other hand, they are required to practice the new language-game with the person who knows how to use the new language-game. By incorporating both ideas into the proposed interpretive learning framework, it can be theoretically asserted that for the change of student language-game, on the one hand it is necessary for students to first experience the standing fast moments. After they built those standing fast experiences, it is necessary to re-shape what students initially want to do in order to make a connection between students' language-game and science language-game.

Language-game provides an explanation for the problem of causal inferences

The main contribution of the language-game theory to the both lines of research studies on multivariable causal inferences and scientific reasoning is the possibility of studying the language-game of causal inferences. This enables the researchers to study both "how" and "what" of the act of causal inference by studying both object- and meta-level rules of the language-game of comparison. At which moments, both lines of research are based on experimental design and analysis of the result of students' causal reasoning (ref, Cheng, 1997; Kuhn, 1993, 2007; Kuhn & Dean 2004; Lien & Cheng, 2000). This confines both lines of research to merely studying the "what" of learning and therefore both lines of research studies cannot provide explanation of how students learn causal reasoning. Language-game provides an opportunity to analyze *how* students generate causal reasoning. Furthermore, the ideas of family resemblance categories can provide a tool to analyze casual inferences in the lower level. A simple causal inference is a one-to-one relation between two aspects in the language-game. This relationship can be broken down into three acts of comparison as follows. One act of comparison in order to see the changes in first aspect, the second act of comparison to see the changes in the second aspect, and the third act of comparison to equate the changes of the two aspects in the same category as the two covariates.

CHAPTER III

METHOD

This chapter describes the method employed for this study. In the first part of this chapter, I will illustrate how the researcher's background formed this study. The main purpose of this part is to illustrate the subjective aspects of the whole investigation. In the second part, it is shown how the theoretical part of the investigation is done. In the third part the empirical part of the investigation is disclosed. It is shown that how the framework is applied to the data of fifth-grade classroom in order to develop the framework by use, and evaluate the framework in order to see the explanation power of the framework for analysis of learning in the level of science classroom.

The researcher's background and how this research is formed

Similar to any other research studies, the researcher's background experiences have influenced on this study. I disclose, here, my background experiences that seems to me connected and formed this research study.

It was after five years of happily teaching in the school I graduated from that I went outside of my teaching safety zone and started teaching in two other schools. The unfamiliar schools with different cultures forced me to realize that teaching is more than knowing science, science curricula, teaching methods, and classroom management. Considering my academic background in physics, I gradually moved toward theories of learning to solve the problem. I thought that if I knew more about learning and how students learn, I would have the golden key to use in any physics classroom and could help students to learn more effectively. With this motivation to study a universal theory of learning that can be applied to any science classroom, I started my PhD study. At the beginning of my study, everything seemed to be matched with my initial ambitions as I was learning about conceptual change theory and felt that I can apply such a theory to

any classroom and increase students' learning. With some further study though, specifically on situative theory of leaning advocated by Greeno (1998, 1997), I realized that there are questions that this universal model of learning cannot explain and one of them is the problem of situated aspects of human leaning. This changed my view of learning as something in the mind toward something in mind, body, and environment.

This problem became more complicated when I learned that the place I was looking for learning is even beyond the body, mind, and environment. Study of cultural-historical approaches to learning helped me to realize that history and culture form individuals and environment. This implies that in a science classroom, students, teacher, curriculum, school culture, and the essence of all the human history and culture mediates what occurs in science classroom. However, this complexity should not be a barrier for investigating about learning.

At this point, I was thinking about two competitive solutions to this complex problem. Frist, I was thinking that it is possible to keep the focus of learning on the individual, break down the complexity to its parts, and investigate about those parts. For instance, investigating the role of the family on student learning, or how a child learns a computer game. The alternative solution was to break the strong connection between learning and individual. It is possible to build a hypothetical construct that is representative of all the complexity of classroom learning and is not bonded to individual students. In the first place, this approach obviously has some shortcoming simply because it investigates the learning at the level of classroom not individual students. For instance, it cannot explain how the family of a student can affect the student's learning. However, the advantage is the practicality of that assumed hypothetical construct. The main point here is not to dismiss the complexity of the learning or the importance of the research studies on individual learning. From the practical point of view, MRI research on brain, as well as research on conceptual framework of individual mind cannot provide the direct answer to the demand of analysis of classroom-level change.

I don't have comprehensive reasoning why I tended to the second solution; however, I believe that the second solution is more viable and pragmatic. I think that If the bond between learning and the individual can be theoretically broken, then it is possible to consider learning as a complex hypothetical construct that can be investigated at different levels such as learning as neuron activity in the brain of an individual, learning as change in an individual conceptual framework, learning as change in the behavior of an individual, learning as simultaneous change of an integrated system of individual and the context, and learning as transformation of culture and society. Therefore it is possible to consider learning as change of "something" in a science classroom. The question is how learning as a hypothetical construct can be defined in the level of science classroom in a way that can include those mentioned complexities can measure the changes, and would not be just the average of learning of individuals. Theorizing classroom-level science learning has pragmatic advantages as it can prevent the research studies from considering all the complex factors affecting the individual learning—the factors that researchers have little access to, or even if they have access to those data, process of that amount of data, as far as I know, is not feasible.

All of these background experiences and belief motivated me to investigate about building such a hypothetical construct that includes all those complexities, not tied to the individual, and can be operationally measure.

The theoretical aspect of the investigation

This interpretive framework was developed through generating the connection between language-game theory and current literatures related to science learning. The researcher intended in examining how language-game theory at the theoretical level can say something practical and meaningful about classroom science learning.

The theoretical aspect of this investigation is about making a connection between Wittgenstein's language-game theory and the current literature related to science learning

in classroom. In this part of the investigation, the two major Wittgenstein's works, *Tractatus-Logico-Philosophicus*, and *Philosophical Investigation* were studied by the researcher. A textual analysis on the second book, *Philosophical Investigation* was conducted in order to classify the ideas that directly related to science learning. The connected ideas were extracted and imported to a spreadsheet for further analysis. Then the data, based on the researcher's understanding of the data and science learning, was re-organized and classified into five categories: nature of science, science practice, learning, act of comparison, and other. Then literature related to science education that could be related to the language-game theories in those first four categories was chosen. Finally the connection between the language-game theory and those four areas of science learning was made. The second and third parts of chapter II describe how language-game theory can open up a dialogue with those four areas and extend the understanding of science learning.

The empirical aspect of the investigation

The second aspect of the investigation employed by the researcher was to examine the framework by applying it for analysis of science learning in classroom. Utilizing the framework for analysis of the classroom data has the double functions ofevaluation as well as development of the framework.

Evaluation of the interpretive learning formwork

Theories of learning can be categorized in two classes. First are the theories that have focus on the "what" of learning. These theories place an emphasis on what should be learned or what kind of change should be observable as a result of learning. Proponents of these kinds of theories of learning tends to present a measurable outcome as a result of learning and have little to say about how these results are produced during the instruction. Second are the theories that emphasizes the "how" of the learning. Studies based on these kinds of theories concern on the process of learning. They can

describe how learning is complicated and depends on multi-factors. However, they tend not to measure the outcome of learning. Sfard (2007) stated that any interpretive learning framework should focus on both the "how" and "what" of learning. She argues that the interpretive learning framework should be able to provide an explanation for the three following aspects of classroom learning:

Focus on object of learning: what is the gap between what students do and what they are supposed to do?

Focus on the process of learning: How did teacher and students work in order to decrease the gap?

Focus on outcome of the learning: has the change occurred? This approach was chosen to evaluate the proposed framework.

The empirical value of the interpretive framework can be measured by its power for the analysis of science learning in the classroom. The criteria for developing interpretive learning framework proposed by Sfasrd (2007) are employed for evaluating the proposed framework. The data of one academic year from a fifth-grade science classroom were chosen and an analysis of the data based on the framework was conducted. Throughout the empirical study, learning as change of classroom language-game or discourse was investigated focusing on three questions: first, what is the gap between vernacular or colloquial discourse students brought to the classroom and classroom science discourses brought to the classroom by the teacher and curriculum?; second how can the teacher's and students' participation in classroom inquiry change the colloquial to science discourse; and third, is the gap decreased? If the interpretive framework has the explanation power in all three mentioned investigations, then the framework has pragmatic value for both educators and researchers.

The context of the study

Participants

The participants in this study are members of a fifth-grade classroom including 16 students and their teacher, Mary. Mary is a teacher who has more than 14 years teaching experience with the last five years of her teaching having been devoted to argument-based teaching. She teaches fifth graders and has been collaborating with a professional development program for five years. She started as an experienced teacher with a traditional attitude toward teaching and learning and gradually she became the exemplar teacher among 40 teachers who worked with our professional program. Mary recently won the Presidential Teaching Award.

The inquiry-oriented classroom environment

The argument-based environment emphasizes the importance of students' initial ideas, developing claims and evidence as a core concept of science inquiry, and communicating science as the dialectical part of science inquiry. In this inquiry-oriented environment, students are supposed to develop their own questions about the topic of inquiry, design and conduct inquires, develop some claims and evidence, and share those claims and evidence with others. In this fifth-grade science classroom, classroom investigation follows the following format: first, initial discussion in which they are developing common ideas about the topic of inquiry through simple observations and classroom discussion. Second, making claims and evidence, M-session, where students develop their beginning ideas by asking simple questions, plan and conduct some experiments, and come up with ideas about the topic of inquiry in the form of a claim and evidence. The third part of the classroom inquiry is the discussion session, D-session in which students discuss their claim and evidence. Students present their claim and evidence and receive critiques from other members of the class. And in the fourth part, students study textual resources in order to find information and concepts that are

connected to their claim and evidence, and discuss their finding (ref, Keys, Hand, Prain, & Collins, 1999).

The demographic information of the school

The school is located in a remote farming area in the state of Iowa, with class size ranging from 12 to 20 students. The majority of the students are white. In the classroom under study all of the students were white. One classroom is assigned to each grade and around 12 to 20 students are in each classroom. The numbers of female and male students are equal. In this school almost half of the students were eligible for reduced-price or free lunch program and 19% of students were categorized as IPE students. Table3-1 shows the demographic information of the school in more detail.

Table3- 1 The demographic information of the school.

Enrollment by Grade:	PK	KG	1	2	3	4	5
Students	0	19	20	17	21	12	17
School Characteristics	Grades Span	Total Students	Classroom Teachers	Students/Teacher Ratio	Type	Locale	
	PK-5	106	10	10.5	Regular	Rural	
Enrollment by Race/Ethnicity:	Amer Ind? Alaskan	Asian/ Pacific Islander	Black	Hispanic	White	Two or More Races	
Students	0	0	1	0	105	0	
Economic condition	Not eligible	Free lunch eligible	Reduced-price lunch eligible				
Students	57	33	16				
Enrollment by Gender:	Male	Female					
Students	53	53					

Source: CCD Public school district data for the 2009-2010 school years.

The Source of data

The empirical investigation is based on analysis of video tapes of Mary's class in the span of one academic year. The data includes 15 video tapes with an overall length of 670 minutes. With 8800 lines of transcripts of the videos (each line represent a person utterances before interruption by others) with the total number of 88,500 words. Some videos include the whole lesson including all four major activities mentioned above and some of them are limited to one activity as shown in Table3-2.

All the videos were watched several times and at least one time all the transcripts were read by the researcher. In order to increase the focus of the study, the study is confined to the analysis of the seven lessons that included both making claim and evidence session, M-session, and discussing claim and evidence session, D-session. As could be seen in the 3-2, these lessons, respectively, are: 1, 2, 4, 5, 7, 14, and 15.

Confining the study to the lessons that had both M- and D-session

During each M-session, students manipulated and compared the materials provided for the inquiry. For instance, in the first inquiry, students were given a paper bag including some of classroom supply such as pens, pencils, highlighters, or sticky notes. They were supposed to guess what was inside the bag by examining the bag. During the making claim and evidence session, M-session, they ran different kinds of testing to figure out what was in the bag. All those tests included a comparison between the objects inside the bag with their previous experiences about classroom objects. In another example, in the fourth inquiry, they compared the bone, stayed for some days, in vinegar with the bone in water to see how those liquid affected the bones. At the end of each M-session, they made their claim and evidence, wrote their claim and evidence on a butcher paper in order to present it in the following D-session.

During each discussion of the claim and evidence session, D-session, students came to the board and presented their claim and evidence and the whole class had a discussion about the presented claim and evidence. Therefore, every D-session was an opportunity for students to talk in more detail about what was compared during the D-session.

Table3- 2 The data of inquiry lessons over one academic year.

The number of videos	The name of the lessons	The activities of a whole lesson				The length of the videos(minutes)	The length of the transcripts(number of words)
		initial discussion	Making claim and evidence	Discussing claim and evidence	what experts say		
1	What is in the mystery bag?	no	yes	yes	no	9.5	1033
2	Who was the murderer?	no	yes	yes	no	31	3643
3	How many parts human body has?	yes	no	no	no	14	1062
4	How the shape of an object affect amount of weight it can hold?	no	yes	yes	no	57	6583
5	What can affect the strength of a bone?	yes	yes	yes	yes	44	5233
6	How many organisms we have?	no	no	no	yes	60	8390
7	How does the respiratory system work?	yes	yes	yes	no	57	7829
8	Human blood type	no	no	no	yes	16	1767
9	Human heart	no	no	no	yes	35.5	4557
10	Muscle	no	no	no	yes	11	1540
11	grouping animals	yes	no	no	no	57.5	7436
12	grouping plants	no	no	no	yes	89	13229
13	Plants and animals	no	no	no	yes	47.5	6661
14	How can I lift the teacher	yes	yes	yes	no	77.5	10496
15	How does mass affect acceleration?	yes	yes	yes	no	63.5	9083

Furthermore, during the D-session, for the first time, students could make a connection between what they did, their claim and evidence, and what other students did. So, during each D-session, students are supposed to make comparisons between their claim and evidence, and other groups' claim and evidence. Because of the connectedness of D- and M-session in promoting "the act of comparison", the study was limited to those lessons that had both M- and D-session. Furthermore, as could be seen in the table3-2, most data available was related to these two sessions.

The context of the chosen lessons

As it was shown in Table 3-2, lessons 1, 2, 4, 5, 7, 14, and 15 are chosen for further analysis. In the following, I will describe a summary of what occurred in each chosen lesson.

Lesson one: in lesson one, a closed paper bag including some school materials such as sticky notes, staplers, pen, highlighter, etc. were given to students and they were asked to guess what was inside the bag. Then they presented their claim and evidence about what was in the bags. This was a beginning lesson to learn about the structure of claim and evidence. Students in this lesson were able to guess what was in the bag. Little discussion between students was observed. Students touched the bags and talked about their feeling when they wanted to describe the objects inside the bags. For instance, when the teacher asked them how they knew what was in the bag, they said that "it feels like a paper puncher."

Lesson two: in this lesson students were give a text about a murder mystery and asked to work with each other and make claim and evidence about who was the murderer. The objective of this lesson was to show students that their claims need evidence and they had to generate the evidence with the available data or they have to produce evidence through experiment. They were highly engaged in the discussion.

Lesson three: in this lesson, students were given some card notes and were asked to make paper-objects and compare those objects in order to see how the shape of an object affects the amount of weight it can hold. This inquiry was intended to help students to develop their understanding of the role of bones in human body.

Lesson four: students in this lesson were given two chicken bones, two bottles, water, and vinegar. They put one chicken bone in water and the other in vinegar, waited for some days, and then examined what occurred to the bones. They made a claim and evidence about the changes of those two bones.

Lesson five: students were given a bottle, straws, and balloon to make a model of a human lung, then they were required to make a claim and evidence about how the respiratory system work. The concept of what mechanism a person inhale and exhale was addressed.

Lesson six: this lesson was about levers. Students were given a wooden board and block and were asked to design an instrument to lift the teacher up with one hand. All of the groups tested their design and all of the students in their second effort were able to lift the teacher up. One group was able to model the activity using a pen and a book. They put the book on a pen and tested how they might be able to do the real experiment.

Lesson seven: in this lesson, students were given some materials such as a cup, washers, blackboard erasers, and twin string. They were asked to make something with those materials to investigate how the mass affects the acceleration of an object.

The analysis of the discourse

How the discourse was used in this study

Discourse analysis has become popular in research studies in the area of teaching and learning sciences. One of the limitations of this type of analysis is the different articulations of this hypothetical construct. For instance, in language acquisition, discourse analysis is equated with analysis of words and syntax. In other words

everything about the structure of language that can be seen in the sentences is called discourse. Fairclough (2001, 1993) has argued that besides this level of discourse which is all about the structure of language, there are two more layers for analysis of discourse.

The first layer is about production and interpretation of the language in use. The person who produces a sentence can intend specific things that cannot be revealed by just looking at the words and structure of the sentence. The audience of the produced sentence can have her own interpretation of that sentence and that interpretation cannot clearly be recognized by analyzing the structure of the response sentences. Therefore Fairclough suggested instead of just looking at the structure of language, it is necessary to look at the trace of interaction between the producer and receiver in the text. He continued to add one more layer to discourse analysis of text, and that is the social structure. He argued that without knowing about culture and history behind the text, a thorough analysis is not possible. In this way, Fairclough brought the meaning of discourse beyond the words and syntax and connected it to the process of production-interpretation as well as social structure.

However the way that Fairclough seek to connect the language to social practices seems to bear a similarity with Wittgenstein's picture theory of language. Chouliaraki and Fairclough (1999) stated that what people do is always represented in the discursive aspect of their action. Thus they intended to make a mapping between an action and its discursive aspect. They stated that 'people always generate representations of what they do as part of what they do' (Chouliaraki & Fairclough, 1999, p. 22). This assertion to some extent is similar to the claim of picture theory of language in which a unique link between the concrete objects and action, and words and sentences were assumed. This unique connection is the main point of disagreement between the early and latter Wittgenstein's theory of language. In the language-game theory, Wittgenstein argues that

the discursive level of practice, for instance the time that the builder said “slab”, is not the representative of what can occur in the level of practice, for instance, the assistant by just hearing this word, went, chose, and brought a slab for the builder. In the discursive level the practice that the builder and his assistant involved was about just calling for materials required for building the house and can be recorded as following: slab, pillar, slab, slab,... . How this discursive level of their practice can reflex what they really do. Intensive construction for some hours may occur while the discursive level of their practice is simply a series of the words “pillar” and “slab.” The main point here is that although *critical discourse* analysis intends to seek the meaning beyond the text and syntax, looking for the process of production of discourse and the effect of social structure. Their search is still confined to analysis of the discursive level of practice and then claiming that this discursive level of practice is a representative of the whole practice. However as was discussed in the reference to the language-game theory, the discursive level of practice is just part of the language-game and cannot fully explain the language-game or discourse.

Scolon (2001) argued that what Fairclough theorized about discourse, takes the discourse beyond the language and connects the practice to discourse. However, he argued that the critical discourse analysis as Fariclough established has an ambiguous connection to practice. He argued that whatever occurs in text can show something about the actual practice; however, this link is not a unique link. To make this point, Scollon reported a study about the development of the simple action of *handing,* getting and giving an object, in a baby. He described that how this simple action can come with different kinds of discursive aspects:

> "What is the relationship between social practice and discursive practice? We have at least five discursive linkages possible (for the caregiver in relationship to the child – the child's repertoire is not as well elaborated, of course) as of 14 months of age: silence, nomination, functional directive, interpersonal directive, behavioral directive" (p.49).

The first link, silence, is similar to what the assistant did in Wittgenstein's example. Silence is absence of discursive action, but silence is a serious role player in human practice. Scollon claimed that the accompanied discursive action to the action of handing does not only represent the action of handing, but is also different practices:

> "As we have seen, handing from the inception in jointly constructed acts between the child and the caregiver up to the reasonably developed social practice of handing in the second year of life may or may not be accompanied by reflexive constructions of that practice. In some cases the caregivers do, indeed, comment on the practice of handing. On the other hand, in many cases the discursive practices which are linked to handing are not at all about that practice, and in further cases there is silence" (Scollon,2001,p.67).

He ended the discussion by concluding that the unique link between the practice and its discursive level is loose:

> "That is to say, contrary to Chouliaraki and Fairclough's assertion that for every practice there is a reflexive, discursive practice about that practice, I have found that while there is much talk which accompanies handing, there are no fixed or concrete linkages between that talk and the practice of handing" (Scollon, 2001, p.13).

Scollon's point of view on the relation of practice and its discursive level is similar to Wittgenstein's argument about the relation of language and practice that led him to construct the hypothetical construct of language-game that has the essence of both language and action.

Out of this brief review on discourse analysis, a brief summary of the discourse is presented:

Discourse is beyond the words and syntax, and is influenced by people who utilized it. Discourse is rooted to culture and history. Discourse includes both discursive and non-discursive actions. The mere discursive part of the discourse is not representing the discourse. Analysis of both non-discursive and discursive aspects of discourse is required for the analysis of discourse.

How the discourse was analyzed in this study

The non-discursive part of discourse discussed in the previous section plays a decisive role in science classroom. Many students' actions during the classroom practice are difficult to detect in the transcripts of that very classroom. If discourse analysis means focusing just on the transcripts of the classroom, many aspects of classroom language-game would be dismissed. Therefore the researcher, following Scollon's suggestion, instead of looking at the discourse patterns only in the classroom transcripts, ran the simultaneous analysis of both videos and the associated transcripts. The analysis focused on describing the language-game or discourse that was utilized in classroom by students and the teacher. The initial criteria for understanding of the classroom language-game were: scrutinizing the vocabulary that teacher and students used as well as scrutinizing students' actions during the communication with each other and with the teacher. Two independent parallel coding systems were employed in order to increase the credibility of the analysis (Anfara, Kathleen, Brown, & Mangione, 2002). Coding and recoding strategy was also employed in each coding system in order to increase the credibility and dependability of the data analysis. The coding system A based on the original ideas of language-game theory was transformed in three major iterations as follows. Coding system B which was concerned with the discursive aspect of the act of comparison and followed the linguistic criteria as will be discussed later.

Coding system A in the first iteration

The resources that were utilized in this phase were the example of language-game proposed by Wittgenstein in *Philosophical Investigation*. The researcher focused on building a similarity between those examples and the moments of communication in students' activity.

Wittgenstein provided some examples of the language-games (2009). Those examples are as follows: First, the story of the builder and his assistant is an example of language-game. The main point of this example is that this language-game is loaded with many different actions, but the discursive part of the language-game is confined to few words related to concrete objects they used during the construction. The second example is about sending someone grocery shopping. In this example the retailer by just looking at some words that are written on a piece of paper, the name of required materials, started to do many different actions to find, choose , and put them in the bag. Similar to the previous example, the emphasis is on the complexity of a series of action done by the retailer and the simple words written on the piece of papers. By mentioning these examples, Wittgenstein intended to emphasize that both communications in the first and second examples are not reducible to the discursive aspect of their practice and argued that they know how to do those complex actions because they have learned the associated language-games. Third, the list of some actions that were mentioned as examples of language-games:

> "The word "language-game" is used here to emphasize the fact that the speaking of language is part of an activity, or of a form of life. Consider the variety of language-games in the following examples, and in others:
>
> Giving orders, and acting on them
> Describing an object by its appearance, or by its measurements
> Constructing an object from a description (a drawing)
> Reporting an event
> Speculating about the event
> Forming and testing a hypothesis
> Presenting the results of an experiment in tables and diagrams
> Making up a story; and reading one

> Acting in a play
> Singing rounds
> Guessing riddles
> Cracking a joke; telling one
> Solving a problem in applied arithmetic
> Translating from one language into another
> Requesting, thanking, cursing, greeting, praying" (Wittgenstein, 2009, p. 15).

These examples give rough ideas about the language-game as Wittgenstein used it, and therefore the researcher looked through the data of the science classroom to examine the similarity between those examples and the moments of the classroom inquiry. At first, some of instances from the above list were chosen, such as forming and testing a hypothesis or presenting the results. However in searching the data, finally the act of comparison was chosen as a topic of investigation. The reasons for choosing comparison as the topic were:

First, the general question of the empirical investigation was about how students' colloquial discourses changed over time to bear more resemblance with science discourse. However this question is too broad to fit in an empirical study. Therefore the researcher was required to narrow the investigation to a narrow topic that held the characteristics of discourse, but as narrow enough to examine.

Second, the act of comparison, as it was discussed in chapter II, plays a critical role in both language-game theory and science. Therefore running an investigation about the transformation of this instance of the science language-game may contribute to classroom science learning. Third, the available data allowed seeing the many instances of the act of comparison over time. Furthermore, as could be seen in Table3-3, in lesson 3,4, 6, and 7, the outcome of the inquiry is a casual inference, and thus students were required to make different kinds of act of comparison during those lessons.

At this point of the investigation, lesson three and seven in which the outcome of the investigation is a causal inference, were chosen to be coded in order to investigate how students played the language-game of comparison. For the coding, the video of the lessons were watched and any moment that was related to the act of comparison was

marked and notes about what occurred were written. The researcher purposefully looked for the moments in which the act of comparison occurred, and then the researcher tried to see how those moments can shed light on the rules and word use in the language-game of comparison. In any marked moment, something was compared, for instance, the softness of bones, wobbling of paper-objects, number of washers, number of books, etc. this gave the researcher an idea about the object of comparison which can be connected to word use. The other thing that emerged in the first iteration was the connection of the object of comparison to other objects. For instance, in the sentence, "How many layers did you put on that one?" layers become connected to a cylinder. This can be counted as a rule of comparison that defines a relationship between layer and cylinder. Furthermore, there were some moments in their conversation during which they talked about more general ideas about the act of comparison. For instance Austin talked about the amount of weight that a small cylinder can hold. And the teacher commented on their activity by asking that: "are you making claim before testing?" By writing notes about moment-by-moment of the the classroom conversation, the researcher was able to build raw ideas about the rules and words of the language-game of comparison. During the coding the following similarities were recognized by the researcher:

Table3- 3the similarities observed in the first iteration

The moments in which students used the object of comparison
The moments in which students did the act of comparison:
The moments in which teacher negotiated with students in order to change the words
The moments in which teacher tried to reinterpret what students had already did into the act of comparison
The moments in which teacher tried to encourage students to do the rest of an action in order to be able to do the act of comparison

Episode 3-1 shows a moment in which students did the activity and tested some paper-objects. the teacher through the conversation was trying to help them to compare two of those objects. This is the moment that is described in the line four. In contrast, in Episode3-2 students were doing the act of comparison and this can be seen in the second row of the table3-3.

Episode3- 1 The moments in which the teacher is negotiating with students on the act of comparison.

002132	Teacher	And did the double cylinder weight hold more? Okay. Can you show me your data? How much did your single layer cylinder hold?
002133	Blake	Uhhh….
002134	Teacher	Should be right there in your chart, right?
002135	Brooklyn	Twenty three point two.
002136	Teacher	23 pounds? And how much did the double layer hold?
002137	Blake	(to Brooklyn) Where's the double layered one?
002138	Teacher	Okay, so double layered held 23 pounds? How about single?
002139	Brooklyn	Twenty five?

Episode3- 2 The moments in which students are comparing what they did and teacher had little direct intervention on this conversation.

002104	Courtney	I have a question for Brooklyn. What was the shape that held the most books, and does that support your claim?
002105	Brooklyn	It was the super shape, and it held (79?).
002106	Courtney	How many pounds was that?
002107	Brooklyn	Twenty nine point two.
002108	Tyler	Which shape was that, and how many layers did it have?
002109	Brooklyn	It had six layers, and it was stuffed with..

All the transcripts were put into an MS Excel file and the developed coding was a one-dimensional coding (Meyer, & Avery, 2009). A sample of coded data into the MS excel is presented in appendix A. Even though this initial coding provided some ideas about the data, it was too general and required a higher resolution coding system in order to provide a description about the research questions. Two ideas developed in the initial coding are: the first was that while in some moments students were comparing the paper-objects easily, see Episode3-2, in other moments teacher moved them forward to do the comparison, see Episode3-1. This was connected to the first research question about the gap between what students did and what they were supposed to do. Second, in the moments that the teacher intervened, students had already done something, and the teacher intervened in order to help students to add or change what they had done. This was an initial ideas to investigate about the learning process and how teacher and students worked together to decrease the gap, as a means to answer the second research question.

The coding system A in the second and third iteration

In this phase of coding, there were two initial ideas about the first and second questions. Therefore the coding in this phase was divided into two classes related to the first and second research question.

Frist research question: the gap between discourses

The moments related to the act of comparison were coded under one dimensional coding(Meyer, & Avery, 2009) to see whether during the comparison students did the comparison with little teacher intervention, as shown in Episode3-2, or with the teacher intervention they did the comparison, as shown in Episode3-1. One of the difficulties of this phase of coding was how to decide to code moments in one of these two categories. This led the researcher to construct following criteria: if the teacher was in the

conversation and indirectly helped students or directly helped students, that moment called the *teacher-assisted* comparison. When students without either direct or indirect teacher intervention were involved the act of comparison, the moment called *standing fast* comparison (ref, Wittgenstein, 1969, Wickman and Ostaman, 2002, Wickman, 2003). In the third phase of coding, further differentiation of the coded data in each category of standing fast and teacher-assisted comparison, indicated that the analysis to this conclusion: in lesson three, most of the teacher-assisted comparison is related to the time that comparison is following a different words, procedure, or need some tools to do it. But in the standing fast category, most of the time the comparison is related to the paper-object that held the most weight. In lesson seven, though, students showed competency in talking about those mentioned procedures or tool-assisted observations and negotiated with each other about those kinds of comparisons. This guided the research for further examination of data in order to provide an answer for the third research question.

Second research question: change of discourses

The coded data in the first iteration was recoded with the focus on the time that that there was a direct or indirect attempt to change the act of comparison. Words and rules of the language-game or discourse are the important aspects of language-game (Wittgenstein, 2009; Sfard, 2008) therefore changes in those aspects may come with some change in the language-game. This was the motivation to divide the coded data into two main categories: communication intended to change the words of the language-game of comparisons, and communication intended to change the rules/acts of the language-game of comparison. The Rules of a language-game explain how to act according the language-game or how the objects of the language-game are related to each other. The following Episode3-3 shows the communication between teacher and students with the intention of making a rule for the language-game of comparison. The rule here is about

the relation of the object of the language-game of comparison and involves words such as layer, support, strength of the paper-objects. In Episode3-4, the teacher is negotiating for replacing the word triangle with triangular prism.

Episode3- 3 teacher-students negotiation on object-level

teacher	why are you changing it from one layer to four?
Nathan	so, they have more support and hold more books
teacher	why do think it hold more books?
Nathan	because, em…, I don't know
teacher	you said something about support
Nathan	it got more support on it
teacher	so, you think, more layers, more support, therefore, it hold more
Nathan	Yes
teacher	it is a claim? Let's see if it is true.

Episode3- 4 the teacher negotiates with students to use the word triangular prism.

Tienna	he is trying to make a triangle and I am making a triangle
teacher	is triangle a 3d object?
Tienna	yes, it can be, oh well no, it has to be...
Teacher	something that has triangular side
Tienna	yah, triangular prism
Teacher	Ok

Further detailed coding illustrated that the communication intending the change of discourse are not confined to teacher, as there are many moments especially in the discussion part of the classroom that the change was negotiated during student-student

communication. Therefore the coding system differentiated the related moments to the following: The moments that the change of the words of language-game of comparison was intended and the moments that the change of rules of language-game of comparison was intended. Then both categories were recoded based upon the direction of communication: teacher-student, or student-student. Episode3-5 illustrates the moment in which students negotiated the rules of the discourse.

Episode3- 5 students are negotiating on the connection of subject of comparison to each other.

002219	Blake	Our layers, this kind, half goes with it and half goes against it, because it has layers, and the oens that have more layers hold more, and the taller one, it, then our other one before this, it was a cylinder, ti held more than the shorter one.
002220	Austin	How many layers was that?
002221	Blake	Six.
002222	Courtney	We had seven, so we had one more layer, and we had a tall one with layers, and a short one with a lot more layers a lot more larger on it, and we had one like this with only five layers, and that one didn't hold as much.
002223	Tyler	I have two things that go against it. We had a two layer cylinder that went 1.4 pounds, and just the plain triangular prism had 13.6
002224	unkown	But it also depends what kind of books you use, because sometimes if you have heavier books, they'll hold more with taller ones, and then sometimes if you have lighter ones, they don't hold as well because they're flimsier.

Third research question: did the gap decrease

To provide the description for the third research question, the coded data in lesson three, which occurred in the early part of the academic year, as compared with the coded data in the lesson seven which occurred at the end of the academic year. The change in the assisted-comparison, and standing fast comparison in lesson 3 were compared with their counter parts in the lesson 7.

The summary of the transformation of the coding system A is presented in Table3-4. This table, to be read from bottom up) shows the first coding attempt in which the relation of the coding and the research questions was vague. In the second iteration, the connection of the coding and the research question was established. And In the third iteration, the mentioned connections become stronger.

Table3- 4 The transformation of the coding system A (reading from the bottom up)

Research questions		
1) what was the gap between the way that students did the act of comparison and the way that teacher wanted them to do?	2) how can the teacher's and students' participation in the classroom inquiry decrease the gap?	3) did the gap decrease?
Third iteration: Mapping to the research questions		
assisted comparison became canonical around comparison by direct observation	how were the words negotiated during assisted comparison	comparing assisted comparison in lesson 3 and 7
the standing fast comparison become canonical around the comparison by observation and improvement by manipulation	how were the rules negotiated during the communication	comparing standing fast comparison in lesson 3 and 7
	between whom the communication did occurred	
Second Iteration: Patterns related to the questions		
what was emphasized on assisted comparison	how the negotiation occurred during the assisted comparison	comparing the moments of lesson 3 with moments of lesson 7
what was emphasized on standing fast comparison		
First iteration: initial coding		
any moments of communication that was related to act of comparison was coded		

Coding system B in the first iteration

Among all fifteen videos of lessons, seven videos that had both M- and D-sessions were chosen (Table3-3). These videos and the transcripts were considered for this part of the analysis.

For the first iteration, all the transcripts were read and comparison sentences coded for further analysis. The criteria for choosing the comparison sentences were as following:

1) Any sentences that had superlative adjectives such as "held the most books" or "the largest bones in the body."

2) Any sentences that had a comparative adjectives such as "Bones are much lighter than steel", "they had more pounds" or "the less layered shapes." Among 5450 sentences that students said, 320 sentences were separated as comparison sentences. A Sample of separated sentences is presented in the Appendix B.

Coding system B in the second iteration

The separated sentences were coded-recoded in many ways. The main problem of coding was that the criteria for comparing the sentences were too connected to the context and it was hard to code the comparison sentences without referring to the context. Sample of the initial coded data was presented in the Appendix B. The main outcomes of this time-consuming process was two categories to separate the data as following:

First category, single comparison: the sentences in which one common aspect of objects were compared. For instance in "yours had even one more layer" the paper-object is only compared based on the number of layers they had. In sentence "bone B is longer than before", students were comparing bone B before and after they put in water. So, one aspect of the object was compared two different times.

Second category: compound comparison: The structure of these sentences by far is more complex than the structure of sentences in the first category. They include two

single comparisons plus an attempt to make a new connection between two covariate aspects. Let me describe the structure of these sentences with some examples. In the sentence: “I think the taller it is, it would be more wobbly”, the tall and short cylinder was compared, and so was the extent to which the paper-object was unstable. For saying such a sentence, two paper-objects, presumably were tested. They were compared to see which one was taller, and then they were compared to see which one was less stable. At the end the conversation of two variables, changes in length and changes in stability were equated with each other. This sentence is a perfect example of making one-to-one connection between two aspects of an object or it can be called a causal inference. Here is another example of these compound comparison sentences: “When we put the block of wood closer to Mrs. Smith then our hand could lift up…her up like a piece of cake.” To begin with the place of the block on the board was implicitly compared, Closer to Mary or far from her. In the same sentence, their attempts to lift her up were compared. At the end, the results of these two comparisons were connected to each other: “being able to lift her up” was equated with “closeness of block” to Mary. The coding system in this iteration showed how the discursive aspect of the act of comparison occurred in each lesson.

As could be seen the criteria for coding the data in this way is as straightforward as possible. The single category is the sentences in which one aspect was changed and compared. And in the compound comparison, more than one aspect was changed and compared. A sample of coded data is shown in Appendix B.

Third research question: did the gap decrease?

The result of this coding in a quantitative manner (Chi, 1997) can show whether the discursive aspect of the language-game of comparison quantitatively improved or not. The linear regression analysis was done in order to check the statistical significance of this change.

Coding system B in the third iteration

In this phase of the analysis, all 320 sentences were analyzed and the compared aspects of the objects were separated. For instance, in the sentence, “Bone A softer than bone B” the softness is an aspect of the bone that was compared several times but was considered once in the group of comparison words related to lesson 4. The other criterion was the pair of aspects in compound comparisons. For instance, in the sentence “the more force, the faster it falls”, changes in the number of washers are on the one side of compound comparison, on the other side are the changes in the speed of the falling objects. And the last comparison is equation of changes of these two variables. A change in the speed of falling is equated with the change of the forces exerted on the object. This is represented in table4-6 as a pair of (changes in force, changes in speed).

Summary of the method employed for data analysis

The objective of data analysis in this study was to examine the changes in the language-game of comparison in the science classroom. In order to do that, the two parallel and independent coding systems were employed as a triangulation strategy. In the first coding system, system A, the data was coded by building two criteria of teacher-assisted and standing fast for classification of the act of comparison. This way of coding in the first place provided an explanation for the available gap between what students did and what they were supposed to do. Within this system, the data also was coded based on the function of negotiations whether it was about word use or rules of discourse. The direction of negotiation was also investigated to see whether the negotiation occurred between teacher-student and student-student. In the second coding system, system B, All the comparison sentences were marked and coded based on whether they were single or compound comparison. Then further analysis on changes in the structure of compound comparison was conducted.

Assessing research rigor and quality of empirical part of the study

Credibility of the research

Triangulation: in the empirical part of the study, two independent coding systems A and B were conducted in order to check the results of the study from two independent analyses. The overall consistency between these two coding system strengthens the credibility of the research study.

Engagement in the field: The researcher has been teaching science for more than twelve years, and in half of these years he has focused on teaching in inquiry-based environment. From the research perspective, he has been engaged in research about teaching and learning in inquiry-based environment for several years. Furthermore, the researcher has been working on analysis of SWH environment for about four years and has done two research studies about the transformation of teachers in this environment.

Checking the credibility of the coding system: in order to check the credibility of the coding system, a group discussion was run. Coding system that was illustrated in Table3-1 was checked as fallows. For the first question: teacher-assisted comparison versus standing fast comparison coding was used to differentiate what students did and what the teacher wanted them to do. Five random chunks of data representing the mentioned moments from each coding were chosen. During a Two-hour discussion session with two PhD science-major students, four moments out of 10 chosen moments were given to them and the reasoning behind the coding was provided. Then they were asked to categorize the moments in the categories of teacher-assisted comparison and standing fast comparison (students made it with little teacher intervention). After their first attempt, the coded data was discussed as part of the instruction process. Then they were asked to code the reset of data. The coded data, at this stage was reasonably in agreement with the coded data by the researcher—the coded data for one of the

participant was 5/6 and for the other was 4/6 agreement with the researcher's original coded data. The disagreements were resolved after group conversation. The other major coding was the coding related to negotiation on words or rules. Three sample chunks of data were given to the same members and the same procedure, as described above, was employed. They were able to see whether the negotiation was about rules or words. The third check was the most difficult. Some parts of the videos from the M-session of the lesson 3 and 7 were shown to the members and they were asked to observe and recode the differences. They did not know the chronological order of the videos. Then a group conversation was run on two questions: in which video did the students complete the experiment more precisely and what is the evidence of that? This question aimed to see whether they can see any improvement in the way that students used the rule of comparison. The second question was: In which videos did the students complete the experiment with less teacher intervention? The members mentioned that students discussed the control of variables in the lesson 7, and in lesson 3 the way students compared big and small objects was not scientific. The interesting discussion was about the way students run the experiment in lesson7 to confirm their ideas about the heavier objects fall faster than the light ones. The members mentioned that students were not correct in that idea and counted that moment as a negative aspect of lesson 7.

Coding system B: The same members were given 20 comparison sentences and after the orientation, were asked to classify the sentence in two categories of single or compound comparison. Here, there was the least disagreement with the coded data, the researcher would suggest that it may be because this has the least subjective criteria for categorization.

Time sampling: The last point about the credibility of the empirical part of the study is pertinent to the time-span of the data. The data represents one academic year. This is the longest time for conducting a longitudinal study on the same group of students who learned something with the same teacher.

Transferability

Through this study, the researcher tried to provide thick description for how the study was done and what was the outcome. providing thick description and disclosing the research process as much as possible may increase the transferability of the research study.

Dependability and confirmability

The following considerations about coding-recoding, triangulation, and reflexivity are part of the effort to make the study more dependable and confirmable: First, as was shown in Table3-1, the code-recode strategy was done in three iterations in order to have a more consistent and detailed coding system. Second, as was discussed the parallel coding system was designed for triangulation. And third, during the analysis of the data, many times an idea emerged and changed the direction of the study; part of these changes can be seen in the three iterations that were necessary to build the coding system.

Toward the non-positivist and non-neo-positivist
qualitative research study: it is believable or not?

The pragmatic research position adopted in this study should be distinguished from the positivist and neo-positivist qualitative research methods that claim to represent reality or truth. All the positivist research tools adopted in this study do not seek to reveal the accordance of the study with truth or reality. For instance, the group discussion for checking the credibility of coding system was not employed as a positivist tool to check whether the truth that was revealed by the researcher can be confirmed by others. I employed that method in order to increase the believability of the conducted research study and pass it through the social consensus which is, to me, the most important criteria for conducting research. This was done to examine the reaction of two representatives of science community to the structure of the research study. The regression analysis that was employed to check statistical significance of the increase in the causal reasoning was not

employed to check whether that increase in causal reasoning really occurred or not. That analysis was instead employed to check the consistency of the constructed interpretation over all the data.

The study, at least explicitly, does not have any claim regarding the truth or reality of what occurred in the classroom. The claim is about introducing a practical framework that has the explanation power for analysis of science learning in classroom but off course for people who can believe it.

CHAPTER IV

RESULTS

Introduction

This chapter is divided in three main sections: in the first section, the main differences between the way that students did the act of comparison and the way that was expected from a person who knows science discourses as a result of the analysis will be reported. Later in this section, what students did and what they were supposed to do will be interpreted through the lens of language-game theory. This analysis differentiates between students' colloquial discourse and classroom science discourse in terms of how to do the act of comparison. If closing the gap between those two mentioned discourses is considered as learning, then the next section is about analysis of the process of learning aiming to decrease the mentioned gap. That section will describe how during the making claim and evidence session, M-session, and the discussion session, D-session, the gap can decrease. The third section will describe whether the mentioned gap really decreased over one academic year or not.

the gap between students' and science discourse

In this section, I will discuss the gap between students' colloquial discourse and classroom science discourse through a case study. The case study is related to one lesson in which students did an inquiry to find out the relation of the shape of objects with the amount of weight they can hold.

How students investigated the problem

In this activity, during the making claim and evidence session, M-session, The teacher, Mary, wrote on the board: "how does shape affect the amount of weight an object can hold? She gave notecards and tape to students, as material to manipulate so that they could build some different paper-objects. The fifth-graders made different

shapes such as cylinder, rectangular prism, triangular prism and put some books on them to figure out which shape can hold more weight. Despite their expectation, they were successful to put many books with a weight of more than 30 pounds on a paper-object. In the discussing claim and evidence session, D-session, students, in their groups, went to the board, presented their claim, and they had a whole-class discussion on each claim and evidence.

Students were supposed to learn the aspects of the paper-objects that can affect the amount of weight they can hold. Those aspects could be the length, width, the number of layers, etc. For instance, students could have compared a tall and short rectangular prism with each other and probably concluded that the short one could hold more weight.

In examining students' language-game in the act of comparison between the objects, Blake and Brooklyn claimed that being tall and having things inside is related to the amount of weight paper-object can hold. If we consider the amount of weight that the paper-objects can hold as dependent variable, both length and things inside can act as independent variables. The problem here is that length and things inside are confounding variables— changes in both of them can affect the changes in the dependent variables. They made a tall cylinder and it held 25 pounds. To strengthen that tall cylinder Blake and Brooklyn put some papers inside of the cylinder and some paper layers around it. The new paper-object held 29 pounds. Then they concluded that the two aspects of that cylinder, layered and stuffed, can be considered as a generalized aspects of the cylinder that can hole more weight. In the D-session, Brooklyn stated that "Shapes that have more layers and have things inside. It can hold more weight." Episode4-1, It seems that Blake and Brooklyn were not following the rule of science language-game that says: when they change the variable A to see its effect on variable B, they need to control all other variables that confounded with A—in order to see the effect of length of cylinder with the amount of weight it can hold, they needed to make only one change at a time, stuffing the

tall cylinder to see the effect of stuffing, or put some layers on the tall cylinder to see the effect of layers.

Episode4- 1 Blake and Brooklyn reported how they improved their cylinder.

002057	Brooklyn	Our claim is "Shapes that have more layers and have things inside. It can hold more weight."
002058	Austin	How do you know that that will happen?
002059	Blake	When we were doing it, our first one, our cylinder, it had, it was a single layered one. It didn't have anything inside it…and it only held like…
002060	Teacher	So you've got your evidence right there.
002061	Blake	25. And then when we made it, we put stuff inside it, and we…some more layers, it held up 29. The taller one. The wider, taller one…

What about other students? Were they similar to Blake and Brooklyn or did they follow the rule of science comparison? In Table4-1, all other students' claims are presented. As can be seen, three of the claims are describing the paper-objects with two variables or aspects. So, it seems that all of those three groups were not following the science rule of comparison. In the fourth claim, there is just one variable, number of

layers; however, despite they came up with fewer layers, due to not considering confounding variables affected their measurement, the results suggest that students did not follow the science rule of comparison in terms of considering the effect of confounding variables.

Table4- 1 Sstudents' claims about their paper-objects.

Names of students in each group	Claim	the words by which the paper-objects was described
Brooklyn, Blake, and Tori	Our claim is "Shapes that have more layers and have things inside. It can hold more weight."	shapes, more layers,things inside, cylinder, layered, stuff inside, wider, taller
Tienna and Tait	Okay. Our claim is "Taller and wider shapes hold more weight."	taller, wider, shape, heavy heavy duty cylinder, layers, big, wide, tall
Austin, Courtney	This is our claim. Shorter objects with layers can hold more weight.	shorter, object, layers, squares, cylinders, triangle, short, shape, tall
Tyler, Katie, and Cris	Our claim is the less layered shapes hold more weight.	layered, shapes, cylinder, triangle prism
Isable, Tanner, and Nathen	Our claim is a cylinder can hold more than a rectangular prism and other.	cylinder, rectangular prism, layers, rectangle

If they did not follow the language-game of science, what was/were the comparison rule/rules that students followed? Focusing on this question, the ways that

students compared the familiar aspects of the paper-objects such as length, width, etc. with the new aspect, the tolerance of weight, were examined. The result is as follows

Blake and Brooklyn: guided by the teacher, they made Battery of shapes such as triangular prisms, rectangular prisms, and cylinders. Among all of the objects, they made a cylinder that held 27 pounds. Then they improved the strength of the cylinder by putting some of the other paper-objects inside of the cylinder and some papers as extra layers around of it. That special cylinder held 29 pounds. So, they had two cylinders one held 27 the other 29 pounds. The latter one was similar to the former except having more layers and more paper stuffed inside. Now the case was ready for them to conclude that the latter one was stronger because it was layered and stuffed. It seems their claim is affected the initiative they had to improve the tall cylinder.

Tait and Tiena: they made a cylinder that had 13 layers, called it the heavy duty cylinder, and it held 30.5 pounds. Then they made a taller and wider cylinder that did not have layers but it held around 40 pounds. So, the changes they made to build the taller and wider cylinder became the base of their claim: “our claim is taller and wider shapes hold more weight.”

Austin and Courtney: they claimed for more layers and wider objects, Episode4-2. Similar to the previous group, they picked the one that held the most weight and then made a relation between its familiar aspects, width and layer, to its ability to tolerate weight.

Tyler and Katie: they made a two-layer cylinder and it held 21.4 pounds, then they made a triangular prism held 13.6. At the end they made a five layered cylinder that held 10 pounds. They claimed that the one that has less layers can hold more weight. They actually made the five-layer cylinder to get better result, but they had, as other

students called it, “weird results.” However, this weird result convinced them that cylinder with fewer layers is stronger than than one with more layers.

Episode4- 2 What Courtney and Austin did.

002198	Austin	This is our claim. Shorter objects with layers can hold more weight.
002199	Tait	How many layers?
002200	Courtney	We have…our most was seven layers. We had two squares, four cylinders, and one triangle. And it held 27.5 pounds and 20 books. Our short shape with seven layers held 27.5 pounds, and then our tall cylinder only held 10 pounds with one layer.

Tanner and Isabel: they made a triangular prism, rectangular prism with two layers and a five- layer cylinder and the five-layer cylinder held more. Then they claimed that “a cylinder can hold more than a rectangular prism and other.” As the last change they made to improve the paper-object was making a cylinder, they emphasized it in their claim.

One similar theme that emerged between their claims is that all of the claims are related to the objects that held the most weight. This would suggest that the object that held the most weight was central in their investigation. This can be supported by the observation of the M-session. During the M-session, they were more excited to “make an object that can hold more books” than comparing the variables of the paper-objects. This may suggest that, at least partially, the game of “can you build a strong shape that can hold more weight?” mediated their classroom activity. The result in table4-1 shows all of the claims are describing the aspects of the objects that could hold the most weight.

Overall, the analysis of the claim and evidence support the following interpretation: during the M-session, students were partially engaged the game of making

a paper-object that can hold more and more weight. Although they made different kinds of paper-objects, the result would suggest that they made them in order to improve their design rather than in order to compare them and find an answer for the teacher's question. All of their claims were focused on the last initiative they made to improve their design. There is no sign of following the rule of manipulation that says you need to keep the confounding variables constant and only change one of them.

The interpretation of what was done and supposed to be done through the lens of language-game theory

So far, the results show that the students did not follow the rule of science, but rather followed some different procedure. In this section, the researcher will try to utilize the language-game theory in order to re-analyze the data with higher resolution. A discussion about the similarity between what students did and some familiar language-game comes first, with the later discussion centered on how the activity was supposed to be. The aim of this section is to show the gap between what was done and what was supposed to be done.

What students did as a language-game

Looking at the problem through the lens of language-game theory, what they did is similar with some familiar language-games of the daily life practices. In the following I will describe two familiar language-games that can be related to analysis of the paper-objects inquiry.

Can you tell me which one is taller?

The very simple and familiar question is the language-game of "question, comparing by observation, answer." A simple example of this game is: consider a mother and her child who was playing with three teddy bears. The mother pointed at the toys and asked which one was taller. The child looked at them and said, "That one." This

language-game becomes a little more difficult when some measurements are included. Despite this simple example in which comparison was done by direct and qualitative observation, some of observations are quantitative and involve measurement. For instance, if a student has a set of marbles and is asked which one is heavier? She would weigh them by hand qualitatively or she would put them on a scale and quantitatively observe which one is heavier. The act of comparison by observation is not limited to "seeing," it can be done by other senses as well. Therefore these language-games can be regularly played when we compare and discriminate the objects by our senses in order to know them. When students looked at two paper cylinders and said this one is bigger than that one, or this one is taller than that one, they seemed to play this language-game. If a student was asked which one is heavier, she may grab the objects, feel them, and would say which one felt heaviest to her. She still played the language-game of comparison by observation, because the comparison was done by the help of direct sense of touch.

Can you make it better?

The second familiar and simple language-game that seems similar to what students did is: consider a child is playing with some building blocks and built something like a tower. Her mother looks at the construction and asks her: can you make it taller? She responds to her mother's question, by putting more pieces on the top of the construction. This language-game of improvement in which we manipulate the world around us to make something better is ubiquitous in our daily-life practices. What students did was similar to this language-game as well. They started to build a paper-object that could hold weight. Then they made another one to improve their previous shape.

The model for the whole activity: "comparison by observation" and "improvement by manipulation"

Students made some paper-objects and put some weight on them, then they improved their design by manipulating some of the shapes and they ended up with an improved object. By looking at their claim, the researcher would suggest that all of the claims were related to their initiative for improvement of the paper-objects. The whole activity in which they were involved can be modeled like this: "make objects; put weight one them to see which one can hold more weight; manipulate one of them to make it better; put weight on them to see whether it can hold yet more weight; and finally making relation between the aspects of the best paper-object and the new aspect of "weight tolerance."

What students were supposed to do as a language-game

By examining the activity through the lens of language-game theory, the researcher would suggest that students were comparing or discriminating the paper-objects in order to build a new *family-resemblance category* that could be called "weight tolerance." With the help of this new category, students could separate the paper objects based on their weight tolerance. This new aspect is kind of an aspect of the object that students may not have used in their colloquial language-game. In order to compare objects based on this aspect, they needed to run a quantitative comparison which cannot be done by just using direct senses alone. They also needed to measure the weight that those objects can hold. On the other hand, they needed to change the familiar aspects of the paper-objects such as length, width, layers, stuff inside, etc. in order to figure out the relation between the familiar aspects of the objects with the new one, "weight tolerance." This can be modeled as an effort to build a many-to-one relation. This task could have been done in a very simple manner following this procedure: choosing a usual aspect of the paper-object, say, big or small, and making two simple cylinders, one big and the

other small. Then putting some books on each to see which one can hold more weight. This would result in making a relation between big and small as the aspect of the paper object they had already known and the new one, "holding more weight." However the activity could have done following a more sophisticated procedure such as: making ten paper cylinders that are identical except their height; Putting the same sturdy book on them; putting weight in a balanced way on the book to see when they were crushed; Putting all the quantitative information about the height of the cylinders and their weight tolerance on a table in order to see whether there is a correlation between their height and their weight tolerance; repeating the entire previous procedure separately for modifications to the amount of width, number of layers, thickness of the papers.

The former simple procedure can be done by an elementary student, while the latter one can be done by high school students. This procedure could also be done by a group of scientists at a science lab that is equipped with a sophisticated way of producing the paper objects, measuring the stress endurance, and analyzing the results. These three different ways of making many-to-one relations come with specific word use, and rules of doing the task. For instance, the weight tolerance can be represented as "5 books", "10 pounds" or "50 Newton." These are words for describing the weight or stress endurance, but they also can say something about the level of sophistication of doing that task. The three mentioned examples also are different in the rules for how to do the task and the rules that make a connection between those words. For the first one, students only make one big and one small cylinder, while for the second one, students have to follow a sophisticated procedure to make 10 paper-cylinders that have all other qualities the same except their height.

As the word use and rules are different, we could say that they follow different language-games. From the perspective of language-game theory, science learning in the level of an elementary class is a change in the language-game used in the class to the more sophisticated one, something similar to the second example. Thus, in general what

students were supposed to do was a change from the way they wanted to do the task to a more sophisticated way that comes with new words and rules.

In referring to the original question, "how does the shape of an object affect the amount of weight it can hold?", the question can be interpreted as a request for building a connection between the aspects of the objects such as long or wide, short, big, and the unfamiliar aspect of the object, "weight tolerance." This connection can be made in three major steps: first, they need to run a quantitative measurement by putting the weight on different paper-objects and comparing all the paper-objects in terms of their weight tolerance. Second, they need to follow a lengthy procedure to compare the paper objects based on many familiar aspects of the paper objects. Students have to follow a lengthy procedure to do this. They need to change one aspect while keeping all others constant, then compare that aspect with the weight tolerance to figure whether that aspect is related to the weight tolerance or not, and if this relationship is positive or negative. For instance, in testing the number of layers, students need to make number of cylinders that are the same then add some layers to them. After doing the tolerance test, they finally can compare the results to figure out the number of layers is positively related to the weight tolerance of cylinder. They can redo the test for other aspects.

The language-game here has something new that is vastly different than the conventional language-game of "comparison by observation." In the language-game of "comparison by observation", students don't need to change the objects of comparison, but rather simply observe them through their five senses and make the comparison. But in the activity described above, they need to make some specific or intentional changes in order to make the comparison. To put it in familiar science terms, they need to manipulate the objects and then compare the effects of manipulatoins. The researcher termed this "comparison by procedural manipulation plus observation". The other difference is that they cannot do the comparison just by direct observation. They need to do the act of observation through some meditational means such as "number of books" or

their "weight" which was measured with a scale. The researcher termed this "comparison by tool-assisted observation." These two language-games are very popular in science discourses. However, in our daily-life activity, they may rarely be used.

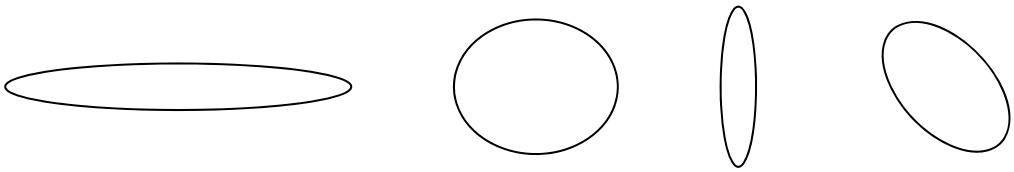
In order to have further analysis of the problem, the researcher would like to offer two examples from a different context, that is, the math context. Running a similar analysis in two different contexts, math and science, can help to analyze the act of comparison in a more decontextualized manner that may result in understanding the structure of the act of comparison. In the first example that follows one aspect of an object is compared to another, the researcher termed this as "one-to-one" relationship. And in the second example, one new aspect of the object is supposed to be connected to some familiar aspects of the object. The researcher termed it as "many-to-one" relationship.

Example one: how does the shape of a circle affect the amount of surface it fills? The familiar aspect of circle is its diameter, D, and the unfamiliar one is its surface, S. With the help of a piece of cross-section paper, students can figure out the amount of surface the shapes fill. This is an example of "comparison by tool-assisted observation." Then they can measure the diameter of each circle and compare the circles based on the length of their diameter which is another tool-assisted observation. At the end they should make a comparison between the changes in the length of the diameter and in the amount of surface and equate that bigger diameter is equated with bigger surface. The last part of the procedure in which the act of comparison resulted in an equation can go further. More advanced students may figure out the formula that connects these aspects to each other: $S = \pi * D^2$. This inquiry is an example of building a one-to-one relationship.

The first version of circle inquiry (the one without formula) can be divided to one act of "comparison by manipulation plus observation" for comparing the Diameter, one act of "comparison by tool-assisted observation" for comparing the Surface, and one act of comparison for *saming or equating* the changes in D and the changes in S.

Example two: how does the shape of an oval affect the amount of surface it fills? In this inquiry, students who have been already familiar with the formula for calculation of the surface of a circle may come up with an idea that the amount of surface has to do with the oval's diameter, with this exception that oval has two diameters. They can make some ovals similar to Figure 4-1, and then by using a cross-section paper they could measure the surface of the ovals. Then, similar to the circle inquiry, they can measure the vertical diameter, b, or/and horizontal diameter, a, of the ovals.

Figure4- 1 How does the shape of an ellipse affect the amount surface they have?



The problem arises when they want to figure out the relation of "a" and/or "b" with S, as "a" and "b" are confounding variables. So, they need to keep one constant while changing the other. This is a complicated problem following a lengthy procedure such as: guessing the aspects of ovals that affect S; making some ovals by changing "a" while keeping "b" constant; measuring the surface of the ovals with the cross-section paper; comparing those numbers to figure out which one is bigger; and equating the increase in "a" and increase in "S". The same procedure can be followed to figure out the relation of "b" and S. The solution for this oval inquiry can be reduced to the solution for two separate circle problems plus the procedure of manipulation of the confounded aspects. Therefore, this activity can be broken to one "comparison by tool-assisted observation" for measuring the surface, one "comparison by procedural manipulation plus observation" for comparing the aspects of paper object, and at the end one "saming or equating" for developing a relation between "a", "b" and "S".

If the oval inquiry is compared with the paper-objects inquiry, many similarities can be found. Table 4-2 illustrates how these two problems are similar. Both are inquiries to find the relation of many-to-one. Both can be break down into the “comparison by procedural observation” and “comparison by manipulation.”

Table4- 2 The similarities between the ovals and the paper-objects problem.

Similar factors	Ovals	Paper-objects
object of comparison	Some created ovals	Some created paper-objects
Unfamiliar aspect/ dependent variables	Surface	The weight it can hold
calculating the unfamiliar aspect	By using cross-section papers	By putting some weight on them
Familiar aspects/Independent variables	"a" , "b", etc.	Length, layers, inside stuff, width, etc.
Changing the familiar aspects	They are confounded; when one is changing the other should be kept constant	They are confounded; when one is changing the other should be kept constant

Table 4-3 illustrates the summary of the language-game model of what was done and what was supposed to be done. As can be seen, the language-game that is required to handle many-to-one relationship inquiry in both math and science is more complicated than just running a number of “question, comparison by observation, answer.”

A serious change in the word use and rules of the language-game of comparison is required in order to see a transformation from the colloquial language-game of “comparison by direct observation” toward the language-game of “comparison by too-assisted observation plus procedural manipulation.”

Table4- 3What was done? And what was supposed to be done?

components of the inquiry	What was done?	What was supposed to be done?
comparing the weight tolerance of the paper-objects	comparison by tool-assisted observation	comparison by tool-assisted observation
comparing the aspects of paper-objects	two separate language-game of "comparison by observation" and "improvement by manipulation"	one complicated language-game of "comparison by procedural manipulation plus observation"
making relation	equating the aspects of the paper object, all together, with the weight tolerance	equating the aspect of paper object, one by one, with the weight tolerance

How can students' and teacher participation in the lesson decrease the gap

The purpose of this section is to illustrate how teacher's and students' participation in science inquiry can change the mentioned gap in the classroom discourse. In other words, how can the discourse or language-game can change during a classroom inquiry. By learning, the researcher means change of discourses or change of language-games in the level of classroom. This section is divided into two subsections: the first subsection focuses on what occurred during the M-session, and the second part is pertinent to the events that occurred during the D-session. In each of these subsections, the research provides the evidence of how the words and rules of discourse can change during the classroom practice.

How ***can*** students' and teacher's participation in the M-session decrease the mentioned gap?

How the words of the language-game of comparison can change during the M-session

Table 4-1 shows the claims students made. In these claims the paper-objects, were called by "shape", "cylinder", "rectangular prism", and "object." The aspects of the paper objects by which they were compared with each other were: holding weight, layered, layers, shorter, taller, wider, and have things inside. These words were frequently used by the teacher and students and formed part of the act of comparison in the M-session. These words did not appear to be new to students as they had probably heard and used those words prior to this lesson. At the beginning of the analysis the researcher considered these words as familiar words that students use in their colloquial discourses. In order to examine the words that maybe connected to science discourse, all the words students used during the M-session were collected and the following words were found: "heavy duty cylinder", "triangular prism", "circle", "triangle", "rectangle", and "cubic" for describing the paper-objects. And the aspects such as holding number of books, big, small, short, thin, height, pieces inside, and thick for comparing the paper-objects. Some of these words such as short, height, and triangular prism were similar to the previous words, and there was nothing which could be counted as more sophisticated words or that could be assigned to science discourses. However, there were some words that were less sophisticated. For instance, the words describing the paper-objects: a cylinder as circle, a triangular prism as triangle. As the comparison words went under scrutiny, the researcher realized that some of the words comparing the paper-objects (as an example consider the words "big" and "small") were not as sophisticated as wide or tall in the context of that activity. The aspects such as tall, short, wide, thin, weight and layers all can be qualitatively or even quantitatively compared. However, comparing the objects based on

their bigness is ambivalent—when we say it is big, it is not clear whether we are talking about height, width, thickness, or all of them. Reanalyzing the words that constructed their claims showed that so called less sophisticated words were not used at any of their claims shown in Table4-1.

In the following, by mentioning some of the episodes of the lesson, the researcher will try to describe how at the beginning of the activity students used the less sophisticated words and how through the classroom practice those words were replaced by more sophisticated words related to the act of comparison.

Triangle or triangular prism

At the beginning of the M-session, Tienna and other members of the group were making some paper-objects, when the teacher asked her about what they were doing:

Episode4- 3 Triangle or Triangular prism?

Tienna	he is trying to make a triangle and I am making a triangle
Teacher	is triangle a 3d object?
Tienna	yes, it can be, oh well no, it has to be...
Teacher	something that has triangular side
Tienna	yah, triangular prism
Teacher	Ok

As can be seen in Episode4-3, while Tienna was making a paper shape, Mary (the teacher) asked her to articulate what she was doing. She articulated the object as triangle and it was throughout this conversation with Mary that she remembered to call it triangular prism rather than a triangle. During the M-session a similar conversation about

the name of the paper objects occurred in which Mary helped them to use the terms rectangular prism and cylinder instead of rectangle or circle.

The bigger the object is, the stronger it is

Tienna and Tait were making two triangular prisms, when they had the following conversation with Mary, Episode 4-4. As can be seen, in the beginning of the conversation, Tienna stated that they were making a big and small triangular prism, and later, mentioned her prediction that the bigger one is probably going to hold more. Following this conversation, Mary went to the other group, Courtney and Austin, who were making cylinders. As can be seen in Episode 4-5, similar to the previous group, they were thinking that the bigger one was going to hold more.

Episode4- 4 The bigger triangle hold more than smaller one.

Teacher	are you using the same size note cards
tienna	he is going to make a bigger one and I am making a smaller one
Teacher	what would be the purpose of doing that?
tienna	to see what shapes stand up to the most weight
teacher	but you are doing the rectangular prim so does he, you are both doing the same shape, what... ganna matter?
Tienna	this probably wouldn't be strong(while holding the smaller one) , that one maybe stronger

Episode4- 5 The bigger cylinder hold more than the smaller one.

Teacher	So, you are making a cylinder, so does he, are they the same or different?
Austin	Bigger
Courtney	one is bigger, and one is smaller
Teacher	why would you do that
Courtney	just to see if the bigger one hold more

The students had two different note cards, with one being square and the other rectangle. They had the same widths, but different lengths. Thus, when they made a one-layer cylinder with a square, it did not matter whether they rolled it from the length or width. But for the rectangle, when they rolled it from the length, they made a taller cylinder and when they rolled it from the width, they made a wider cylinder compared with the cylinder they made with the square shape note cards. Students considered that both sets of cylinders included a big and small cylinder. The teacher negotiated with them that they might want to use tall versus short or wide versus thin. During the conversation with Austin and Courtney, they decided using wider instead of bigger. Mary had similar conversation, Episode 4-6, with Blake and Brooklyn helping them to call their cylinder tall and short rather than big and small.

Things inside or layers

While students tested the paper-objects they made, some of them came up with the idea of supporting the shape by wrapping the cylinders with card notes. Episode4-7 shows how Mary reacted to this new initiative during the conversation with the students.

Episode4- 6 Tall is a better word than big.

teacher	ok, what have you done?
brooklyn	big cylinder hold 5.6
teacher	by big, what do you mean? Do you mean wide or tall?
brooklyn	tall
teacher	maybe you should say tall then. Because when I think big, I could think wide,
brooklyn	ok,
teacher	do you agree with me or you should leave it big
brooklyn	no, tall,
teacher	why do think tall
blake	because, big might be weigh more, or ..
teacher	ok, so tall might be a better choice

Episode4- 7 Things around or layers

Teacher	what is different about your cylinder?
Isabel	em, different?
Teacher	because that is not look likes other cylinder I have been noticing(she was pointing to the layers of the cylinder)
Isabel	we put a lot of paper on this, because
Teacher	so, how many layers does it have?
Isabel	it has… four
Teacher	you might wanna make sure you record that. So that has four different layers, correct?
Isabel	Yes

As could be seen, Mary asked Isabel to articulate how they made their cylinder. At first Isabel was not able to answer her, but as she pointed to the layers of the cylinder. Isabel answered Mary that they put “a lot of paper” on it. Mary asked about that specific

aspect of the cylinder but did not used the word assigned by students, “a lot of paper” and interpreted that aspect as “layers.” Isabel’s response showed that she was able to switch to this new word and communicate with Mary about the number of layers of the cylinder. At the end the teacher mentioned about the importance of recoding the number of layers they used.—the conversation about recording data will be discussed later. One advantage of “layer” over “a lot of paper” is that it is a countable word and students easily can count the number of layers an object has and compare it with other objects.

Episode4- 8 “Little one in it” or layers

Teacher	how was this different than the first one you did
Cris	it has lots more of the little one in it
Teacher	how many more, you said lots of little things
Cris	all of them
Teacher	how many?
Cris	I don't know
Teacher	cris is saying he is not sure how many of little things are inside? By little things inside he is talking about layers?
tyler and ..	Yah
Teacher	so, how many layers are inside this one?
Cris	I think it is about five layers
Teacher	how many were in the first cylinder
Tyler	Two

When Mary was with Tyler’s group, they were putting some books on a cylinder and they stated that this cylinder was special, because it was made with two notes cards. The teacher asked them to write that aspect of the cylinder in their note books. Latter, when Mary came back again to their group, they were testing a different cylinder, Episode4-8.

In this conversation, students had made a new cylinder, and called what was inside as “lots more of little things inside”, while the teacher interpreted that as “layers.” They made two cylinders; the first one was made with “two note cards” and the other with “lots more of little things inside.” These two aspects were not easily comparable for them. However with the negotiation with the teacher, they decided to consider both cylinders as layered cylinders, one with two layers and the other with five layers. This paved the way for a claim about comparison of two- and five-layer cylinders.

Number of books or weight

Students had a discussion on how to measure the weight that the paper-object could hold. Students were supposed to weigh all the books a paper-object could hold. However, during the M-session, they tended to just count the number of books they were able to put on the paper-objects. In some cases they were only recording the number of books. Mary was reminding them the steps that they had planned to follow in order to measure the weight of the books. This part of the activity was intended to quantify the amount of weight the paper-objects held and made possible for them to compare the weight tolerance of objects with each other.

Episode4- 9 Number of books or their weight

Teacher	What is the next step according to your steps you should do?
Courtney	Get all of books and weigh them

<u>How the rules of the language-game of comparison can change during the M-session</u>

The researcher has attempted to illustrate while students were improving their paper-objects, the teacher came to them and asked them to articulate what they were doing, and then she negotiated with them to rename the objects and aspects of those

objects with the names and aspects that can easily become part of the language-game comparison. In the following, the result of similar analysis on the question of how the rules of language-games can be changed will be illustrated. It is shown how throughout the negotiation between Mary and students, the rules of act of comparison are incorporated into the classroom language-game.

Which one can hold more?

Isabel was holding a rectangular prism in hand when the teacher came to their group and started the following conversation. As illustrated in Episode 4-10, students were going to put some more "stuff" in it. When the teacher asked her about making a second object to compare, a gap between what they were going to do and what the teacher wanted them to do became clear. She said that they may need the second object as an extra object in case the first one did not work they would be able to use the second one. However, presumably Mary wanted to hear something about the act of comparison. Then, the teacher reminded them the main question of inquiry and again asked them about the reason for making the second object. Although it is not clear whether they were convinced of the need to make the second shape or not, later they did proceed to make a cylinder in addition to their rectangular prism. This episode illustrates the gap between what students wanted to do and what the teacher expected them to do. However, what they wanted to do can be interpreted in different way: they made a rectangular prism and were going to put some books on it. If they had made the second shape, and put the books on that as well, they would have had two cases to compare. In other words, what they wanted to do could be re-interpreted as the part of what the teacher expected them to do. And this reinterpretation was done through the negotiation between Mary and students.

Episode4- 10 Making some paper objects that can hold weight

Teacher	you said you have made a what… rectangular prism?
Isabel	Yes
Teacher	and, now what are you going to do with that
Isabel	we are gonna try to see if it hold stuff(with a doubtful voice)
Teacher	Ok, so, are you gonna do one shape? More than one? What are you thinking? Would it be important to do more than one shape?
Isabel	you can try different shape in case one does not work
Teacher	Ok, and if your question is how does the shape affect the amount of weight it can hold? Can you answer that question if you have one shape?
Isabel	no
teacher	so, you might wanna do other shapes
Isabel	Yes

Comparing the two-layer with five-layer cylinder

Tyler, Cris, and Katie were putting some books on their first cylinder, the two-layer one, when the teacher asked them to record that it was made with two note cards. Later, when they were putting books on their second cylinder, Mary started the conversation by asking them about the number of the layers used for the second cylinder, and ended the conversation by asking again about the number of the layers of the first cylinder (Episode 4-8). In the previous section, it was pointed out that Mary incorporated the word “layer” in their activity. Here we see that while students were engaged in testing of their improved objects, Mary implicitly coached them to compare this one with the first one with two layers.

Doing the short one in order to compare it with the tall one

Blake, Brooklyn, and Tori were gathered around their table when the teacher came to them and asked about the result they had obtained from the tall object. In the previous conversation, the word tall was incorporated into their activity. In this Episode, it seems Mary was reminding them to focus on the short one. However, the way she framed the conversation suggests that she was also implicitly emphasizing the purpose of doing that: the comparison of the tall and short one.

Episode4- 11 Which one can hold more, tall or short?

Teacher	so tell me tall held how much?
Brooklyn	35 books
Teacher	did you do the short one?
Blake	not yet
Teacher	are you planning to do the short one?
both blake and Brooklyn	Yes

Based on the main question of this inquiry, the students' claim and evidence were intended to be about the relation of the aspects of the paper-objects with its new aspect, the amount of weight it can hold. In other words, their claim and evidence should have included some aspects of the manipulated objects and weight tolerance. In the following we will see how the act of comparison can be incorporated into the students' activity while students and teacher played the language-game of making claim and evidence.

Recording the amount of weight

Courtney and Austin were putting the books, one by one, on their big cylinder and Mary was watching them. When the paper-objects crashed, Courtney said 29 books, went

to her notebook, and was writing something on it. At this point Mary reminded Austin about the importance of what Courtney was doing as noted in Episode4-12.

Episode4- 12 The result of the testing should be recorded.

teacher	I like how Courtney is now recording record
teacher	Austin, I like how Courtney are recording her data
Austin	ok(he took the pencil from Courtney and wrote the result on his notebook)

She was implicitly coaching them to record the result of the testing. This data could facilitate the process of claiming and evidencing. At the same time it provided an opportunity for comparing the result of this testing with other results.

The aspects of the paper-objects should be recorded

Tyler, Cris, and Katie were putting some books on their two-layer cylinder, and they were telling the teacher that they made that cylinder with two note cards, and Mary encouraged them to write down what they did as noted in Episode4-13.

Episode4- 13 The number of layers of the cylinder should be recorded.

teacher	so you used two note cards to make one shape?
Tyler	Yes
teacher	you might wanna make sure you record that on your data
Tyler	Ok (cris and tyler are writing that down on their notebooks)

As can be seen, Mary placed emphasis on requiring students to record the condition or aspects of the cylinder they were testing. Later when they were testing another cylinder (Episode 4-8), Mary asked them to make sure they recorded the number of layers of the previous cylinder, the two layer one (Episode 4-14). Here again that emphasis was part of the language-game of making claim and evidence and at the same time it was facilitating the act of comparison. As it was discussed in the chapter III, the discursive part of the action is not necessarily representing the action (Scollon, 2001). Sometimes the action comes with silence, and sometimes the action comes with the discourse that is related to other actions. Here the discursive part related to the language-game of making claim and evidence; however, this action can be counted as part of the language-game of comparison—based on this recorded data, later they were able to compare the two- and five-layer cylinders.

Episode4- 14 Recoding the number of layers.

teacher	how many were in the first cylinder
Tyler	Two
teacher	did you record that
Tyler	Yes
teacher	if you not, you want to
teacher	is that an important thing to write it down
Tyler	Yes

The smaller cylinder hold less than the bigger one

Austin and Courtney did their big paper-object and now they were to test the small cylinder. Austin started to explain his opinion about how much weight the smaller cylinder could hold, Episode4-15.

Episode4- 15 Connection of the claim with the comparison of two cylinders.

Austin	I wanna try this, I think it gonna hold only five pounds (he is kind of sure about what he is saying)
Teacher	tell me why you predict this?
Austin	because this is bigger (holding the big cylinder) and this is smaller(hold the smaller)
Teacher	so, you are making a claim right now that the smaller holds less?
Austin	Yes
Teacher	I guess you will find out in a few minutes

In the first line of this episode, Austin was making the prediction, without calling that as prediction: "it's gonna hold only five pounds." It was Mary who named it as a prediction. The prediction was made based on the comparison between big and small cylinder. Thus, in the first three lines of this episode, a connection between prediction and comparison was made. In line four, the teacher made a more explicit connection between comparison and what Austin wanted to say at the beginning. This can also be considered as an attempt to show the kids how to generate the claim and evidence. The last line of this Episode is a connection between claim and evidence. Later, when Austin and Courtney tested the small cylinder and saw that despite their prediction, it held more, Mary started conversation with Austin to emphasize that he needs to check the accordance of the claim and evidence as noted in the Episode4-16.

Episode4- 16 A connection between the claim and evidence.

teacher	oh oh, is this going with your claim
Austin	no(shaking his hand)

As could be seen in Episode 4-16 and 4-15, while the conversation between Austin and Mary can be interpreted as part of the language-game of generating claim and evidence, it also can serve as a negotiation about how to compare those two cylinders. This aligns with what Scollon (2001) argued about the intersection of actions without being explicitly represented by their discursive part as discussed in chapter III.

Claiming that more layers, hold more weight

As Isabel, Tori, and Nathan were putting some books on their four-layer cylinder, The teacher started the following conversation with them about making a claim. As can be seen in the Episode 4-17, the first line is the connection between the previous shape and the one under testing, that is a comparison between the two. The students' answer in line 2, is a topic of the next question that makes a connection between the idea of "more support with more layers results in holding more weight." This Episode is similar to the previous ones, suggesting that playing the game of making claim and evidence can helps Nathan's group to make a comparison between the single- and four-layer cylinders.

Episode4- 17 Claiming: more layers, more support, holding more weight.

teacher	why are you changing it from one layer to four?
Nathan	so, they have more support and hold more books
teacher	why do think it hold more books?
Nathan	because, em…, I don't know
teacher	you said something about support
Nathan	it got more support on it
teacher	so, you think, more layers, more support, therefore, it hold more
Nathan	Yes
teacher	it is a claim? Let's see if it is true.

The results demonstrated that students initially focused on the language-game of "comparison by observation" or "improvement by manipulation." However through the conversation with the teacher, students were occasionally able to use the new words and rules of the language-game of comparison. For instance, students vocationally used the term weight instead of the "number of books" or used "tall and short" instead of "big and small."

In the next part, the changes in the rules followed by students are described. Students were doing something which could be considered a part of the language-game of comparison, and the teacher helped them to re-interpret what they were doing and encouraged them to complete the act of comparison with more alignment with the science language-game. For instance, in Episode 4-10, students made one cylinder and put the books on it but there was no clear sign of their intention for doing so with the second object. The teacher, through conversation with students, re-interpreted their activity and encouraged them to do so with the second object. Or in another case, the students tested two objects, and the teacher helped them to re-interpret those two tests as connected activities in which they could compare those two objects. For instance, in Episode 4-11, students did the two layers, and then they made the better one, five-layers. Then the teacher discussed with them and helped them to connect those two attempts together and saw them as an act of comparison of two-layer and five-layer cylinders.

The researcher also highlighted that the key words and rules of claim and evidence were incorporated into their activity. It is suggested that in some moments of classroom activity both language-game of comparison and the language-game of claim and evidence are mixed with each other and this can be introduced as a mechanism for changing the language-game of comparison.

All of these activities and conversations led students to write down a claim and evidence on a piece of paper which they took to the next session, D-session in which those claims and evidence were the subject of discussion.

How ***can*** students' and teacher's participation in the D-session decrease the mentioned gap?

How the words of the language-game of comparison can change during the D-session

Table4-4 illustrates all the claims and evidence that students generated during the M-session. The two last columns are emphasizing the words students used in those claims and evidence. These are the topics of discussions in the D-session. In this section, it is suggested how the language-game of comparison can change through the discussion of the generated claim and evidence.

As can be seen in the last two columns, the negotiated words appeared in students' claim and evidence. And also the first two columns illustrate the results of the negotiations about how to compare the paper-objects. For instance, in Tyler's claim, the two- and five-layer cylinders were compared and the results appeared as a claim. Based on this, the researcher suggests that some changes in the language-game of comparison can be observed in the students' claim or evidence.

Table4- 4 Students' claims and evidence and the word use.

Names of students in each group	Claim	evidence	the words by which the paper-objects was described	the words by which the weight tolerance was described
Brooklyn, Blake, and Tori	Our claim is "Shapes that have more layers and have things inside. It can hold more weight."	When we were doing it, our first one, our cylinder, it had, it was a single layered one. It didn't have anything inside it…and it only held like… 25. And then when we made it, we put stuff inside it, and we…some more layers, it held up 29. The taller one. The wider, taller one..	shapes,layers,things inside, cylinder, layered, stuff inside, wider, taller	weight, number
Tienna and Tait	Okay. Our claim is "Taller and wider shapes hold more weight."	Our evidence is- our group's shape, we called it a heavy heavy duty cylinder, 13 layers, held 30.5 pounds. Also, all of the big, wide, and tall shapes held more than ten pounds.	taller, wider, shape, heavy heavy duty cylinder, layers, big, wide, tall	weight, number, pounds
Austin, Courtney	This is our claim. Shorter objects with layers can hold more weight.	We have.. Our most was seven layers. We had two squares, four cylinders, and one triangle. And it held 27.5 pounds and 20 books. Our short shape with seven layers held 27.5 pounds, and then our tall cylinder only held 10 pounds with one layer.	shorter, object, layers, squares, cylinders, triangle, short, shape, tall	weight, number, pounds, books

To be continued

Table 4-4-continuted

Names of students in each group	Claim	evidence	the words by which the paper-objects was described	the words by which the weight tolerance was described
Tyler, Katie, and Cris	Our claim is the less layered shapes hold more weight.	When we used a two layered cylinder, it held 21.4 pounds...And the triangle prism had 13.6 pounds. And we had a 5 layered cylinder that only held ten pounds	layered, shapes, cylinder, triangle prism	weight, number, pounds
Isable, Tanner, and Nathen	Our claim is a cylinder can hold more than a rectangular prism and other.	Evidence is…when we did the cylinder, which had four layers, it could hold 53 books, and the rectangle could only hold 15 books.	cylinder, rectangular prism, layers, rectangle	number, books

The shapes of the paper-objects

As can be seen in the fourth column of Table 4-4, students still used the word "triangle" to mean triangular prism. One interesting use is in evidence presented by Tyler's group in which they wrote "triangle prism" which shows that they mixed the two old and new nouns and made a new one. This may suggest that for using this new word, triangular prism, they are in the middle of the process of learning to substitute the old word with the new one. And this is not just limited to their claim and evidence, it could be seen in the D-session as well.

The word "circle" was used to name the cylinder, but not used in their claim and evidence at all. In the previous section, most of their testing was about cylinder and the cylinder is ubiquitous word in all of claims and evidence in Table4-4. The researcher

suggests that the word cylinder became part of the classroom language-game due to the centrality of this word in the investigation and multiple times of usage.

Episode4- 18 Triangle or triangular prism.

002368	Isabelle	Yeah, we did a triangle, and…
002369	teacher	Can you tell us your data again? I don't think we were all listening enough during that part.
002370	Isabelle	For…we did a rectangle and it did 15 books, and we did a triangle, which held 4 books, and we did a cone, which held none.

As could be seen in the Episode 4-18, Isabel used the word "triangle" or "rectangle" in the D-session, while she was presenting their claim and evidence. An Interesting observation is that during her presentation when other students were critiquing Isabel's claim, at first she used "square" instead of rectangular prism, and while Blake responded to her talk, he used "rectangular prism." Later during the conversation Isabel again used the word square and tried to change what she had just said: "the square, it had, I mean the rectangle." This is a case to illustrate that in M-session, teacher tried to incorporate some words into the students' activity, later in D-session, some students adopted those words into their language. furthermore, some students were trying to incorporate those words into other students' activity as if in D-session some students played the role that teacher had played in M-session.

Taller and wider or bigger

Another example of the mix of the old and new words can be seen in Episode 4-19 when Tienna used both the old word of "big" she initially assigned to the cylinder and the teacher's suggestion of "tall and wide." Although she used tall and wide in their claim, when she wanted to explain their evidence, Tienna and Tait used the old and new

words together (line 2155, 2158, and 2160). When we look at their claim(line 2153), it seems that they have adopted the new words, tall and wide, but it is during the discussion that it become clear they still use the mix of both. The point is that the D-session provides an opportunity for them to apply those words into their conversation practice and this can help them to gradually revise it, as happened for Isabel When she said “the square, it had, I mean the rectangle.” In the following we will see more of this kind of revision of word use.

Episode4- 19Taller and wider, or bigger.

002153	Tienna	Our claim is "Taller and wider shapes hold more weight."
002154	Teacher	All right, give us your evidence.
002155	Tienna	Our evidence is- our group's shape, we called it a heavy heavy duty cylinder, 13 layers, held 30.5 pounds. Also, all of the big, wide, and tall shapes held more than ten pounds.
002156	Tyler	I don't really get what you mean by your evidence.
002157	Teacher	No, but that's, those are good things. We didn't have time to process that, so if you could tell us again.
002158	Tait	My group shaped the heavy duty cylinder and held 30.5 pounds. All the big and tall and wide shapes held more...
002159	Teacher	Did that help clear it up, or do you still have questions?
002160	Tienna	So, what we're saying is the taller, wider, and bigger shapes that we had held more than..at least ten pounds.

The weight tolerance of paper-objects

As noticed previously, students tended to use “the number of books” as a scale to talk about the weight tolerance of the paper-objects. The process of “taking books to the scale and weighing them” helped them to use the terms “pounds” and “weight.”

However, as could be seen in the fifth column of Table 4-4, three groups did not used books in their evidence, and used the words weight, number, pounds; The last group still used books and number; and one group used the mix of both scales. However, this is the usage occurred in their writing that demands more conscious action. During the spontaneous talk in D-session students used books as a scale more often. For instance, in Episode 4-20, while Brooklyn was explaining their evidence, she used the number of books as a scale. Courtney then asked her to name the weight.

Episode4- 20 Number of books or weight.

002105	Brooklyn	It was the super shape, and it held (79?).
002106	Courtney	How many pounds was that?
002107	Brooklyn	Twenty nine point two.

This word use was further noted when Isabel explained their claim and evidence. Courtney and other students asked for the weight, and Mary had to intervene in order to make an exception for Isabel's group to use number of books instead of weight (Episode 4-21). This is another moment in which students played the role that the teacher had played during M-session.

It was not just the direct negotiation of Mary and students that could change the word use in the discourse; there were two aspects of the language-game of "claiming and evidencing" that provided an opportunity for students to learn these words as well. One of them was during the time they wrote their claim and evidence. As can be seen in Table 4-4, all those important words could have been applied into their claims and evidence. The second aspect was during the discussion time in which they had to use either the old

or new words when they wanted to discuss their claim and evidence. This was an opportunity for them to revise these words during the discussion, as illustrated by the example when Isabel changed the words “square” in her talk without having heard any direct comment.

Episode4- 21Teacher made an exception for Isabel for using “number of books” as weight.

002358	Courtney	With…would it be more weight or more books? Because you didn't mention that in your claim. Would it be more weight or more books?
002359	Teacher	Tanner? Did you hear her question? It shouldn't just be Isabelle talking. Tell them about your problem. What was your problem? What did you guys forget to do?
002360	Isabelle	We forgot to put down weights. Well, we weighed it, and then I forgot it and then forgot to put it down.
002361	Teacher	Okay. So they're just going to talk about number of books. Does that still give them data to go by? Yes. So, they're just going to talk about number of books this time, okay?

How the rules of the language-game of comparison can change during the D-session

In the previous section, it was illustrated that during the M-session, when students made some shapes to build paper-objects that could hold more weight, the teacher tried to help them to see the problem from the comparison point of view and to encourage them to make some explicit comparisons between those shapes. She also reminded them that they needed to record the specific information of the tested objects and the amount of weight they held. This provided the context for students in order to build their evidence. It was also described that while students tested some of those shapes, Mary was making a

connection between what they did and the claim they could have made. In this section, it will be demonstrated that how the language-game of claim and evidence during the D-session can strengthen the rules of the language-game of comparison.

The evidence column of Table 4-2 shows that students were able to collect some of the shapes they tested in order to support their claim. This suggests that they were able to make a connection between some of individual acts of comparison. However the way they acted during the M-session suggested that they were not seeing this kind of comparison as an important part of the activity they were doing. For instance, when Tyler, Cris, and Katie were testing the cylinder that was made with two note cards, they were simply attempting to make something strong enough to hold more books. Through the conversation with teacher they were convinced that what they built could be seen as a cylinder with two layers and they recorded that new way of seeing the cylinder. Later, when they built the second cylinder that had "a lot of things inside" there was no sign that they made a connection between this one and the previous two-layer cylinder. It was through the conversation with teacher that the shape was interpreted as a five-layer cylinder and then the connection between this one and the previous one was made. Table4-2 shows that what they made as their claim and evidence have all those connections. Their claim was about those two cylinders and the number of layers they had. The point here is that what was difficult for them during the M-session was practiced during the time they were writing their claim and evidence. These comparison connections were embedded into their claim and evidence.

During the D-session they had the opportunity to talk about the comparison connections they made. They were asked about the details of those comparisons and in this way they were required to communicate more about what they compared during the M-session. Furthermore, during the D-session, they became engaged in a new part of the language-game of "generating claim and evidence," which is a new comparison between all the claims and evidence that were made by students. The whole-classroom talk was a

new opportunity to know more about the paper-objects and the many-to-one connection they were supposed to make. In the following, it is illustrated how discussing the claim and evidence can engage students in the language-game of comparison.

The discussion should be confined to what was claimed

When the first group presented their claim, Austin asked about the relation of height and the amount of weight the cylinder could hold was not something that they claimed. Here Mary coordinated the discussion and asked them to focus on what they claimed (Episode 4-22). The main point here is that when students were asked to talk about what was presented, they would talk in many ways and the discussion could digress from the main point. Later Mary clearly defined the main point of the discussion. When Tienna and Tait presented their claim and evidence, Mary asked whether anyone had some data that went against Tienna's and Tait's claim. This question is one of the main points of the D-session she emphasized.

Episode4- 22 The discussion should be confined to what was claimed.

002064	teacher	But, really, your claim has nothing to do with height. Can you read your claim again, please?
002065	Blake	Claim. Our claim is "Shapes that have more layers and have things inside. It can hold more weight."
002066	Tianna	But that doesn't say a lot about the height of it. It just says…
002067	teacher	Their claim is "Shapes that have more layers and stuff inside hold more weight." Right? Their claim is nothing about heights, small short, fat wide. Their claim is "more layers, stuff inside- holds more weight."

As can be seen in Episode 4-23, the main point of the D-session or one of the main point of the language-game of " claim and evidence" , helped students to go to

another layer of comparison in order to compare the presented claim and evidence with their own claim and evidence.

Contrasting the claim and evidence in whole class discussion

In Tait's and Tienna's claim, the tallness and wideness together was related to the weight tolerance of the paper-objects, and what Courtney added (line 2182) was evidence that went against their claim. Tienna reacted to that response by recalling that their claim was about both tallness and wideness (line 2183) and probably what Courtney presented was about only tallness. Although the conversation was left unfinished, the discussion was about to converge to add both pieces of evidence together and make a new claim that a "wider object can hold more weight."

Equating the claim and evidence

Similar to inviting students to talk about some evidence that goes against the presented claim, Mary invited students to share something that arees with the presented claim as well.

Episode4- 23 Any evidence goes against it?

002181	Teacher	Yes? Any other questions for this group? Does anyone have data that would go against their claim? Look at your notebooks. Does anyone have a tall one that didn't do as good as a short one?
002182	Courtney	We had a tall cylinder that only held 10 pounds and 29 books, and then we got a littler cylinder, and it held 15.8 pounds and 38 books.
002183	Tienna	Well, were they wide?

When Tyler, Cris, and Katie presented their claim, “the less layered shapes hold more weight”, and the evidence they use to support that claim, Mary asked other students whether they had any evidence that supported the presented claim (Episode 4-24). From Blake’s comment it is clear that nobody in class had something that supported that claim, or at least not that they were willing to share. Most of the members of the class were convinced that more layered is related to more weight tolerance. Mary then asked any evidence that went against it, and Austin responded by comparing their claim with the presented claim. Tyler’s claim was just about layers and did not have to do with the tallness. So, Austin, similar to the previous Episode4-23, had to compare one aspect of his claim with the presented claim. This suggests that the discussion promoted in the D-session can help students to realize that they have to compare one aspect at a time. This bears more resemblance to the key rule of “comparison by manipulation” which says for comparing the dependent with independent variables, it is required to control the confounding variables.

Episode4- 24 Any evidence that support it?

002307	Teacher	Anybody have evidence that supports their claim?
002308	Tyler	I didn't think anybody would.
002309	teacher	Anyone have evidence that goes against?
002310	Courtney	Our claim….
002311	Austin	Our claim was that shorter objects with more layers would hold more weight.

Smilar to what she did in M-session, Mary negotiated with students about the rule of comparison based on what students did, but this time the negotiation was about

something more complicated. During the M-session, Mary's negotiation was about preliminary rules of comparison such as "for comparing, you need to have two objects" or "are you going to do the short one?" However during the D-session, students had already generated the result of the act of comparison as their claim and evidence. The role of Mary in this part of the lesson was more canonical on revising those claims and evidence.

The heavy duty cylinder can be omitted from the evidence

When Tienna and Tiat were presenting their claim and evidence, Mary was directing them to think based on the rules of comparison. Episode 4-25 is an example of this kind of direction. In this episode, their claim was about the tall and wide cylinder, but in their evidence, they had a heavy duty cylinder that held the most. Other students suggested that, as in the evidence they had the heavy duty cylinder with lots of layers, their claim should say something about the layers. At that time, Mary intervened in the discussion to mediate between students' ideas. Through a step-by-step discussion, she helped students to realize that even if the take out the heavy duty cylinder, they still can make that claim, because they have enough evidence. Although during that step by step comparison, more than one variable changed, "the number of layers" as an extra variable that made the comparison more difficult was eliminated.

Is it fair to change both variables?

As can be seen in Episode (4-26), during the discussion with Courtney and Austin, as they compared both layers and width, Mary reminded them that it was probably more "fair" if they just changed one variable.

In terms of helping students to learn the rules of comparison, what Mary did during the D-session was similar to her role during the M-session. In the M-session, students made some paper-objects and Mary made some comparisons connection between those objects in order to help the students to compare them. Here, they have

already made those comparisons, and Mary helped them to refine their comparisons to be more precise way. The similarity between these two examples is related to the point that in both situations students did something and Mary tried to make a connection between what they did and what they were expected to do.

Episode4- 25 they have enough evidence without the heavy duty cylinder.

002171	teacher	Okay, 30.5. Got that in your brain? The tall, wide one can hold more, tell us about the short shapes. How much did the short shapes hold?
002172	Tienna	Our short shape, which was a small cylinder, held 7 pounds.
002173	teacher	Okay. Got any more short shapes?
002174	Tianna	We had a triangular prism and a rectangular prism and they both held 4 pounds.
002175	teacher	Did you try- anyone have any questions before I ask this?- Did you try- maybe you're thinking this, too- Did you try any tall, wide shapes that didn't have all the tape and the extra layers?
002176	Tienna	Yes.
002177	teacher	And how did those tall shapes do?
002178	Tienna	Good. They did good. They held, like, one was a big cylinder, it was pretty tall, and it was kind of wide. It didn't have any layers and it held 10 pounds.
002179	teacher	Which is still…Does that still go with their claim? Because it's still the short 7 and the short 4.

Episode4- 26 Did you need to keep one variable constant?

002201	teacher	And did you say they were both cylinders?
002202	Courtney	Yes.
002203	teacher	Did they both have the same amount of layers?
002204	Courtney	No.
002205	teacher	So is that fair? I'm just asking.

The key point of the language-game of comparison

At the end of this D-session, in two moments of the class discussion, two of students talked as if they had a sort of understanding of the problem of "many-to-one" relation that is the problem with confounding variables.

As it was shown in Episode 4-27, Isabel, Tanner and Torri claimed that cylinders can hold more weight than rectangular prisms. Their evidence was that they had a cylinder with four layers and a rectangular prism with two layers. Tyler and Courtney mentioned the problem of the comparison. At that time both of them were convinced that layers can affect the weight tolerance of paper-object. And they tried to mention implicitly that perhaps the cylinder held more because of the extra two layers rather than its shape.

Episode4- 27 Layers should remained constant while the shapes were compared.

002376	Courtney	So how many layers did your cylinder have?
002377	Isabelle	Four. And then we did one with three layers..
002378	Courtney	In the cylinder with 4, was it all cylinders, or were there other shapes in it?
002379	Isabelle	Others. Other shapes, too.
002380	Austin	Like what other shapes?
002381	Isabelle	A square and a triangle. The cone..
002382	Tyler	How many layers did the rectangular prism have?
002383	Isabelle	Two.
002384	Tyler	So wouldn't that, um, well it doesn't go against the claim, but what if you had four and it held up just as many. I mean, to have that claim, you would've had...
002385	Courtney	But you also had less layers in your rectangular prism.
002386	Tyler	And that could've affected it.

The next moment that shows how Tyler touched the relation of many-to-one in a competent manner was shown in Episode 4-28. After Isabel presented her group's claim, Mary asked to see if someone had any evidence that challenged the presented claim. Tyler mentioned about their testing with a five-layer cylinder that held less than a rectangular prism with one layer. At first, the teacher thought that he was not correctly comparing those objects because those objects did have different layers.

Episode4- 28 Two variables can be compared if… .

002403	Teacher	Did anyone have that would go against this? That something besides a cylinder held the most weight that they tested? Does anyone have anything that goes against their claim?
002404	Tyler	I have something that goes with it and against it at the same time. We had a cylinder that had…okay never mind. We had a five layered cylinder that held ten pounds, but then a triangular prism that had 13.6 pounds.
002405	Teacher	And what would be my question that's in my head right now? Did they have the same number of layers? And did they?
002406	Unkown	No.
002407	Teacher	If not, then can we truly say that the triangular prism held more? Because what might have affected it?
002408	Unkown	The weight.
002409	Tyler	But it was only one paper. It was only one paper.
002410	teacher	But you said one had five layers and one had four.
002411	Tyler	The cylinder had five layers.
002412	teacher	And what about the triangular prism?
002413	Tyler	It didn't have any.
002414	teacher	So it only had one layer.
002415	Tyler	Yeah.
002416	teacher	So you're…say that again, this is interesting. Your five layer cylinder held ten pounds. A one layer triangular prism held..

But as Tyler explained, Mary realized that actually Tyler was correctly comparing those two variables at the same time without keeping the one variable constant. He simply meant that even though the cylinder had layers, it could not have held as much as the triangular prism with one layer.

In this section, the researcher has described how students' and the teacher's participation in the D-session can change the language-game of comparison. Students were provided an opportunity to write down all of the comparisons they made as the claim and evidence, and thus the act of comparison can be seen in a more organized manner. During the D-session, students had the opportunity to talk about what they compared, and this helped them to have more focus on the act of comparison. For instance, students through comparison of their own claim with the presented claim can approach the problem of comparison. Participating in the language-game of claim and evidence can change the act of comparison. This can occur during the negotiation between teacher-students or student-student.

Was the gap decreased?

This section illustrates the changes in students' discourse of comparison. The section is broken down into two parts. In the first part, one of the lessons that occurred at the end of the semester is described. How the word use and the rules of the language-game of comparison have changed will be highlighted. In the second part, the changes of the language-game of comparison are described in a more quantitative manner for the all the data representing the entire academic year.

Analysis of the case of "how mass affects acceleration":

did the words and rules of the language-game of

comparison change?

The last lesson of the year is about making a causal inference about the relation of mass and acceleration. Mary wrote down the topic of inquiry on the board: how does mass affect the acceleration of the object? She then asked students to write down their ideas about that question. After they thought for a while about the question and wrote down their ideas, she asked them to talk about the question.

What is mass?

In Episode4-29, Austin is sharing what he was thinking about the topic of investigation.

Episode4- 29 What is mass?

009905	Austin	What is mass?
009906	Tienna	I think it might be weight or something.
009907	Blake	I think mass is like a, this has a greater mass than this.
009908	Tyler	I think the like the.
009909	Tienna	The weight of an object.
009910	Tyler	No, not exactly weight,
009911	Blake	This has more to it than this thingy.
009912	Tyler	Yea.
009913	Blake	Because this has more stuff in it, like.
009914	Unkown	More grams.
009915	Tyler	Sort of, it's kind of like the stuff that's inside. Yea I think that's what it is but I'm not sure. Um.

As was seen in Episode 4-29, Austin's question is about one of the aspects of the object. Following his question, Tienna made a connection between mass and weight which is a common connection elementary students make. However, what Blake, Tayler, and one other student added to the discussion suggests that some students were developing a connection between "mass" and "the stuff inside of an object." Overall, this discussion suggests that some of the students had an understanding about one side of the comparison. The following discussion in Episode4-30 suggests that they also developed some understanding about the other side of the comparison that is acceleration, as well.

Acceleration as speeding up

Blake (line 9918 and 9920) mentioned an experiment in which they could drop a bigger object and a smaller object, and record the results.

Episode4- 30 Acceleration as speeding up.

009918	Blake	I wrote down that I think we are going to drop a bigger object.
009919	Tienna	I think it's weight.
009920	Blake	And drop a smaller object and record the results, I also. Also that the more mass, the more gravity pulls on it, because there is more to pull.
009921	Teacher	What do you think about what he said? Half of you weren't even paying attention.
009922	Tyler	I like it.
009923	Teacher	What do you like about it, Tyler?
009924	Tyler	Well, like I'm pretty sure it's true that the more mass an object has, the more gravity has to pull down on it, and like if it were going downhill it might make it go faster with more weight.
009925	Austin	Ohh, like going uphill on like a semi that's ahead of a car going straight, and then when a semi is going up a hill, um the force is slowing it down because it's heavier, and then the car is passing it.

Although his experimental design here not what teacher planned for it. His idea was an apt design for the topic of inquiry. He changed the mass of the objects and he explained in line 9920, that these two objects are pulled down by gravity in different ways, implicitly stating that the bigger object is going to fall faster. Tyler in line 9924 continued the idea of "heavier objects fall faster" by equating what Blake said about the falling object with the heavy car that goes downhill. And Austin in line 9925 continued the idea by comparing two heavy and light cars that go straight and then go uphill. All these comparisons and equations suggest that they have some understanding of the idea of "speeding up" and "slowing down" which is critical for understanding of acceleration. Furthermore, in this episode they made the following comparisons: first, bigger objects fall faster than smaller objects; second, heavier cars go faster on downhills; third, heavier cars go faster on straight roads; and fourth, heavier cars go slower on uphills. They also made comparisons to equate between: first, the more mass, the more gravity pulls on it; second, the more mass an object has, the more gravity has to pull down on it; and third, force is slowing it down because it's heavier(the heavier, the more force). They also used some words of the activity during this conversation such as weight, record the result, mass, gravity, pull down, faster, and force. Making those related comparison, and using the words of the activity increase their chance to change their way of talking, their discourse about mass and acceleration.

The previous Episode also showed that their way of talking is more similar to the traditional discourse about the falling objects: the heavier objects fall down faster. Following this idea, Austin and Blake ran two separate experiments.

Heavier objects fall faster

As could be seen in Episode 4-31, two experiments followed each other to test their claim about the idea of "the heavier object falling faster." Austin compared a sock with a pen and concluded that pen is heavier and fall faster. At first he dropped the sock and then dropped the pen, but to have an observable comparison and fair one, he held

both objects in one hand and dropped them together. After that Blake held a pen in one hand and a set of highlighters in the other hand and dropped them together, and concluded that highlighter fell faster as they had more weight. The interesting part of this Episode is where the teacher asked him "how do you know", he stood up, asked some students to sit on the ground to see which one hit the ground first, dropped the objects, and those students endorsed that the highlighter hit the ground first. In both experiments what they did was following the rules they learned: "you have a claim, you need to support it with evidence." They followed the rules of comparison as well: dropped the objects at the same time; dropped them at the same height; and in Blake's case, three persons observed the result to get a more precise answer. The final point that emphasizes that they were playing the language-game of comparison better than before was that they came up with this experiment and the experiment was not at all planned by teacher because it did not serve the Newtonian framework teacher intended to teach. From the language-game perspective, both these examples can be considered as cases for the discourse of "comparison by observation plus procedural manipulation."

Making something in order to compare

After students shared their beginning ideas, Mary wrote down on the board name of the materials they were going to use in that lesson: paper clip, erasers, cup, washers, twine string, desk. She asked students to discuss what students can do with that stuff to investigate about the topic of the inquiry: how does mass affect the acceleration of the object? Students started a whole classroom discussion on what they were going to do with those materials. The beginning of the discussion is presented in Episode4-32that came with two novel scenarios suggested by students without any teacher interventions.

Episode4- 31 Heavier objects fall faster: running a "comparison by observation plus procedural manipulation."

Line number	Names	What they said	Observational notes
009981	Austin	You could do like get up and drop a sock.	he drops a sock and then drop a pen
009983	Austin	And then.	and then drop a pen
009985	Austin	And it goes faster.	pen goes faster
009987	Austin	Or you could drop it at the same time	he drops them both by one hand
009988	Blake	And you could do it like this.	he drops a pen and a set of highliter fasten toghether
009991	Blake	Like um, six highlighters and one pen, the highlighters hit the ground a split second before this.	
009992	Teacher	How do you know that? Are you sure of that?	
009993	Blake	Yea.	
009994	Austin	Or you could just like	
009995	Blake	You could have someone get on the ground and watch it.	he stands and three students sat on the group to see which one will hit the ground first . He released the objects
009996	Teacher	I'll just put it on the ground okay.	
009998	Katie	Highlighters.	while their head was on the ground and waited for the object to hit the ground
009999	Cheyanne	Highlighters.	
010000	Katie	The highlighters hit first.	

In Episode 4-32, following the teacher, Austin described a plan that applied the material and could provide an answer to the topic of the inquiry. Although it is hard to realize what he meant, it seems that his basic ideas is to drop all the materials at the same

time and record which one fell faster. Based on previous episode he would have probably predicted that the heavier one fall faster.

Here the evidence of following comparison by observation, procedural manipulation was evident. He offered a way of comparing the objects through a procedural manipulation: holding the objects, presumably, at the same height, dropping them at the same time, observing which one hit the ground first, recording the result.

In the rest of the episode 4-32, the idea of "making something" was proposed by Isabel, and Blake proposed to make a parachute. The following design can be interpreted from their discussion: Making a parachute with the squished cup and twine string, attach the washers as weight, and change the number of attached washer to change the acceleration. This is another example of novel design suggested by students to investigate about the topic of inquiry. It has the procedure how to manipulate the falling objects in order to see how mass is related to acceleration. However in both cases, while they changed mass, students actually changed the force applied to the mass and acceleration has to do with both force and mass. Force and mass are the confounding variables for measuring the acceleration of an object.

We need a stopwatch

As Blake and Tyler were talking about their plan, they were talking about putting some washers on the string and letting them fall, then changing the number of washers and repeat the test. They wanted to see the relation of the mass of the object, a set of washers, and the time that took them to hit the ground. As Episode 4-33 shows, Blake asked teacher to give them a stopwatch for measuring the falling time. As we saw in the previous episode, Blake demonstrated in class that a set of highlighters fell faster than a pen, and his evidence was the time that it took to hit the ground. So, for him, the hit-time was a criterion for comparing acceleration of the washers. The way he planned to do the measuring of time as the number of washers was changed is a tool assisted observation.

Episode4- 32 Two scenario based on "comparison by observation and procedural manipulation."

10006	Teacher	Those are our materials, we have chalkboard erasers, a cup, a paper clip, twine, string whatever you want to call it, and washers. Find me a discussion as an open group, what might you might be doing with those, open discussion.
10007	Austin	I think you have like chalkboard erasers and like a cup and you drop them at the same time, and record which one would fall first and then you would, which one ever one, you would be like chalkboard erasers and paper clips, or like chalkboard erasers and go through all of them and record what would happen and then like go through cups all the way, and then paper clips
10008	Tori	And then twine and then washers.
10009	Blake	Okay, and you do chalkboard erasers and you do everyone and then you do the cup and every one and then the ones we havent done together like paper clips and twine and washers and twine and washers and
10010	unkown	And record them all. Record them all at once.
10011	Teacher	Does everybody think that? Or what other ideas could there be?
10012	Austin	Maybe we could put them like, maybe make, like maybe put some thing together.
10013	Tori	Yea, maybe like
10014	Isabelle	Maybe we could make something
10015	Blake	Yea maybe like a parachute or something.
10016	unkown	Why would we make a parachute?
10017	Isabelle	Air, air particles.
10018	Austin	What would we use, what would we use for the chute then?
10019	Class	The cup.
10020	Austin	Squish a cup or something?
10021	Blake	No, use the cup as a parachute.
10022	Tyler	And then it could catch it.
10023	Blake	And you could slide the string

To be continued…

Episode4- 33-coninuted.

10024	unkown	We could put the twine through the cup and the paper clip on the opposite side and then wooo.
10025	Austin	But then what would you use the washers for?
10026	Tyler	That could be the weight.
10027	Blake	And the chalk erasers and the paper clips could be weights too. But then what would that have to do with acceleration?
10028	Tyler	Oh, it says, it says,
10029	Austin	You could put more weight.
10030	Blake	Yea.
10031	Austin	Maybe you could put more weight on it each time. I know.

And the plan for changing the number of washers and measuring the time can be considered as procedural manipulation. Therefore the whole plan can fit to the language-game of "comparison by tool-assisted observation plus procedural manipulation."

Episode4- 34 Tool-assisted observation: we need a stopwatch.

010163	Blake	We need a stopwatch.
010164	Teacher	Uh, oh, but that wasn't one of the supplies.
010165	Blake	Yea. We could count in our head.
010166	Tyler	Na.
010167	Teacher	Hmm, how reliable is that?
010168	Tyler; Blake	Not very

<u>Even though my left hand is weaker, this eraser goes faster</u>

Cris and Courtney attached some washers on the erasers in a way that the washer prevented the erasers from touching the desk. Cris pushed two erasers across the desk

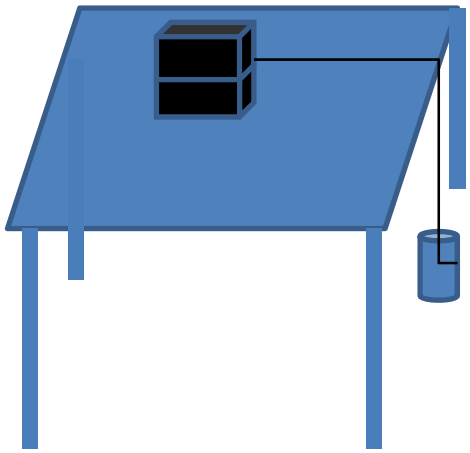
multiple times, one of them had washers stuck in it, and the other did not. The one with the washer went further and seemed to go faster than the other one as well. When Mary went to their desk, Cris wanted to show her what they did (Episode 4-34). In line 10192, after Mary watched the demonstration, she asked Cris about the sameness of the exerted force in order to show him that he needed to think about a design in which he could be sure about exerting the same amount of force. She made a case that right hand is usually stronger than left hand, so he may have exerted more force with right hand. Cris responded that one eraser went faster, because the one that went faster and further was the one that he pushed it with his left hand and his left hand is weaker than his right hand. So, he competently compared the effect of the changes they made on eraser, even though the amount of force exerted on erasers was not the same. This is similar comparison we saw in Episode 4- 28.

Gradually the class converged on the specific design that appeared to be planned by teacher, Figure 4-4. Students put some washers as force on the cup and the cup fell down as well as the erasers. By putting one eraser on the top of the other, the students were able to change the mass, and by adding washers into the cup they were able to change the force exerted to erasers.

Episode4- 35 Even though my left hand is weaker, this eraser goes faster.

010190	Cris	See, it does make it go faster.
010192	Teacher	But how is, how do you know it's the same force?
010193	Cris	I'm pushing it the same.
010194	Teacher	But how do you know it’s the same strength? Maybe my right arm can push harder than my left arm.
010195	Cris	I'm using my left arm on this which is weaker.
010196	Teacher	Then they're not the same.
010197	Cris	It's still going farther.

Figure4- 2 The set up for investigation to see how the mass of an object affects its acceleration.



Weight or force?

Blake, Tyler and Isabel attached five erasers to one side of the string and on the other they had the cup with 19 washers inside. The system moved slowly. Episode 4-35 shows how they talked about the important aspects of the objects they were supposed to make relation between them, mass and acceleration. As could be seen in Episode 4-35 teacher negotiated with them about the important aspects of setting, similar the negotiation she had with them about the words of paper-objects. She is also talking with them about adding washer to see the changes.

So, this suggests that her role as a teacher did not change much compared with what she did in the early session of the class. However, in this episode, the mass and force have been quantified by students respectively by number of erasers and washers. Furthermore, as it was shown in previous episodes students talked competently about changing one aspects to see how another changed (look for instance on episode 4-32 or 4-33).

Episode4- 36 Weight or force?

010272	Teacher	Take some more what, Tyler?
010273	Tyler	It'll take some more weight to pull them mass down.
010274	Teacher	Okay, and what are the washers representing?
010275	Blake	Weight.
010276	Teacher	Not weight.
010277	Tyler	Gravity
010278	Blake	Force.
010279	Teacher	Force. And force should, force is a what?
010280	Tyler	Um, a push or a pull, I think.
010281	Teacher	A push or a pull, and what's it doing?
010282	Blake	Pulling.
010283	Teacher	Pulling. Okay, lets see if you're right, lets see if itll take more.

For instance, in the following moment after Episode 4-35, in order to move three erasers, students added some washers into the cup to see the effect of change of force and they repeated the procedure for two more times to be sure that when they add force they get higher acceleration.

Washer and eraser or force and mass

During the D-session, as usual students presented their claim and evidence and other students asked them some questions about the details of what they did. However, what contrasted this session from the paper-object session was that in the paper-object session most of the time of the session was spent about how they did their comparisons, and how their claims were opposing each other. In this recent session, they had less

disagreement with each other, and they put more time into revising their own claims by adding more science words to their claims. For instance, in Episode 4-36, while Tanner and Tait presented their claim, Mary negotiated with them to use science words in their claim. Through the negotiation, the students themselves suggested to change the word erasers to mass, and washer to force.

Episode4- 37 Washer and eraser, or force and mass.

006083	Tanner	More erasers, more washers
006084	Teacher	So let's see now, let's change that into using science words in their claim. Instead of saying more erasers, what could you say now? Just a second let them think about it…The erasers were the what?
006085	Tate	The erasers were the mass
006086	Teacher	So say more mass needs…
006087	Group	More force
006088	Teacher	what do you guys think about that?
006089	Class	Yeah, umhm.

Revising the claim

This revision of their claim and evidence occurred for the other groups as well. For instance, Courtney and Cris, completed their experiment with three erasers and kept them constant, instead they changed the number of washers. Their claim was not communicating with what they did. They claimed that the "chalkboard erasers represent mass and washers represent force, which is affecting the acceleration of the mass." Throughout the negotiation with the teacher and suggestion made by other students (Episode 4-37), they changed their claim to "As we added more force the mass accelerated faster."

Episode4- 38 Revising the claim.

006244	Brooklyn	Maybe they can switch faster and acceleration, maybe we can switch that, like you could say…
006245	Teacher	So let's go see, now let's go with Brooklyn and now see what you could write.
006246	Courtney	Ok, as we added more force to the…
006247	Teacher	As we add force…
006248	Courtney	As we add force it makes mass accelerate.
006249	Teacher	As we added, so the more force, you're saying the object did what?
006250	Courtney	Accelerated fast
006251	Teacher	You may want to say accelerated faster because they all accelerated right? Even that one that you said was slow. Didn't it stop, wasn't it not moving and then it moved?
006252	Courtney and Chris	Yeah
006256	Courtney	As we added more force the mass accelerated faster.

This process of revision was done for four of the five groups. The revised claims in most of the cases were not different from the initial one in terms of what they compared. However, the language they used to express their claim changed and the revised claims as it was shown in Table 4-5 bore more resemblance to a typical classroom science claim.

Coming back to the starting question in this section, the results suggest that students still need negotiation about the words and rules of the language-game. They can play the language-game of comparison better than at the start of the year. As it was described, they showed that they can design a procedural manipulation to make the case ready for comparison; they showed they can equate the old with new aspects of the objects, they handled the quantified observation about the washers and erasers. However,

they have not yet shown competence with to the problem of confounding variables although they were able to approach to this issue in some respects.

Table4- 5 Students' claim and evidence was changed through the discussion

Names of students in each group	Initial Claim	Revised Claim
Tienna and Brooklyn	the more mass you have the more force you get out of the object	The more force you need to make it [start to] accelerate?
Austin, Katie,	The more erasers the slower, the more erasers the slower it goes but if you have less erasers it goes faster	The more washers you have in the cup, the faster the erasers go.
Tanner and Tait	More washers, make the cup go to the ground	More mass needs, more force
Blake, Isabel, and Tyler	Our claim is the more mass you have, the more force is needed…	Not changed
Cris and Courtney	Our claim is that chalkboard erasers represent mass and washers represent force, which is affecting the acceleration of the mass.	As we added more force the mass accelerated faster.

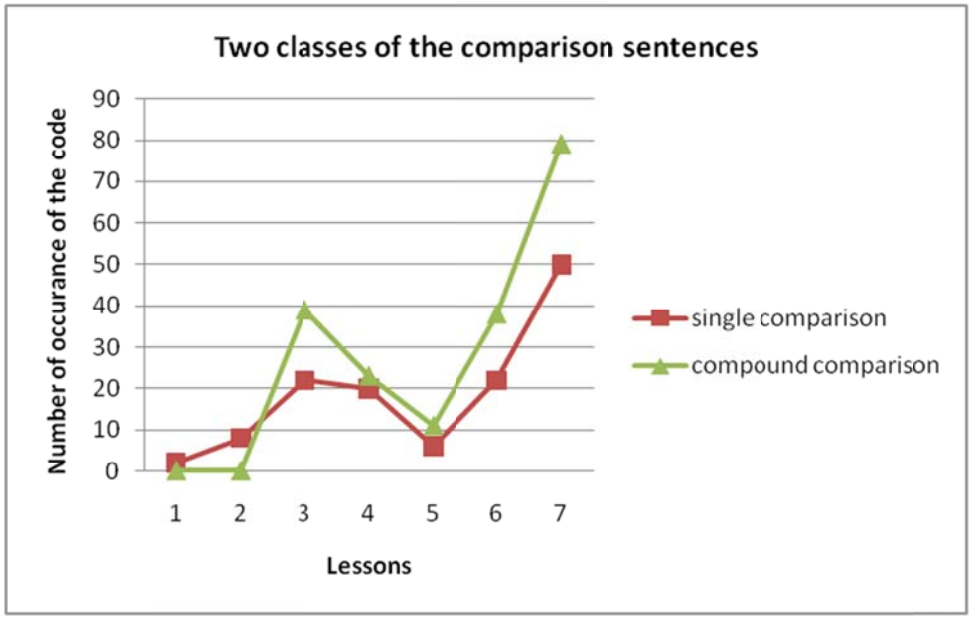
The researcher would suggest that the teaching method was effective and made the gap shorter but the gap is still there. It seems that the students have a long way to go to play competently the complicated language-game of "comparison by tool-assisted observation plus procedural manipulation."

The analysis of videos representing the whole academic year: how the words and language-game of comparison changed

The trend of occurrence of compound sentences made by students across the year

As could be seen in graph4-1, the occurrence of single and compound comparison over one academic year was described. The linear regression analysis suggests that the changes in single comparison sentences over the academic year was not significantly increased ($P< 0.053$). However, the same test suggests that number of compound comparison sentences significantly increased ($\beta=10.17$, $R^2=0.61$, $p =0.036$). The test also suggests that the total number of comparison over the academic year increased ($\beta=15.75$, $R^2=0.60$, $p=0.043$).

Figure4- 3 single and compound sentences that were occurred in students' talk.



Analysis of comparison sentences made by students

More important than the overall increase in the number of these comparisons made by students is the quality of these comparisons. As could be seen in the third column of the table 4-6, all the compared aspects of objects that occurred in those 320 sentences were collected.

Table4- 6 the words use and pair of causal inferences.

Lesson	topic of the lesson	The compared objects and their aspects	pairs of aspects compared in compound sentences
1	What is in the mystery bag?	Bigger	---
2	who was the murderer ?	person, gushy, watery, falling	---
3	how the shape of an object affect amount of weight it can hold?	circle, bigger, smaller, taller, wider, thicker, wobbly, closer, larger, pounds, shape, layers, thicker, weight, rectangular prism, cylinder, books, holding weight,	(layers and things insides ,holing more weight),(taller, more wobbly),(more layers and thing insides , holding more weight), (less layers, hold more),(big, tall and wide, holding more),(shorter and more layers ,holding more weight), (taller, holding more pounds),(more layers , get wider),(cylinder versus rectangular, holding more weight), (cylinder versus rectangular , holding more)
4	what can affect the strength of a bone?	vinegar, hollow, stuff, weight, bones, faster, harder, longer, shorter, softer, smaller, larger, egg, thinner ,	(bones versus steel, stronger),(exercising, stronger bone), (vinegar versus water , making bones stronger),(more vinegar , dissolving bone),(longer versus shorter bone , dissolve faster), (thinner versus thicker bones , dissolve faster),(vinegar versus water , making bone harder), (water versus winger, more smelly), (water versus vinegar, making bone weaker), (water versus vinegar, making bone grow), (water versus vinegar, making bones stronger)

To be continued…

Table 4-6-continued.

Lesson	topic of the lesson	the aspects were compared	pairs of aspects compared in compound sentences
5	how does the respiratory system work?	room for air, air going out, lung, balloon, straws, smaller, bigger, inhaling, exhaling	(inhale versus exhale , making lung bigger)
6	how can I lift the teacher with one hand?	gravity, longer, harder, closer, shorter, pushing, lifting,	(adult versus young, weight more),(taller , more muscle), (block closer to Mary, lifting her up),(shorter one side, lifting her up),(closer to block , weight goes into block),
7	How does mass affect acceleration?	erasers, washers, powerful force, force, stuff, grams, gravity, pulling down, acceleration, speed, weight, mass, accelerate, faster, bigger, closer, heavier, lighter, shorter	(more gravity, faster the object),(heavier ,slowing down),(more mass ,slowing down), (more acceleration ,going faster),(more mass, drop faster),(more mass, more force), (more mass , more heavier),(more eraser ,slower the cup),(more washer ,slower the eraser), (more eraser ,slower the eraser),(more washer ,eraser goes faster),(more washer ,slower the eraser), (more washer, faster the eraser),(more washer ,more eraser), (more mass ,more force),(slower the eraser ,less force),(more force ,accelerate faster)

A qualitative comparison between the set of words of each lesson suggests the sets of words related to the ending sessions has more classroom science words, such as lifting, pushing, force, acceleration, mass, or gravity, than the sets of words used in the early sessions.

The fourth column of Table 4-6 shows the pairs of words between which students tried to make connections. It represents how students made a one-to-one or many-to-one relationship. For instance, (vinegar versus water, making bone stronger) in lesson 4, shows that at least in one of the comparison sentences students stated that in comparison with water “vinegar makes bones stronger.” As another example, in the same lesson, the

pair (water versus vinegar, making bone grow) shows that at least one group of students concluded that while the length of the bone in vinegar did not change, the length of the bone in water increased. They concluded that "water makes bone grow." As it was shown in Table 4-7, the qualitative comparison of these pairs of words over the seven lessons suggests that over time, these pairs are becoming more scientifically conventional. I don't want to say that the other pairs are wrong; all of these pairs of comparison represent students' attempt to make a new one-to-one or many-to-one connection. They are all part of the process of change of language-game or change of discourse. However, as the number of conventional ones increases, it may suggest that students' language becomes more similar to science language.

Around 60 percent of 320 comparison sentences, 190 sentences , are related to the act of compound comparison. As was mentioned, all of those sentences are related to make one- or many-to-one connections. For instance, "I saw Tanner when he demonstrated breathing and when he did his chest kind of got bigger kind of inflating" shows that the students on the one side saw the act of breathing in and out and on the other side saw the movement of the chest. So, "breathing in" and "chest is getting bigger" are the two covariates (Cheng, 1997) she saw, and made the conclusion that "breathing in" is equal to "chest is getting bigger." A Similar act of equating has occurred in all of 190 sentences. All of these compound comparisons are causal inferences in which two aspects of an objects covariate with each other and their changes equated with each other and then one of them is named as the cause of the other.

Overall the analysis suggests that the quantity and quality of causal inferences made by students increased over time. And this is more evidence to support the decrease of the gap between colloquial and science discourse.

Table4- 7 The number of distinct (not-repeated) pairs of connected aspects in each lesson as well as the number of pairs that are scientifically conventional.

Lesson	number of equated pairs in each lesson	how many of them are scientifically conventional(a teacher may look at it and says it is correct)
1	0	0
2	0	0
3	10	6
4	11	6
5	1	1
6	5	5
7	16	13

CHAPTER V

DISCUSSION

In this chapter, based on the results presented in Chapter Five, the researcher discusses how the proposed interpretive framework can contribute to analysis of science learning at the level of classroom. The discussion will be presented in four sections: in the first section, the researcher discusses how the interpretive framework can provide an explanation for the gap between what students bring to the investigation as their background and what is expected of them to do in science classroom. In the next section, the process of learning in that particular classroom will be the topic of discussion, and it will be argued how the framework can address the process of learning and the critical role of the instruction and the teacher in student learning. In the third section, the connections of this study and the studies on causal inferences will be discussed. In the fourth section the limitations and implications of the study will be discussed. In the last section, the improvement of the framework as a result of the investigation will be discussed.

What was the gap between what students did and what they were supposed to do?

The analysis of the videotapes together with the transcripts of the class indicated that the manner in which students completed the act of comparison and talked about it did not resemble the conventional ways that people talk and act in science. The students did not focus on the topic of the inquiry which was the comparison of paper-objects in order to make a causal inference about the relation of the shape and weight tolerance of the paper-object. Rather, they were, at least partially, engaged in improving their design in order to build the strongest paper-object.

Language-game theory was applied to see what kind of old language-games were mediating the way students did the act of comparison. Two colloquial language-games

resembled what students did in the class: the language-game of "comparison by direct observation" where comparisons are made using the five senses in the absence of tools and manipulation of the objects of comparison. The next colloquial language-game that resembled students' action and talk was "improvement by manipulation" which led students to make stronger and stronger paper-objects. The former language-game is directly related to what students were supposed to do while the latter one indirectly affected the purpose of the activity.

The result of the analysis about how students talked and acted at the beginning of the paper-object session can be presented with more resolution, if the results are seen in the light of other research studies which are based on language-game theory (Sfard, 2007; Sfard & Lavie, 2005;Wickman, 2003; Wickman and Ostman, 2002). In this section, a summary of the results in the light of the mentioned studies is discussed.

Focusing on what students did

Wittgenstein, in discussing the meaning of words, argued that "don't look for meaning, look for use." The initial words that students were using and the connection they made between those words at the beginning of the investigation come from the language-game they have already learned. For instance when the students used the words big and small, two groups of students assumed that the bigger object would hold more weight. This association of bigger and stronger can come from the many colloquial language-games, for instance, the language-game of cars that kids are so engaged with; the bigger the car is, the stronger it is. The second example is the moments the term "papers around" was used to say how the students wrapped the cylinder with another paper in order to support it. The third example is the moments the term "stuff inside" was used to say how they put some paper inside the cylinder in order to make it stronger. All these words they utilized during the classroom investigation are mediated by the old language-games they have already experienced. Wittgenstein (1969,2009) stated that

when a person is acting on an object, what strikes the person or what "stands fast" is the aspect of the object that "is immediately intelligible." He stated that those things that strike us as "standing fast" are brought to attention through the comparison of the current situation and what has been already experienced (ref, Wickman & Ostman, 2002).

In the paper-object case, the things that struck students as "standing fast" could be collected in two groups: First, the way that they acted which has to do with the language game of "comparison by observation" or "improvement by manipulation." Second the narratives they utilized in their actions which have to do with the way they utilized the words and the way they connected the words together. For instance, they used big and small in a narrative that connected those words to the word strength.

As can be seen, the nature of those groups is different. The first group talks about the way students acted and does not have to do with how they used words and connected them to each other. However, the narratives in the second group are similar to causal inferences and can be understood practically as the connections between words. Two emerged categories are similar to what Sfard called object-level and meta-level rules of discourse (Sfard, 2008). Object-level rules define the regularities based upon on how the objects of a discourse behave and are related. And meta-level rules define how the discussants of the discourse are acting. The initial condition of the classroom discourse is summarized in Table5-1.

The comparison between these two object- and meta-level rules indicates that the object-level rules are more contextual than the meta-level rules. Thus by changes of the topic of investigation, they will appear with a set of new words and the new connections between them. However, meta-level rules are more decontextual and are expected to occur similarly over two different topics of investigation. The other difference between these two language-game categories is their discursive aspects. The object-level rules can be collected by examining the transcripts of the classroom activity. Those words and their relation are explicitly delineated in the discursive level of the act of comparisons.

Thus, scrutinizing the transcripts of the classroom practice can reveal this level of the rules of discourse. Although students were not directly talking about "comparison by observation," these rules were interpreted by comparing the standing fast moments and finding similarities between all the standing fast moments. This emphasizes the importance of simultaneous analysis of discursive and non-discursive aspects of classroom practice (ref, Scollon, 2001).

Table5- 1The initial condition of the classroom discourse versus classroom science discourse in both Object-level and Meta-level rules.

Object-level rules of classroom discourse	
What was standing fast(immediately intelligible)	What was supposed to be
The bigger it is, the stronger it is	The taller it is, the weaker it is
The more paper around, the more stronger it will become	The more layers it has, the more stronger it will become
The more stuff in it, the more stronger it will become	The wider it is, the stronger it will become
	Cylinder is stronger than rectangular prism
	Cylinder is stronger than triangular prism
Metal-level rules of classroom discourse	
What was standing fast(immediately intelligible)	What was supposed to be done
Compared the aspects of objects by direct observation	Compared the aspects of the objects by tool-assisted observation
Manipulated the objects to make them stronger	Manipulated the objects in order to compare the aspects of the objects

Focusing on what students were supposed to do

The topic of classroom investigation shows what the classroom discourse was supposed to be about. The topic in the paper-object investigation was: how does the shape of an object affect amount of weight it can hold? Two other lessons have the same

topic structure (see, Table3-2, lesson 4 and 7). The short answer to these topics is a causal inference, and thus the students' claims are supposed to be a causal inference. However the classroom inquiry is not only confined to the final outcome, but it also about how students work with each other to generate those outcomes. Cheng (1997) stated that for making any causal inference, at least two covariate variables and the casual power are required. Based on the first requirement, to make a causal inference, students needed to observe changes of two variables through their investigation. However, their investigation did not have just two variables and they faced multi-variable cases (in lesson 3, 4, 6, and 7). Thus the students needed to follow the procedure of control of variables to make the causal inferences for all those investigations. When they changed the variables to see how those variables change they needed to run a tool-assisted observation rather than a direct observation. In the paper-object investigation, for instance, the variable for strength of the paper-object was measured based on the weight they could hold. In the last session, as another example, the amount of mass and weight was determined respectively by the number of erasers and washers. Table5-1 shows what the discourse was expected to be about.

As shown in Table5-1, the classrooms initial discourse was different than the expected discourse. In terms of Object-level rules, the expected ones are more quantitative and give more precise information about the strength of the paper-objects. In terms of Meta-level rules, the expected ones are more dependent on procedure and tools.

Despite all the differences between the object- and meta-level rules in the initial part of the class and what was expected to be, many similarities are observable. In object-level rules, by replacing the word "paper around" with the word layers, the two object-level rules become the same. In terms of meta-level rules, although the expected rules are more complicated than what students did, all of expected meta-rules are basically based on observation. The differences, as shown in the Table5-1, suggest the gap between students' discourse and the classroom science discourse, the thing that was asked as a

first research question in this study. However, it is the similarities between them that are more pedagogically important. The differences show the distance that students need to go, but the similarities show how much far they have come since their infancy. This rationalizes the importance of building the learning upon what students have already learned rather than approaching teaching as if learning had to be done from scratch. The metaphor of learning as change of discourse or language-game which is chosen as the foundation of the proposed framework emphasizes this point. This subtle point of emphasizing similarity between students and science discourse rather than the differences has pedagogical value. The research on misconception emphasizes the differences between students and scientific concepts and more recent studies that focus on learning progression, the successor of misconception studies trace the misconception over time. The very things that they call it misconception and try to replace with good-conception are what are called *standing fast* in the proposed framework. Standing fast is the way that students make a connection between the old and new discourses, and by finding a similarity between what stands fast and a science counterpart, it is possible to change the colloquial discourse to science discourse. The art of the act of negotiation will be discussed in the next section addressing how through situated negotiation how a similarity between standing fast and its counterpart is made.

How can teacher's and student's participation decrease the gap?

Focusing on words use

In the Chapter Four, it is shown how students started with the initial ways of talking and acting, and how the teacher by communicating with them encouraged the students to re-shape their words and actions. In the M-session, students started with some words to describe the paper-objects and the teacher directly communicated with them in order to make a connection between those words and the ones that were more related to

the expected activity. As was shown in the Table5-3, a summary of the results about the word use and the negotiation between the sides of communication is provided. During the M-session, through the communication between teacher and students, new words were generated. This generating process has two sides: on the one side, what stood fast for the students and on the other side was the new word suggested by Mary. The students had an opportunity to learn those suggested words by using the suggested words in other moments of the investigation. For instance, the word layer was generated when students reported how they wrapped a paper around the cylinder to support it, then that word was emphasized in two other moments: the moment in which the teacher emphasized the need to record the number of layers, as well as the moments in which the teacher emphasized the need to compare the five layers with the two layers, etc.

By the time students started the D-session, they had some opportunities to infuse those words into their activities. During the D-session, as it is shown in the second part of the Table5-2, two new patterns emerged. The first is about the word use, students started to utilize the new words while they kept the old words. The second is about the direction of the negotiation, where despite the M-session in which the direction of communication was teacher-student, during the D-session, most of the negotiation about the word use occurred between student-student.

In comparing these words in terms of object- and meta-level rules, most of the negotiated words are related to the objects of the discourse and are bonded to the topic of the lesson, as shown in the last column of the table. However, the word claim and prediction in M-session, and the word evidence in D-session, are not topic-bounded and related to the language-game of investigation and claim and evidence, therefore, they are categorized under meta-level rules.

Table5- 2 What words were standing fast for students and what was suggested to them through the communication.

The communication about the word use during the M-session			
what was standing fast(immediately intelligible)	what was negotiated	Communication between	Primarily related rule
triangle	triangular prism	teacher-student	object-level
Rectangle	rectangular prism	teacher-student	object-level
things around	Layer	teacher-student	object-level
things inside	Layer	teacher-student	object-level
number of books	Weight	teacher-student	object-level
Bigger	Taller	teacher-student	object-level
Bigger	Wider	teacher-student	object-level
I think this smaller is going to hold less	are you predicting…?, is this your claim…?	teacher-student	meta-level
we put some paper around it to support it	is this your claim that…?	teacher-student	meta-level
The communication about the word use during the D-session			
What was standing fast	What was negotiated	Communication between	Primarily related rule
taller and wider or bigger	Taller	student-student	object-level
triangle and triangular, triangle prism, and triangular prism	triangular prism	student-student	object-level
number of books and weight	Weight	student-student	object-level
what we did was…?	can you read your evidence again?	teacher-student	meta-level

Focusing on the rules of language-game

Similar to what occurred for word use, the rules of the language-game of comparison were under negotiation. During the M-session, as students mainly focused on making a paper-object that can hold more weight, it was during the negotiation with teacher that they were encouraged to do the comparison in a more explicit manner.

Table5- 3Shows the summary of the results on what action was standing fast for students and what was suggested to them through the communication during the M-session

The communication about the word use during the M-session			
what was standing fast(immediately intelligible)	what was negotiated	sides of communication	primarily related rule
making the second object in case if the first one did not work	making the second object in order to compare with the first one	teacher-student	object-level
making the five layers in order to improve the two layer	comparing the five- and two-layer in order to see which one hold more	teacher-student	object-level
putting the weight just on the tall one	putting weight on the short one in order to be able to compare it with tall one	teacher-student	object-level
weighing the amount of books	recording the result in order to compare it with the next one	teacher-student	meta-level
discussing about the aspects of the paper-object	recording the aspects of paper object in order to compare it with the next one	teacher-student	meta-level
predicting that the smaller cylinder hold less weight than the bigger one	making a claim before doing the test	teacher-student	meta-level
thinking how to improve the cylinder with adding some layers	making a claim about layers and amount of weight tolerance	teacher-student	meta-level

During the D-session, as was shown in the second part of Table5-2, two new patterns emerged. Students were comparing what they did with what was presented and they questioned the way that presenter compared the paper-objects.

Table5- 4 The summary of the results on what action was standing fast and what was suggested to them through the communication during D-session.

The communication about the word use during the D-session			
what was standing fast	what was negotiated	communication between	related rules
just talking about what they have done	directing the class to talk about claim and evidence	teacher-student	meta-level
just talking about what they have done	contrasting the claim and evidence in whole class discussion	teacher-student	meta-level
just talking about what they have done	equating the claim and evidence in the whole class discussion	teacher-student	meta-level
the taller and more staffed cylinder is, the more it tolerate the weight	the taller one may wobelling and fall	student-student	object-level
cylinder hold more wieght than rectangular prism	the rectangular hold more than cylinder	student-student	object-level
the less layered cylinder hold more than more layered cyilider	the more layer cylinder hold more than the less layered one	student-student	object-level
insisting on heavy duty cylinder as evidence of their claim	omitting it from the evidence as it is not supporting or rejecting the claim	teacher-student	meta-level
comparing tow variables of layer and width together	separating those variables and then compare it in order to be fair	teacher-student	meta-level
comparing the objects with two confounded	questing about the comparisons in which two variables were	student-student	meta-level

variables of layer and shape	changed

The researcher would suggest that, while in the M-session teacher negotiated with students about how to make a comparison, in the D-session student-student discussion was the mechanism to revise the result of those comparisons. The teacher still kept the role of negotiator, but the negotiation here is not about the connection between the aspects of paper objects. Rather the teacher placed an emphasis on how students were supposed to discuss their claim and how they were supposed to make the comparison, as was shown in Table5-4. One major difference between the negotiations in the M- and D-session, is related to this change in teacher role. In the M-session she was the teacher who constantly suggested that students compare the paper objects. However, in the D-session, through the structure of the D-session, it was the students who compared their works with other and provided suggestion for the presenter group.

In term of meta- and object-level aspects of communication, as can be seen in the last column of Table5-3 and Table5-4, in both M- and D-sessions, the communication was about both object- and meta-level rules. However, as can be seen in the third row of Table5-3 and Table 5-4, most of the meta-level rules were negotiated between the teacher and students. Furthermore, more negotiations between student-student about the object-level rules occurred during the D-session.

With regards to the main question of this section on how the teacher's and students' participation in the lessons can decrease the mentioned gap, the overall analysis suggests the following as major points of the classroom participations that can affect the learning gap.

With the focus on the old language-game that students brought to the class, the results suggests that what made the new situation intelligible for students is that "standing fast" has critical role in changing of discourse. For instance, students utilized the old

language-game and wrapped a paper around the cylinder. This was presumably related to the old language-games in which the thickness of something has to do with its strength. So, that action and the associated word "things around" were what stood fast and came from the old language-games they were already familiar with (ref, Wittgenstein, 1969; Wickman & Ostman, 2002). What the teacher did in order to change the students' language-game was infused the word layer into their language-games. Even though the teacher suggestion was based on what stood fast, just one time "transplanting" (ref, Sfard, 2008) the words in the students' language was not enough, the teacher took care of use of that words in other occasions. In two other moments, during the M-session, she came back to that word and helped students to replace what was standing fast with layer. Based on the similarities between the moments of negotiations, the following point as the aspects of negotiation is suggested: first, the teacher negotiation with students was based on "what stood fast" or what was immediately intelligible for students. Second, the suggested words or actions required to be renegotiated. Second, in the rest of activity, students needed to use it over and over before the suggestion become part of the students language-game.

With respect to the focus on teacher-students communication, the overall analysis suggests that the teacher communicated with students through both old and new language-games of comparison (by old, I mean the students' initial language-games that they bring to the classroom). Through the teacher and students communication, as students utilize the old language-game to do the classroom investigation, the teacher negotiated with them to utilize some of the words and rules of the new language-games. Through the constant negotiation with the teacher, students gradually utilized some of the negotiated words and rules of the new language-games. The teacher maintained this role in both the M- and D-session. Higher resolution analysis of meta-and object-level rules suggests that object-and meta-level rules were negotiated in both sessions by the teacher; however, during the D-session the teacher had higher focus on meta-level rules.

With respect to the focus on student-student communication, the results suggest that the emphasis on student-student communication can decrease the gap between old and new language-games. Students communicated with each other through the old language-games. But gradually as the new language-game was infused into their talk and action, they began communicating with the words and rules of the new language-game with each other. The main difference between their communications during the M- and D-session is that during the D-session some of the students not only adopted the new language-game, but also negotiated the rules or words of the new language-games with other students. The higher resolution analysis of meta- and object-level rules suggests that the rules adopted by students mainly were object-level rules either in M- or D-sessions. Accordingly the act of negotiation between them was also primarily confined to object-level rules.

Did the gap decrease?

In order to see whether the mentioned gap through the academic year decreased or not, in the results part the final lesson, mass and acceleration was described and contrasted with the paper-object lesson which occurred in the beginning of the academic year. The main similarity between these two lessons is that in both lessons students started by making a claim and evidence in M-session, and then in the D-session they discussed the claim and evidence. Throughout both lessons teacher communicated with students based upon what was standing fast and then negotiated with them on new suggestions to either change the words or change the rules. One of the main differences is about the sides of communications. In the last session students are more involved in process of negotiation than in the early session. The results suggest that students partially play the negotiator role of teacher.

Based on comparison of Table5-5 with Table5-3 and Table5-4, higher resolution analysis suggests that in the earlier lesson the object-level rules were negotiated by the

teacher in the M-session while in the D-session students become more competent to communicate and negotiate the object-level rules of language-game. However in the later lesson, students were negotiating object-level rules from the beginning of the M-session and continued their negotiation throughout the D-session. One observable difference between the earlier and later D-session is the flexibility of students to come to agreement and to change their own claims. In the paper-object lesson, for instance, just one claim which is an object-level rule was tentatively changed—the claim about higher strength of less layered cylinder. However, in the later session, all of the claims except one, were negotiated and changed.

Table5- 5 What was standing fast and how the negotiation aiming to re-shape them.

The communication about the word use during the D-session			
What was standing fast(immediately intelligible)	What was negotiated	Communication between	Primarily related rules
mass as weight	mass as stuff inside, mass as grams	student-student	object-level
the more mass, the more gravity pulls it down, fall faster	heavier car, fall faster on down hills	student-student	object-level
a sock falls slower than a pen	pack of six highlighters falls faster than a pen	student-student	object-level
dropping the sock and pen at the same time	dropping the sock and pen at the same time plus asking three other to see which one hit the ground first	student-student	meta-level
dropping eraser, washer, and cup to see which one fall faster	drop them at the same time, record them at the same time	student-student	meta-level
Maybe we could make something	Yea maybe like a parachute or something, and use washer as weight, see which one fall faster	student-student	meta-level

the left eraser slide faster than the right one	how do you know you exerted the same force? And he responded to teacher that "even though my left hand is weaker, this eraser goes faster"	teacher-students	meta-level
weight is pulling down the cup	force is pulling down the cup	teacher-students	object-level
washer and eraser	force and mass	teacher-students	object-level
chalkboard erasers represent mass and washers represent force, which is affecting the acceleration of the mass.	As we added more force the mass accelerated faster	teacher-students	object-level

The main difference is related to the negotiation of meta-level rules. As can be seen in the last column of Table5-3 and Table5-4, few student-student communications were primarily related to meta-level rules in the early lesson, however in the later lesson, see Table5-3, students negotiated about meta-level rules from the beginning of the M-session. They talked about how to compare through tool-assisted observation such as measuring the force based on number of washers or measuring the time by stopwatch. They talked about how to design an experiment by procedural manipulation such as dropping the object at the same time, recording the time, assigning different observers to record which object hit the ground first, making a parachute in order to see whether the heavier object fall first or not.

The overall shifting from M to D session, intra-lesson changes, is shown by light gray color in Figure5-1. As can be seen in the early session, in shifting from M to D, students started to negotiate the object-level rules of science language-game. This suggests that their talk is infused by objects of the science discourse. However, there is little sign of utilization or negotiation of metal-level rules of comparison. But, when the changes are considered over a whole academic year, then the inter-lessons shift suggests

that students utilized and negotiated the meta-rules of science, shown by the dark gray area.

One consideration revealed in Figure5-1 is that the intra-lesson changes observed in the early lesson (light gray area), are not consistent with the intra-lesson changes in the later lesson. The main difference is that in the early lesson, they started to negotiate about object-level rules in D-session, but in the later sessions, they negotiated the object-level rules in both M- and D-sessions. This may be pertinent to the emergence of meta-level rules in the later lesson. Meta-level rules are the ways that the interlocutors talk and act upon the discourse (Sfard, 2008).

Figure5- 1Shows the classroom science language-game of comparison was utilized by teacher (T) and students (S). Besides, it shows overall intra-lesson changes (light gray) shifting from M- to D-session as well as inter-lessons changes (dark gray) throughout the entire academic year.

M-session			
	Words	object-level rules	meta-level rules
who used it	T,S	T,S	T
negotiated between	T—S	T--S	T--S
D-session			
	Words	object-level rules	meta-level rules
who used it	T,S		T
negotiated between	T--S and S—S	T--S and S--S	T--S

M-session			
	Words	object-level rules	meta-level rules
who used it	T,S	T,S	T,S
negotiated between	T--S,S—S	T--S, S--S	T--S, S—T
			
D-session			
	Words	object-level rules	meta-level rules
who used it	T,S	T,S	T,S
negotiated between	T--S and S—S	T--S and S--S	T--S, S—S

In science investigation students are supposed to follow the meta-level rules of the science language-game to make or generate the object-level rules of the language-game of science such as a simple comparison, a causal inference, or a scientific law, which is including the number of causal inferences. National Research Council (1996) emphasizes science inquiry as a way of doing science which is close to the meta-level rules of science language-game and the council also emphasizes the content of science which can be interpreted as object-level rules of the science language-game. National Research Council states that science inquiry can promote learning of science content. The more students know how to do science inquiry, through using meta-level rules of science language, the more they can make scientific causal inferences, or object level rules. This can be presented as an assertion based on the qualitative analysis of classroom language-game*: as students become more cognizant of object-level rules of at science language-game, they should become better at making object-level rules.*

The result of the coding system B independently supports this assertion. The occurrence of the comparison sentences as a building block of causal inferences or object-level rules increased over one academic year. The result of the analysis showed (Figure4-5) that the number of object-level rules increased over the span of one academic year. The further qualitative analysis of those casual inferences suggests that the causal inferences made by students in the later part of the year are more scientifically conventional than those causal inferences made in the early part of the year.

Summing up this discussion, the qualitative study of the language-game used in the classroom suggests that there were a change in utilization and negotiation of meta-level rules in the later part of the academic year. The researcher would suggest as students become more involved in the meta-level rules, they also become more involved in making object-level rules of science language-game. The results of both independent analyses support this assertion. The analysis of comparison sentences suggests that throughout the academic year, the number of causal inferences as well as their quality increased. And the comparison study of the language-game utilized in early and later lessons suggests that students are talking more about the meta-and object-level rules, which suggests the there is a decrease in the gap between students' colloquial language-game and science language-game.

The Implications of the investigation

The proposed framework can be applied for analysis of the change in other classroom language-games. Learning the language-game of "generating claim and evidence" which is related to the data of this study, can be a topic of investigation for future research on how the discourse of generating claims and evidence changes over time. Conducting a longitudinal study on how that language-game changes and develops at the level of science classroom may have practical value. Many questions regarding the language-game of generating claim and evidence are worth investigating such as how

students conduct the investigation, how during the investigation they generate a claim, how they generate the evidence to support their claim, and how they mix their background experiences with the gathered data to generate the claim and evidence. It seems that the language-game of "generating claim and evidence" influences the meta-level rules of the language-game of comparison. Further study can illustrate the interaction of different language-games on each other and how they influence each other.

Research studies (ref, Kuhn, 2007; Kuhn & Dean, 2003; Lien & Cheng,2000) state that students' theoretical background affects the way the make inferences; however, research studies that investigate how this theoretical background affects the generation of claims and how instruction can influence this process have been limited. Throughout this study, it was observed that in many moments of classroom inquiry, students' background experiences influenced the way that they generated claims and evidence. For instance, students built the big and small cylinder and predicted that the bigger one is going to hold more weight. This idea affected the way that they initially generated the claim; however, it was shown that this object-level rule about the relationship between weight tolerance and bigness of the object changed and, at least temporarily, was replaced by the relationship between weight tolerance and width and height. Discussion of those moments was limited in the current study and this topic could be further discussed in a future study. The relation of what stands fast for students, their initial claim or prediction, and their presented claim and evidence during an inquiry lesson as well as changes in these relations over one academic year can be topic of future investigation.

Language-game theory may affect pre-service teachers' views on the nature of science. Language-game theory claims that the way we see the world is based on categorial differences and similarities and there is no essential aspect that can distinguish concrete objects from each other. Those categorial differences and similarities are based on family resemblance categories that can be different from one community to the other. In other words, based on language-game theory, what we see in the world is a generation

of internal connections which is relational to culture and social conventions, and socially constructed. Practicing to see the world based on the categorial differences and similarities and practicing not to see any intrinsic and essential differences and similarities in the world can help a person to become cognizant that the act of seeing is tentative, temporary, provisional, and contingent to social conventions. Pre-service teachers, by learning the language-game theory, may be able to see the world in a more tentative manner and be able to see the connection between culture and society and how we see the world. Accordingly, this may affect the way they articulate science for students. This is a raw proposal at this point and demands more research and practice to reach the point that it can become an instructional package for a science education classroom.

The explanation provided in this study on what was the classroom gap and how the gap can decrease may provide some insight for in-service teachers about how to communicate with students in order to change the classroom discourse. Noticing what stands fast for students plays a key role in changing of discourse. Teachers should provide an opportunity for students to talk explicitly about what stands fast for them. This opportunity can be provided through a classroom inquiry. However, what stands fast by default is not what students are supposed to learn and do in science classroom. Negotiation plays the critical role in this phase of classroom learning. Teachers should negotiate with students and build upon what was standing fast for students. And also structure the classroom investigation in a way that students can communicate and negotiate with each other throughout the classroom practice. Emphasizing what stands fast for students and negotiation hand in hand may result in changes in classroom science discourse. Helping teachers to see what stands fast for students in their own classroom and helping them to learn the art of classroom negotiation may affect the way they teach science.

The Limitations of the investigation

Although the limitations of this study are more than the handful points mentioned in the following, these are those limitations that become explicit to the researcher.

First, although the researcher has been working on this data for some years, has seen the videos, read the transcripts several times, the major analysis for the first and second research question is based on the analysis of two whole lessons. Analysis for finding the gap and how the gap can decrease is based on analysis of what was happening in these two lessons. If some middle lessons were added to the analysis, a more comprehensive picture could be provided. The researcher's general knowledge of the data as well as the independent study of comparison sentences support the consistency between what was reported and what occurred in the early and later session; however, extending the analysis to data taken from a lesson at the middle of the academic year may have strengthened the study.

Second, the study is built on analysis of the video tapes and their transcripts. Therefore, the study is limited to the lens of the camera that was controlled by the teacher. The credibility of the research would have been increased if the researcher had an opportunity to be part of that classroom. Being in the classroom environment could have opened up a different way of seeing the classroom. In many moments of the study of the transcripts and even video analysis, the researcher had to go backward and forward to understand the wholeness of what was going on that classroom. Being in the classroom and developing an understanding of the classroom could have helped the researcher to better understand those difficult moments and to make sense of the classroom.

Third, although the regression analysis suggests an improvement over the academic year, the analysis on the increase in the number of times that acts of comparison were made by students, could have had different results if the number of lessons or the topic of the lessons were different. This analysis is based on the coding the seven lessons and if the number of lessons was more the analysis could be more precise.

Besides, the occurrence of the act of comparison is sensitive to the context of the lesson. For instance, look at the low amount of the act of comparison in Table4-6, this occurred because the main question for that lesson was about making a model of a lung in order to understand how lungs work rather than making a causal inference. Therefore, students did not have much opportunity to do the act of comparison.

Fourth, the students in this study had practiced similar instructional approaches since science they were in the second grade. Their familiarities may make this group of students very different than other students who have not experienced this approach. Therefore, it may decrease the transferability of this analysis to other context.

Fifth, theoretical part of the investigation could have done in a more rigorous manner. The search to find studies which are connected to language-game theory should have done in a systematic manner and more studies should have been addressed and analyzed. Due to the time limitation, the chosen studies are those that have explicit and strong connection to language-game. The empirical research studies about the casual inferences are also limitedly reviewed and their connections to this study were weakly constructed.

Sixth, although the empirical part of this investigation is based on the teacher's level of expertise, the teacher changed through that academic year and become a more professional teacher in terms of conducting classroom inquiry. Specifically, her attitudes about nature of science changed, for instance, in some moments of the whole-classroom discussion, she asked students how they were going to prove their claim, and then she corrected herself and said that "not proving your claim, how are you going to support your claims." This shows that she exercised what she was learning through the professional development program she was engaged in. In order to focus on changes of classroom discourse due to changes in students' ways of communication, the teacher's changes were dismissed in this study. It was assumed that the teacher followed a persistent instruction.

Reevaluating the proposed interpretive framework

This investigation began with the ambitions of constructing a hypothetical construct representing science learning at the level of the classroom. The proposed framework at first was just an idea. In the theoretical aspect of the investigation the initial connection between the language-game theory and related research to science education was made. Those connections were introduced as the first attempt to propose the framework. In the empirical part of the investigation, the framework was applied to the classroom data and the explanation power of the framework was evaluated. The interaction between the theoretical and empirical parts of the investigation enabled the researcher to improve the proposed framework. In the following, some of the improvements are discussed.

The connection to culture and society

What standing fast is the first connection that students make with the classroom practice. For example, the language-games of improvement by manipulation and the object-level rule of the bigger is stronger are two examples that show how *what stands fast* for students was culturally mediated and decisively influenced classroom investigation. Thus, the application of the proposed framework addressed the actual examples of the connection of culture and classroom practice. Examining this connection can be a topic for further study.

Connection to measurable aspects of language-game

At the beginning of the empirical investigation, the only tool associated with the proposed framework for analysis of change in the classroom language-game was the ambiguous ideas of word use and rules of language-game. However through applying the framework to data, two things conspicuously became connected to the analysis,the moments of standing fast and negotiation. What standing fast is the initial and the weak

connection between the old and new discourse and can be re-shaped and become stronger through the purposeful communication which can be done by the art of situated negotiation. Furthermore, the analysis of the classroom language-game by the initial measurable criteria, word use and rules, helped the researcher to see the connection of those criteria with other aspects of the discourse constructed by other researchers (Sfard, 2008, 2007, 2004). Seeing the object- and meta-level rules of discourse in the actual data helped the researcher to see the critical role of those aspects of discourse. As was shown in Table5-6, after conducting the investigation, the measurable aspects of language-game were extended and became operationally clearer. This will help the development of a framework that aims to measure learning at the level of the science classroom.

Table5- 6 The transformation of the measurable aspects of the hypothetical construct of language-game.

The transformation of measurable aspects of the discourse	
Before conducting the investigation	After conducting the investigation
Rules of language-game	What standing fast as connection of old to new discourse
Word use in language-game	Negotiation as an art of change from old to new language game
	Meta-level rules as how the discussants acted based on the language-game
	Object-level rules as how the discussants make a connection between the objects of the of language-game
	Words as the objects of the discourse

Connection to family resemblance categorization

At the beginning of the study, the importance of the family resemblance categorization was ambiguous and there was weak connection between this ideas and the proposed framework. However, throughout this investigation many moments of the classroom could be explain by this idea and this made a stronger connection between the proposed framework and family resemblance categories. One example of this connection is when students were building the paper objects. They made one paper object by wrapping a paper around it, and they built other paper-objects by putting all previously built objects in it. At first, students did not make any specific connection between those two objects. However the teacher through negotiation with students interpreted those paper-objects as layered cylinders and put those different objects into the same family resemblance category. This categorial similarity made those two cylinders comparable based on the number of layers they had. Family resemblance categorizations enable the discussants to make two totally different things *similar* or make two similar things *different.* This is the mechanism of knowing the ontology of the objects stated by Wittgenstein about half a century ago and open to further investigation. *It seems that humans collectively invent external objects by the art of making similar things different and making different things similar*.

APPENDIX A

CODING SYSTEM A

The Sample of coding system A

Coded line	Speaker	Talk	Note taking	Teahcer-asissted or standing fast moments	Negotiated moments on rules or words	Sides of negotiation
002067	teacher	Their claim is "Shapes that have more layers and stuff inside hold more weight." Right? Their claim is nothing about heights, small short, fat wide. Their claim is "more layers, stuff inside- holds more weight."		teacher helped them to limit the discussion to what was claimed not everything		
002068	Blake	Yeah, because our other one, we had a short one, a different one that was short and…shorter…and was smaller around, and didn't have anything around kind of, and didn't have anything to reinforce it. That one didn't hold up as much. It held 23.	comparing two cylinders with three aspects: layer, inside and smaller, most probably both shorter and thinner			
002069	Austin	But I still would think…Wouldn't they all have to to be like the same size when you put the layers in? Because otherwise, they're taller ones. It wouldn't be…stable?	his emphasizing that the taller cannot hold much even if it has layers, it will be wobbling and fall down	the ideas of tallness and wobbling is standing fast for Austin	Taller or shorter	student-student

To be continued…

The sample of coding system A-continued

Coded lines	Speaker	Talk	Note taking	Teahcer-asissted or standing fast moments	Negotiated moments on rules or words	Sides of negotiation
002070	Tyler	Um, how many layers did you put on that one?	asking for the quantification of the layer aspect	layers standing fast for both tyler and brooklyn		
002071	Brooklyn	Six.				
002072	Tyler	Oh.				
002073	teacher	Very good question, though. So they're saying six layers, and what type of object was it? A six layered cylinder. A question- Does anyone know what they mean by 'things inside?' They'll understand that?	emphasizing on quantification of the layer		words	teacher-students
002070	Tyler	Um, how many layers did you put on that one?	asking for the quantification of the layer aspect	layers standing fast for both tyler and brooklyn		

APPENDIX B

CODING SYSTEM B

Sample of coding system B

coded line	separated sentences as comparison sentences(the key words for comparison as criteria for separating this sentences were capitalized here)	Initial coding	related lesson	type of comparison	words of comparison	what were equated in the compound sentences
002057	Our claim is "Shapes that have MORE layers and have things inside. It can hold MORE weight."	equating	4	compound	layers and things inside	more layers, holding more weight
002061	25. And then when we made it, we put stuff inside it, and we…some MORE layers, it held up 29. The TALLER one. The WIDER, TALLER one..	manipulation	4	single	taller wider	
002062	Why couldn't it be a SMALLER one? Because I think the TALLER it is, it would be MORE wobbly, and the SMALLER it is to the ground, it would be MORE stable.	equating	4	compound	taller	taller, more wobbling

To be continued…

Sample of coding system B-continued

coded line	separated sentences as comparison sentences(the key words for comparison as criteria for separating this sentences were capitalized here)	Initial coding	related lesson	type of comparison	words of comparison	what were equated in the compound sentences
002065	Claim. Our claim is "Shapes that have MORE layers and have things inside. It can hold MORE weight."	equating	4	compound	more layers and have things inside	more layer and things inside, more weight
002068	Yeah, because our other one, we had a short one, a different one that was short and…SHORTER…and was SMALLER around, and didn't have anything around kind of, and didn't have anything to reinforce it. That one didn't hold up as much. It held 23.	equating	4	compound	shorter and smaller	shorter and smaller, hold less
002069	But I still would think…Wouldn't they all have to be like the same size when you put the layers in? Because otherwise, they're TALLER ones. It wouldn't be…stable?	equating	4	compound	taller	taller, less stable
002080	This one used to be a square one. This was a SMALLER cylinder. All the other shapes were kind of tweaked a little bit, and turned into..	d-observation	4	single	smaller and tweaked	

REFERENCES

Anfara, V. A., Brown, K. M., & Mangione, T. L. (2002). Qualitative analysis on stage: Making the research process more public. *Educational Researcher, 31*(7), 28.

Cheng, P. W. (1997). From covariation to causation: A causal power theory. *Psychological Review, 104*(2), 367.

Chi, M. T. H. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *Journal of the Learning Sciences, 6*(3), 271-315.

Chouliaraki, L., & Fairclough, N. (1999). *Discourse in late modernity: Rethinking critical discourse analysis* Edinburgh Univ Pr.

Dewey, J. (2005). Art as experience Perigee.

Dewey, J., & Sleeper, R. (1984). Later works of john dewey, 1925-1953.

Duit, R. (1991). On the role of analogies and metaphors in learning science. *Science Education, 75*(6), 649-672.

Fairclough, N. (1993). *Discourse and social change* Polity Press.

Fairclough, N. (2001). *Language and power* Addison-Wesley Longman Ltd.

Ford, A. (1991). Category theory and family resemblances. Quantum Implications: Essays in Honour of David Bohm, , 361.

Ford, A., & Peat, F. D. (1988). The role of language in science. Foundations of Physics, 18(12), 1233-1242.

Ford, M. (2008). Disciplinary authority and accountability in scientific practice and learning. Science Education, 92(3), 404-423.

French, A. P. (1985). *Niels bohr: A centenary volume* Harvard Univ Pr.

Gee, J. P. (1989). Literacy, discourse, and linguistics: Introduction. *Journal of Education, 171*(1), 5-17.

Ghaziani, A., & Ventresca, M. J. (2005). Keywords and cultural change: Frame analysis of business model public talk, 1975–2000. *Sociological Forum, , 20*(4) 523-559.

Glock, H. J. (1996). A wittgenstein dictionary Wiley-Blackwell.

Gray, E. M., & Tall, D. O. (1994). Duality, ambiguity, and flexibility: A" proceptual" view of simple arithmetic. Journal for Research in Mathematics Education, 25(2), 116-140.

Greeno, J. G. (1997). On claims that answer the wrong questions. Educational Researcher, 26(1), 5.

Greeno, J. G. (1998). The situativity of knowing, learning, and research. American Psychologist, 53(1), 5.

Hume, D., & NetLibrary, I. (2011). *An enquiry concerning human understanding* Alex Catalogue.

Kelley, H. H. (1973). The processes of causal attribution. *American Psychologist, 28*(2), 107.

Keys, C. W., Hand, B., Prain, V., & Collins, S. (1999). Using the science writing heuristic as a tool for learning from laboratory investigations in secondary science. *Journal of Research in Science Teaching, 36*(10), 1065-1084.

Knorr-Cetina, K., & Mulkay, M. J. (1983). *Science observed: Perspectives on the social study of science* Sage Pubns.

Kuhn, D. (2007). Reasoning about multiple variables: Control of variables is not the only challenge. *Science Education, 91*(5), 710-726.

Kuhn, D., & Dean, D. (2004). Connecting scientific reasoning and causal inference. *Journal of Cognition and Development, 5*(2), 261-288.

Kuhn, T. S. (2009). The structure of scientific revolutions. Philosophy After Darwin: Classic and Contemporary Readings, , 176.

Latour, B., & Woolgar, S. (1986). Laboratory life: The social construction of facts. *Princeton: Princeton UP,*

Lemke, J. (2004). The literacies of science. *Crossing Borders in Literacy and Science Instruction: Perspectives on Theory and Practice,* , 33-47.

Lemke, J. L. (1990). *Talking science: Language, learning, and values* Ablex Publishing Corporation.

Lewontin, R. C. (1991). Biology as ideology. Concord, Ont.House of Anansi Press Limited,

Lien, Y., & Cheng, P. W. (2000). Distinguishing genuine from spurious causes: A coherence hypothesis* 1. *Cognitive Psychology, 40*(2), 87-137.

Longino, H. E. (2002). The fate of knowledge Princeton Univ Pr.

Lynch, M. (1997). Scientific practice and ordinary action: Ethnomethodology and social studies of science Cambridge Univ Pr.

Malcolm, N., Wright, G. H., & Wittgenstein, L. (2001). Ludwig wittgenstein: A memoir Oxford Univ Pr on Demand.

Meyer, D. Z., & Avery, L. M. (2009). Excel as a qualitative data analysis tool. *Field Methods, 21*(1), 91.

Miller, J. (1982). *The body in question* Vintage Books.

National Research Council (US). National Committee on Science Education Standards, & Assessment. (1993). *National science education standards* National Academies.

Nisbett, R. E., & Ross, L. (1980). *Human inference: Strategies and shortcomings of social judgment* Prentice-Hall Englewood Cliffs, NJ.

Osborne, J., & Dillon, J. (2008). Science education in europe: Critical reflections. *London: Nuffield Foundation,*

Phillips, D. L. (1977). Wittgenstein and scientific knowledge: A sociological perspective Rowman and Littlefield.

Rorty, R. (1980). Pragmatism, relativism, and irrationalism. Proceedings and Addresses of the American Philosophical Association, , 53(6) 717-738.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching, 41*(5), 513-536.

Scollon, R. (2001). *Mediated discourse: The nexus of practice* Psychology Press.

Sfard, A. (2007). When the rules of discourse change, but nobody tells you: Making sense of mathematics learning from a commognitive standpoint. Journal of the Learning Sciences, 16(4), 565-613.

Sfard, A., & Lavie, I. (2005). Why cannot children see as the same what grown-ups cannot see as different?—early numerical thinking revisited. Cognition and Instruction, 23(2), 237-309.

Smith, S., Booth, K., & Zalewski, M. (1996). International theory: Positivism and beyond Cambridge Univ Pr.

Wickman, P. O., & Östman, L. (2002). Learning as discourse change: A sociocultural mechanism. Science Education, 86(5), 601-623.

Wittgenstein, L. (1921). Tractatus logico-philosophicus, trans. DF Pears and BF,

Wittgenstein, L. (1953). Philosophical investigations, trans. GEM Anscombe, 261

Wittgenstein, L. (1969). On certainty,(eds.) GEM anscombe & GH von wright,(tr.) D. paul & GEM anscombe. Basil Blackwell., UD (1992).'Skeptical Arguments from Underdetermination', Philosophical Studies, 68, 1-34.

Wittgenstein, L., & Anscombe, G. Hacker, PMS and schulte, J (translators, editors)(2009) philosophical investigations: The german text with an english translation.

Wittgenstein, L., Waismann, F., & Baker, G. P. (2003). The voices of wittgenstein: The vienna circle Routledge.