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FROM THE TEACHERS' EYES: AN ETNOGRAPHIC-CASE STUDY ON DEVELOPING MODELS OF INFORMAL FORMATIVE ASSESSMENTS (IFA) AND UNDERSTANDING THE CHALLENGES TO EFFECTIVE IMPLEMENTATION IN SCIENCE CLASSROOMS

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ABSTRACT

The emphasis on socio-cultural theories of learning has required the understanding of multi-dimensional, dynamic and social nature of acquiring the scientific knowledge and practices. Recent policy documents suggest a focus on formative and dynamic assessment practices that will help understand and improve the complex nature of scientific learning in classrooms. This study focuses on teachers' use of "Informal Formative Assessments (IFA)" aimed at improving students' learning and teachers' frequent recognition of students' learning process.

The study was designed as an ethnographic case study of four middle school teachers and their students at a local charter school. The data of the study included (a) teachers' responses to history of teaching questionnaire (b) video and audio records of teachers' assessment practices during two different scientific projects (c) video and audio records of ethnographic interviews with teachers during their reflections on their practices, and (d) field notes taken by the researcher to understand the assessment culture of the school. The analytical tools from sociolinguistics (e.g., transcripts and event maps) were prepared and discourse analysis based in an ethnographic perspective was used to analyze the data. Moreover, Cultural-Historical Activity Theory (CHAT) was also introduced as an alternative data analysis framework for understanding the role of division of labor among the elements of the community on the challenges and the outcomes of IFA practices.

The findings from the analysis of the classroom discourse showed three different types of IFA cycles: connected, non-connected, and repeating. The analysis of the teachers' reflections showed that the effectiveness of these cycles did not only depend on whether the cycles were connected, but also on other variables such as the phase of the lessons and student's identities and abilities. Teachers' reflections during researcher-teacher meetings on the concept and the aims of IFA improved through the use of academic literature on IFA and video-cases of their own practice. Teachers also reflected on the challenges for effective implementations of IFA and they emphasized challenges due to the division of labor among the classroom participants and the open nature of scientific knowledge. Through participation in the study, the teachers helped develop an IFA model for middle school science classrooms designed to capture the complex nature of teacher-student interaction. This model can be used for further analysis of IFA activity and professional development activities focused on assessment practices.

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Ten years ago, I attended a graduation ceremony and watched a PhD graduate walk down the aisle with his cap and gown. That was the moment I started dreaming about walking down the aisle with *my* PhD diploma. Two years after this dream, I started graduate school in Istanbul and every single day I discovered my passion about research in my field of Science Education. My passion and dreams kept my motivation alive to look for opportunities around the world until the day that my advisor, Dr. Gregory Kelly accepted me as his advisee and assistant for the journal Science Education. I would like to express my deepest gratitude to Greg, who guided me through this study. This is the product of my journey to my dreams. To fulfill this dream, I had to leave a city I adore, a family I love and friends I care about to travel thousands of miles across the Atlantic. The adjustment would not be easy if I did not have an advisor who picked me up from the airport, offered me help when I needed it, and calmed me down with Bob Marley. During my four years of PhD life, Greg helped me grow as an academician, with experiences in research and writing, and by modeling his strong work ethic. I am honored to have worked with a person who really knows how to value and respect the ideas and experiences of a young scholar.

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&

my teachers, my teacher friends and other teachers,
willingly devoted their time and energy to inspire the future generations for learning

Chapter 1

Introduction

Assessment activities have been a part of educational process since the early times in the history and served for many different purposes such as selection, placement, and accountability (Linn, 2000). As increasingly emphasized in the educational research literature, another reason for using assessments has been improving student learning by means of frequent feedback embedded in collaborative interactions. One of the earliest known examples of assessments with a focus on the student learning process was found in Socratic dialogues.

During his dialogues, Socrates was trying to understand his interlocutor's idea flow through question-response sequences. This questioning was continuous in Socratic dialogues in order to collaboratively guide students' development of new perspectives on the ideas (Saran & Neisser, 2004; Poehner, 2008). Most recently, Socratic dialogues have gained interest among educational philosophers who have suggested these dialogues as a technique for fostering inquiry and reasoning in educational context and considering the questions posed during the dialogues as examples to assess the quality of reasoning (Saran & Neisser, 2004, Paul & Elder, 2006).

Assessment of how students reason with ideas, concepts, theories, and phenomena is appealing to science education communities holding the view of "science as a human endeavor, embedded in a social milieu of society and conducted by various social communities of scientists" (Aikenhead, 2006, p. 1). In order to assess students' reasoning, researchers are improving interview protocols that ask students to define and elaborate their ideas (e.g., Lederman et. al., 2002; Solomon, 1992). Like academicians, teachers also need to improve techniques to assess students' reasoning, as they are responsible to help students to learn how to think scientifically.

This study focuses on teachers' use of assessment activities aimed at students' reasoning with ideas, referred to "Informal Formative Assessments (IFA)." IFA are constructed through the discursive moves between teachers and students during everyday instruction and do not require any official or written record keeping. The purposes of IFA include improving students' learning and teachers' frequent recognition of student understanding. Through observations in middle school science classrooms and teachers' guided reflections on their practice, the study aims to achieve two overarching goals: (a) Develop a IFA model for middle school science classrooms, which is theoretically plausible and practically efficient for teachers' implementation. (b) Examine teachers' reflections on video-cases to determine the influence of such reflections on evolving teaching and assessment practices and perspectives. In addition to these primary goals, the data collection process led to an emergent goal of fostering teachers' reflections on IFA as an intervention in the process of developing an IFA model. The researcher-teacher meetings arranged for teacher reflections and model-developing process involved mediating video and written artifacts that served as a guide for the further studies on science teacher education. The methods chapter (Chapter 3) will explain these artifacts in detail.

Why Study "Informal Formative Assessments (IFA)"?

IFA are a kind of formative assessments. Such assessments include teachers' eliciting and interpreting students' responses to formulate feedback for the purposes of improving students' learning and instruction (Bell and Cowie, 2001; Black and William, 1998; Clarke, 1995; William and Black, 1996). Formative Assessment has been used to differentiate "continuous summative assessments" by teachers implemented internally at the classroom from standardized, large-scale summative assessments, given by external examiners at limited times and aimed at national qualifications, selection and placement.

Since 1960's, the scores from the standardized large-scale summative assessments have been an important norm for the U.S. schools. These scores have been considered as important criteria to evaluate the strengths and weaknesses of schools, teachers, and students. The passage of *No Child Left Behind* Act (2002) made it official and routine to use the test scores on critical decisions such as determining whether students can advance to the next grade and judging the quality of schools (Assessment of 21th Century Skills: The Currents Landscape, 2005).

A number of books published by educational policy makers and Educational Testing Service (e.g., *America's Perfect Storm: Three Forces Changing Our Nation's Future*, 2007; and *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, 2007) emphasized the low scores on large scale assessments and the need for increasing the standards in the schools with the aim of ranking high in international comparisons on these exams. The most current national policy reports prepared to explain the plans for improving science and mathematics education not only mention the significance of national evaluations, but also the need to align with international large-scale assessments. In one of the latest reports, *The Opportunity Education: Transforming Mathematics and Science Education for Citizenship and the Global Economy* prepared by the Carnegie Corporation of New York and Institute for Advanced Study (2009) underlines the importance of international large-scale assessments:

> …new assessments should be informed by and calibrated against the most reliable international measurement systems in mathematics and science—the Programme for International Student Assessment (PISA), which periodically assesses the skills and knowledge of 15 year olds in mathematics, science, reading, and problem solving and measures changes in student performance, and Trends in International Mathematics and Science Study (TIMSS), which periodically measures the performance of fourth and eighth graders—and the skills and knowledge those systems assess.

The above quote from the report suggests the development of assessment methods aligned with the large-scale exams; PISA and TIMMS. In the same report, focused on understanding the school and student performance, recommends that "wider use of internationally benchmarked assessments would give states and the federal government a more meaningful picture of student and school performance and would inform district and state efforts to improve American schools" (p. 5).

Although summative, large-scale assessments at national and international levels offer an overview of general trends, specific information about student learning is "invisible" to practitioners (Britton and Schneider, 2007). According to Wiggins (1989), "standardized tests have no more effect on a students' intellectual health than taking a pulse has on a patients' physical health" (p. 704). Moreover, emphasis on standardized tests overlooks some important aspects of students' learning by mostly measuring the lower level mental processes, failing to capture the scientific practices such as reasoning and argumentation, and lacking in providing feedback to improve instruction.

It is also paradoxical that some policy reports, while advocating for increasing the amount and influence of the large-scale tests in the schools, agreed that these tests should not be used to monitor the classroom instruction (Wiggins, 1989). Recently, these reports started to mention alternative formative assessment methods that will provide feedback to improve instruction. The National Research Council's report on *Classroom Assessment and National Science Education Standards* (2001) states the necessity of assessment activities aiming "to inform the teacher and/or the students in deciding the next step" (p. 1). *The Opportunity Education: Transforming Mathematics and Science Education for Citizenship and the Global Economy (2009)* report also mentioned the use of formative assessments in the classroom:

> The Commission also encourages the development of more sophisticated formative assessments for classroom use, along with systems by which teachers can access proven assessments, share techniques and instruments, and collaborate in refining them. At its best, a formative assessment delineates and measures a student's progress not only against a rigorous standard in totality but against component skills as they fit together (p. 30).

The report does not only suggest the use of formative assessment, but also sees it necessary for "a good assessment, by illuminating the broad spectrum of skills required for mathematics or science success, can inform instruction by revealing strengths and gaps in a student's understanding and enabling a skilled teacher to calibrate the needed instructional response" (p. 30).

During the last four decades, formative assessments have generated considerable interest in educational research. Some research on formative assessments has examined the nature of feedback and tried to theorize the feedback process (Black & William, 1998, 2008). There have also been researchers working on more authentic formative assessment techniques (e.g., portfolios, journals, simulations, etc…) to evaluate those aspects of students' learning invisible on the multiple choice or written exams (e.g., Barton & Collins, 1997; Dori, 2003; Yung, 2001).

Use of formative assessment activities has helped teachers guide their instruction and provided students more frequent feedback on their progress (Black & William, 1998; Bell and Cowie, 2001). While formative assessment activities are helpful to understand teacher and student progress to accomplish the objectives for scientific subject matter (Black & William, 1998; Bell and Cowie, 2001), they may not be enough for a comprehensive assessment of dynamic social construction of scientific knowledge and students' skills to reason, argue, and evaluate the scientific knowledge. The increasing demand for knowledge production in today's world and the availability of the knowledge through media resources has challenged the traditional view of content focused curriculum designed to transfer a body of selected knowledge to students.

Recent national educational reform movements and research in science education emphasizes that scientific learning should not consider only conceptual learning, but also focus on students' acquisition of social and epistemic goals. Therefore, Duschl (2008, p. 277) suggests the following three domains for the assessment of scientific learning in educational contexts:

- The conceptual structures and cognitive processes used when reasoning scientifically,
- The epistemic frameworks used when developing and evaluating scientific knowledge, and
- The social processes and contexts that shape how knowledge is communicated, represented, argued, and debated.

Furthermore, according to a study in New Zealand (1994), "teachers gather a large amount of diverse information on student learning during informal interactions with them" (as cited in Bell and Cowie, 2001, p. 12). Therefore, a careful analysis of assessment activities in the classroom discourse of every teacher-student interaction can be more informative.

Recently, science education researchers started to study such assessment activities, which are embedded into teacher-student discursive moves (e.g., Duschl & Gitomer, 1997, 2003; Ruiz Primo & Furtak, 2007). They focused on the effectiveness of these informal formative assessments on students learning of science and some general challenges that teachers may have during implementation. However, how teachers can learn an effective implementation of informal formative assessments is still an open question. Moreover, the challenges facing teachers need to be analyzed in more detail to see the difficulties of the existing models in practice. For this reason, my study, related to Informal Formative Assessments (IFA), attempts to answer the following research questions:

1. In what ways do middle school science teachers use IFA prior to having opportunities to engage in video case reflections regarding their assessment practices?
2. What are the middle school science teachers' reflections on their use of IFA?

3. In what ways do video case reflections on assessment activities change middle school science teachers’ IFA perspectives and practices as stated by teachers?
4. What models of IFA do middle school teachers develop?
5. What are the challenges middle school science teachers faced during the implementation of IFA practices?

Furthermore, this study introduces Cultural Historical Activity Theory (Engestrom, 1987) to understand the middle school teachers’ challenges related to the division of labor among the participants of their classroom community while they are using informal formative assessments. Thus, in addition to the questions above, the study aims to answer the following research question:

6. What are the opportunities and challenges afforded through the division of labor among classroom participants for reaching the teachers’ aims of IFA?

Chapter 2

Theoretical Framework and Review of the Related Literature

The theoretical framework for this study draws from the socio-cultural views of learning in social environment of a classroom culture. Therefore, the study will first visit how a socio-cultural theory of learning led to the changing views of assessment followed by the concepts of assessment aligned with this view i.e., dynamic assessments, IRE/F sequences, assessment conversations, and informal formative assessments. Second, teacher reflection, as a way to improve teachers' practices on IFA, will be reviewed with a concluding section on how socio-cultural views influenced the ideas and studies of teacher reflection. Finally, the framework of CHAT will be introduced as a way for paying more attention to the social and cultural dimensions of teachers' assessment practices and reflections.

Reshaping Assessment Under the Influence of Socio-Cultural Views

Recent interpretations of Vygotsky and his colleagues' works from 1920s and 1930s led to consideration of new learning theories. Vygotsky's consideration of learner's social and cultural environment on the inter-psychological plane challenged the learning theories at that time focusing on individual mind and stable characteristics. Sociocultural views supported the ideas that learning occurs in social environments and *mediation* is very important for the development of abilities (Vygotsky, 1978, 1983). In

1980s, the popularization and reconsideration of the learning theories emphasizing the importance of cultural, social, and historical artifacts, and have resulted in increasing number of research studies in different fields of education, including science education. As Leach and Scott (2002) discussed

> … insights about students' mental structures' are useful in explaining why science is difficult to learn for many students. However, in our view such insights are not enough to explain how students learn science in classrooms. Consideration of the social environment through which learners encounter scientific ideas is also necessary (p. 93).

The reason that social environment is important in science classrooms is related to new aims of science education. Recent research in science education and policy and state documents state that students should not only learn already known theories in science but also improve skills (such as use of scientific tools and practices, reasoning, argumentation, experimentation) to be able to understand the construction of scientific knowledge, criticize, compare and contrast the theories, and hopefully contribute to the field (College Board Standards for College Success-Science, 2009; Gitomer & Duschl, 2007; National Research Council, 1999). These are the skills that cannot be learned by only expecting students to memorize conventional scientific facts and theories. Rather, students need to experience the construction of the knowledge through active participation in classroom discourse that has been influenced by the cultural and historical backgrounds of students and teachers (Driver et. al., 1994). For this reason, detailed analysis of the classroom discourse has become the main focus of many science education studies during the last twenty years to understand the nature of student learning (Kelly, 2007). Discourse in science classrooms also includes teachers' assessment of student improvement through different strategies including questioning and feedback.

Therefore, some science education researchers have been interested in assessment embedded into the discourse of science classrooms (e.g., Duschl & Gitomer, 1997, Duschl, 2003, Ruiz-Primo & Furtak, 2007). These informal and more frequent assessments involved in the classroom conversations are necessary to establish a basis of an assessment system. For Gitomer and Duschl (2007), an assessment system should be "externally coherent" meaning the consistency of assessment systems with "accepted theories of learning and valued learning outcomes" (p. 289). Shepard (2000) also mentioned the need for the change in classroom assessment "to be compatible with and to support this social-constructivist model of teaching and learning"(p. 7). By providing an historical overview of the curriculum, learning theories and assessment, Shepard showed the consistency between socio-constructivist models and how instruction changed over time, yet assessment practices remained traditional. Finally, he suggested an emergent paradigm for the reformed curriculum, recent learning theories, and assessment practices aligned with such reforms (Figure 2-1).

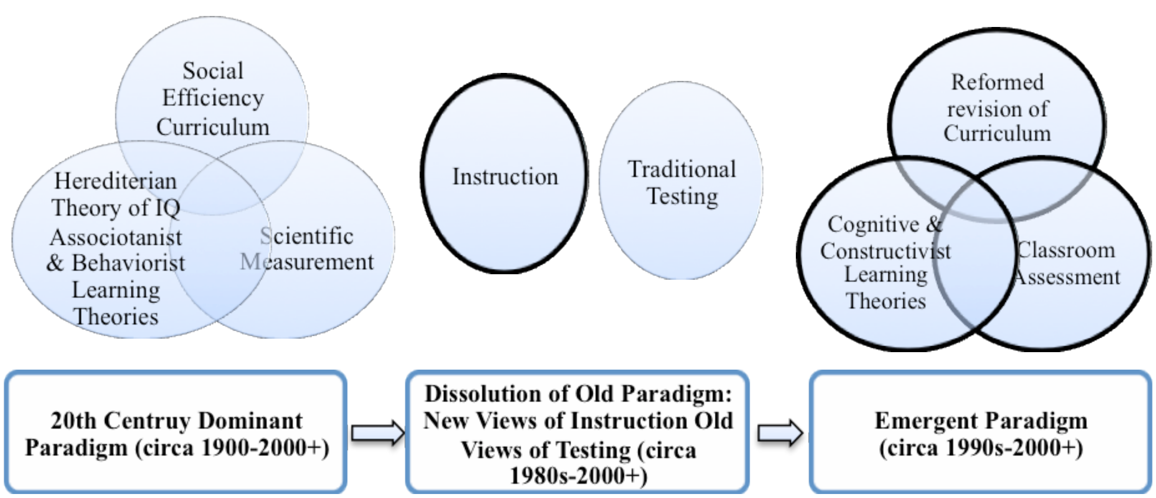

Figure **2-1**: An historical overview illustrating how changing conceptions of curriculum, learning theory and measurement explain the current incompatibility between new views of instruction and traditional views of testing (Shepard, 2000, p. 5)

On this emergent paradigm of the new century, Shepard (2000) defined the characteristics of the new curriculum, what we expect students to learn when the cognitive and constructivist learning theories have been used and the types of classroom assessments consistent with the reformed curriculum and the recent dominant learning theories (Figure 2-2).

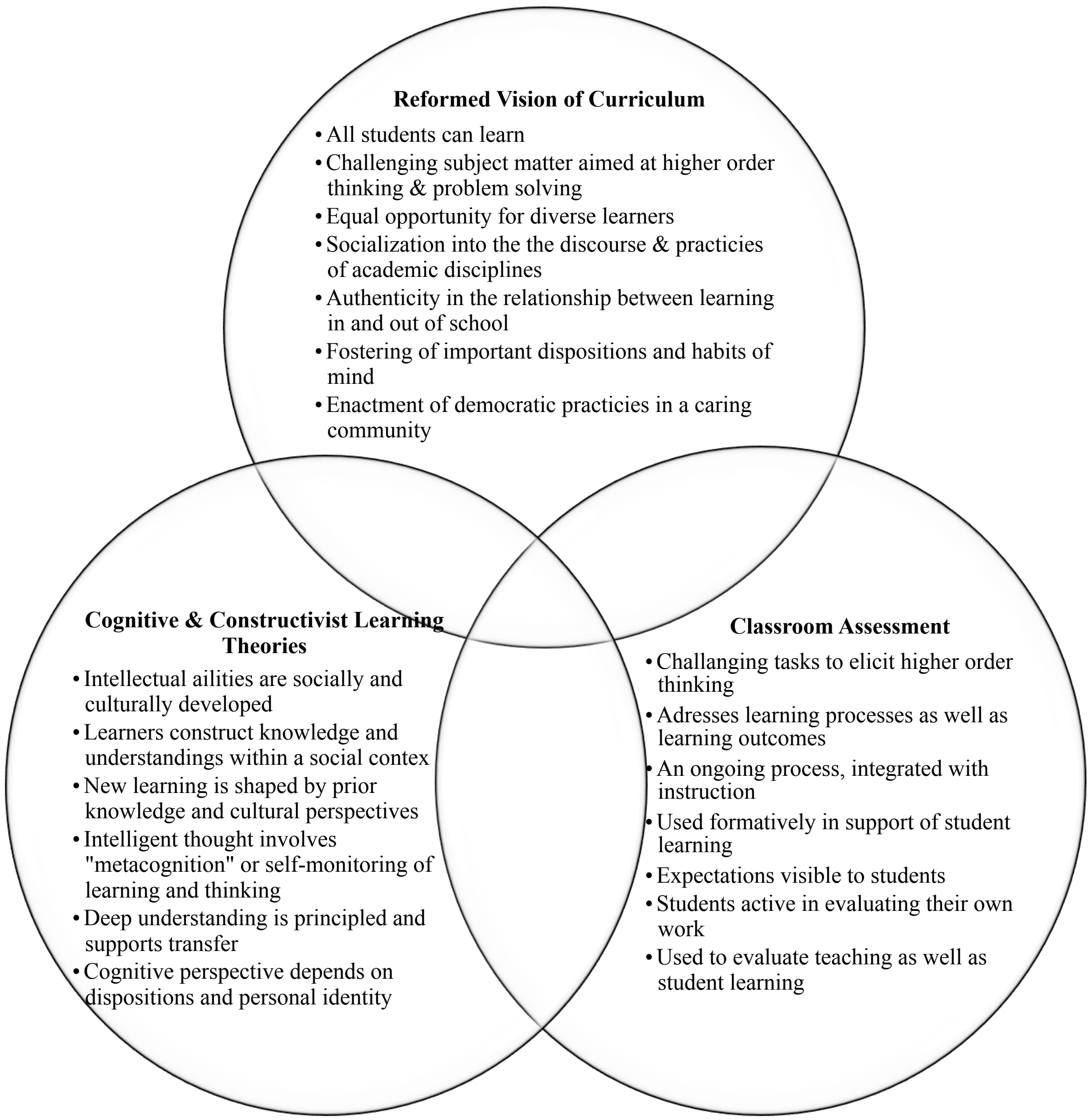

Figure **2-2**: Shared principle of curriculum theories, psychological theories and assessment theory characterizing an emergent, constructivist paradigm (Shepard, 2000, p. 8)

As is seen in the figure 2-2, classroom assessments consistent with reformed curricula and recent theories of learning are more than official tests given students at certain times during the semester. Rather, these assessments are "ongoing," "integrated with instruction" and they aim to "evaluate teaching" as well as "student learning."

The cognitive approach to learning, including the socio-cultural perspectives, leads to the redefinition of the construct of science understanding. Therefore, science education researchers have called for and designed activities to assess this redefined construct. Not only in science, but also in other fields of education, the Vygotskian perspective has influenced assessment activities (Haywood & Wingenfeld, 1992; Lloyd, & Fernyhough, 1999). Researchers in educational measurement question the efficiency of quantitative standardized tests based on the stable characteristics (e.g., IQ). Considering Vygotky's "Zone of Proximal Development" theory, based on the view that human abilities can be improved through mediating artifacts under adult guidance, new assessment strategies aiming the development of the ability have been studied. These assessment strategies rejected the idea that individuals possess a certain measure of ability and they accepted the assumption that these abilities are developmental and mediation helps development of these ideas (Sternberg & Grigorenko, 2002). One of the assessment concepts emerged from these discussions was "Dynamic Assessment" that has been the focus of numerous studies in language and special education. The following section will define the concept of dynamic assessment, discuss its affordances and drawbacks, and also review some studies used dynamic assessment.

Dynamic Assessment

Dynamic assessment (DA) is a type of “interactive assessment” with a structured mediation under the guidance of more knowledgeable others (Haywood & Tzuriel, 2002). During mediation, test taker is given feedback for the improvement of his or her abilities and the type and amount of assistance may change from one individual to another (Elliot, 2003). Even though DA is a term used for different models, which will be explained in detail further in this section, it can be either in “sandwich format” or “cake format.” In the sandwich format, test taker is given a pre-test, which is followed by an instruction for the improvement of skills. Finally, test taker is given a post-test, an alternative form of the pre-test to be able to understand the improvement of the test taker. Sandwich format can be used both in a group and individual settings. However, individual settings allows test giver to arrange the type of instruction according to the individual. Cake format, on the other hand, uses hints while the test taker continue from item to item in the test instead of giving feedback at the end. First, an item is given to the student and if the answer is incorrect, hints are provided until the examinee answers the item correctly. When the item is answered correctly, test taker is given another item. Since this format looks like the “layers of icing on a cake,” it has been called as “cake format.” As the number of icing on cakes can vary, number of items given can vary from one individual to another (Sternberg & Grigorenko, 2002).

Models of dynamic assessment

I will group the dynamic assessment models as "Interventionist" and "Interactionist" as Poehner (2008) did in his book on dynamic assessment. The reason for choosing this grouping is that interactionist models are more similar to IFA activities, which is at the focus of this study.

Interventionist dynamic assessment models: Dynamic assessment has been called interventionist when "the mediation offered to learners is standardized" (Poehner, 2008, p. 44). The reason for standardization is to form more objective assessment. One of the earliest DA approaches was Budoff's "Learning Potential Measurement Approach." Budoff's work on dynamic assessment has been inspired by Luria's (1961) work on underprivileged children, which was based on the thinking that if these children make high scores on the test, then, we can talk about "learning potential" rather than intelligence. He used an experimental method in his studies as he gave pre-test, intervention and post-test respectively. To interpret the abilities of the children, he used structured and "psychometrically well established" measurement devices. Since he used experimental methods and structured psychometric tests, his approach may not be truly considered as DA (Poehner, 2008). Budoff's model moves testing beyond measuring a stable characteristic. The model suggests evaluating the learning potential; nevertheless, limiting the testing to only pre and post tests and standardizing the intervention may not help understanding the authentic and dynamic nature of learning.

A second prevailing model of DA is Guthke's "Lerntest Approach." Guthke, together with his colleagues at Leipzeig University developed a model of dynamic assessment that they named as “ Lerntest” or “Leipzing Learning Test (LLT).” According to this model, a question is given to the test taker, and then the following steps has been taken:

First attempt to answer the question: unsuccessful	⇨	That’s not correct. Please, think about it once again
Second attempt to answer the question: unsuccessful	⇨	That’s not correct. Think about which rows are most relevant to the one you are trying to complete
Third attempt to answer the question: unsuccessful	⇨	That’s not correct. Let’s look at rows three and four
Forth attempt to answer the question: unsuccessful	⇨	That’s not correct. Let’s look at rows three and four and focus on the differences in both the positions of the objects and the words
Fifth attempt to answer the question: Unsuccessful	⇨	Examiner’s statement of the correct answer and explaining why it is correct.

Then, a score was given based on “the number of prompts needed and the amount of time taken to complete the test” (Poehner, 2008, p. 48). Moreover, a profile can be created for each learner based on “an analysis of the types of errors that the examinee made and the types of assistance to which the examinee was most responsive” (*Ibid*., p. 48). As opposed to Budoff’ s model, Guthke’s “Lerntest Approach” provided an assessment model embedded partially into the learning process through series of prompts. I think the limitation of this approach was the assumption that examiner has a specific correct answer that the learner needs to reach at the end of the assessment process. By structuring the feedback with the sentence “That’s not correct”, the examiner may neglect the partially correct ideas or different ways of thinking and may not create a dialogic learning.

Third common model of DA is Carlson and Wiedl's "Testing-the-Limits Approach." They mainly worked with underprivileged children and focused on the thinking processes of the examinee rather than the correct or incorrect answer. Therefore, examiner asks for verbalization of the reasoning. Hints are provided to think aloud so that examiners can see where the problems occur during the reasoning process. A score and report has been prepared as in LLT but the report is more comprehensive and involves future recommendations (Poehner, 2008). Carlson and Wiedl's "Testing-the-Limits Approach" was a step towards an assessment method for learning as it provides more detailed feedback and tries to understand one of the learning processes-reasoning. Nevertheless, like other interventionist models, "Testing-the-Limits Approach" used structured hints, which do not let the examiner understand the authentic nature of the learning processes. Moreover, another limitation of interventionist models for authenticity is that they do not aim to be used frequently during learning process.

Interactionist dynamic assessment model: Dynamic assessment becomes interactionist when instruction and assessment are completely integrated. One of the known interactionist model is Feuerstein's "mediated learning experience (MLE)" model. Feuerstein model of dynamic assessment depends on his assumption that intelligence is a quickly changing characteristic. To prove this idea, he worked with disabled people that he called "retarded former" whose intelligence can be improved through MLE. MLE is an interactional process between the adult and the child during which the adult is responsible for altering the mediation given and the cognitive abilities of the children. During this experience "mediating agent" (a parent, an adult, or a caregiver) makes learning more effective from the stimuli existing in the environment. The following are the steps of Feuerstein' s approach of dynamic assessment (Sternberg and Grigorenko, 2002, pp. 50-51):

1) The selection of the stimuli: The caregiver selects those stimuli that he or she believes will profit the child
2) Scheduling of stimuli: The caregiver needs to schedule the presentation stimuli so that the child will be able to learn from them in an optimal way
3) Anticipation: The child needs to be taught to anticipate certain outcomes as a result of certain actions
4) Imitation: The provision of models that the child can imitate
5) The provision of specific stimuli: Such stimuli are usually culturally determined and that the child's attention consistently directed toward the stimuli
6) Repetition and variation: Necessary for full internalization to take place. Internalization can also be facilitated by learning to solve problems across various problem domains
7) The transmission of the past and representation of the future: The child learns what has been true in the past and what he or she can expect of the future
8) Comparative behavior: By which the child learns to see how things are similar and different.

MLE can be both as an intervention of a caregiver or as a cultural transmission of the child's environment. Working with low-achieving children, special needs children, educationally deprived children, immigrants in Israel, Reuven Feuerstein and his colleagues in Israel developed an instrument "Learning Potential Assessment Device (LPAD)" with the aim of looking at the potential in specific cognitive processes. This instrument measures the change in intelligence and cognitive abilities. This testing follows by a suggested intervention for strengthening the cognitive structures in different cognitive domains (Sternberg and Grigorenko, 2002). Since the interactionist models suggested an assessment approach that would be used thoroughly during the learning process, these models can be more successful for assessing the complexity of learning.

However, due to the focus on only cognitive abilities and stable characteristics, the LPAD device underestimates the other dimensions of learning such as social, cultural and epistemological. Another limitation of the interactionist model is that it looks at the interaction only between examiner and an individual examinee, while ignoring the learning opportunities created among the peers of the examinee as in many authentic learning environments.

Advantages and limitations of dynamic assessment

Haywood and Tzuriel (2002) state some conclusions about how DA activities have contributed to learning, development, and improvement of instruction by looking at a relatively small number of research studies (pp. 44-47):

1. Test performance improves after teaching or mediation
2. Mediation of logic strategies leads to greater performance improvement
3. Mediated strategies and the solving of new problems
4. Estimates of learning potential
5. Observation of DA and static normative testing (The observations of DA led to the improvement of teaching/instruction because observations of DA provided more useful feedback and information for teachers)
6. Obtainable knowledge (DA strategies made knowledge available for everyone)
7. Potential is a useful concept for habilitation and rehabilitation efforts (since DA looks at potential rather than static characteristic, this approach became useful tool when studying with disabled people)
8. Defeating the pessimistic predictions from statistics tests (DA approach gives hope on everybody can learn and abilities can be improved).

Dynamic assessments have been beneficial for improving learners' potential, mediation/teaching, and rehabilitation and to remove the negative psychological effects of testing. However, some researchers have challenged the psychometric properties, methods and constructs of dynamic assessment and mention the following drawbacks (Sternberg and Grigorenko, 2002, pp. 30-31):

1. The relative lack of published data on the reliability and validity of dynamic testing
2. Insufficient detail on the presentation of methods-which has made replication difficult
3. The constructs are not familiar and do not fit well with what psychologists and educators learn about testing during the years they are in training.

The reasons for these drawbacks can be explained by the differences of the goals of DA and the traditional tests, which would have better psychometric properties. DA aims to improve the learning potential rather than taking a measure of a construct at one specific moment. Although DA models give more space for improvement of potential during the assessment process than traditional tests, such structured mediation is limited in its authenticity. Another issue with DA approach is the lack of focus on how feedback is provided for the improvement of examiner or the mediation techniques. An interactive assessment should, on the other hand, provide feedback for the improvement of the examiners, mediations (instruction/program/training) and instruments used.

Implementations of DA

The case studies of DA, we can see that there are activities developed for its implementation in educational environments. When we look at the case studies conducted by Sternberg and Grigorenko (2002), it is possible to see the use of different tasks and activities for the implementation of DA. For example, in one of the studies they utilized "dynamic testing to reveal hidden potential" (p. 127). The sample of the study was rural

Tanzanian rural school children between the ages of 11-13: 358 experimental group children (161 boys, 197 girls) and 100 control group children (40 boys, 60 girls). The study aimed to understand the affordances of dynamic assessment as compared to conventional static testing for underprivileged children raised in under-developed countries. The children were introduced three tasks: syllogisms (related to mental visualizations), sorting (among cards with different colors and shapes), and twenty questions (about what they children think the geometric shape could be). These tasks have been given during pre-test, intervention, and post-test. The analysis of the students' scores on three different tasks from pretest to posttest showed that the "improvement for experimental group children was significantly greater than for control group children (p. 133)." The improvement was also different among different tasks: The twenty questions tasks by 220%, syllogisms by 117%, sorting by 111%.

In another case study to measure language-learning ability, Sternberg and Grigorenko (2002) aimed to devise an instrument CANAL-FT (Cognitive Ability for Novelty in Acquisition of Language as applied to Foreign Language). This test was aimed to be theory based, ecologically valid, and that "utilizes the dynamic paradigm of testing". While working with 63 Yale University college students (34 females, 25 males, 4 unknown), researchers developed a technique to teach the language "Ursulu" as a foreign language. At the first step, they integrated the unknown words into paragraphs where the meanings of these words are implicitly stated in the context. Then, according to the responses from learners, they used more explicit strategies i.e. direct comparison with English words has been used as a method of mediation. The statistical analysis (correlations with other instruments, factor analysis for the subsets of the instrument) of the test scores showed that CANAL-FT is a valid instrument to predict success in learning foreign language, individual profiles of learners' stylistic preferences, and the best possible placement of learners within a program.

Initiation-Response-Evaluation/Feedback (IRE/F) Studies

As the sociocultural theories of learning draw our attention to look at the classroom talk as an evidence of how students make meanings, science education researchers developed models of assessments embedded into the conversations between teachers and students by considering the common discursive turns of the classroom. These discursive turns have been previously studied in applied linguistics. Sinclair and Coulthard (1975) tried to explain this classroom discourse structure by defining its ranks and levels. According to them, discourse involves: lesson, transaction, exchange, move, and act. *Initiation-Response-Feedback (IRF)* move that they identify as part of the move action and redefined as *Initiation-Response-Evaluation (IRE)* by Mehan (1979) has been identified in classroom discourse studies, and used as tool to understand teacher-questioning studies (Christie, 2002).

Mehan's IRE model was used in studies where questions and possible evaluative comments specific to a certain topic were used by the teachers. Through observation of classroom discourse, the researchers identified and simplified the discourse patterns in a classroom as Initiation-Response-Evaluation. Later, the instruction in these studies was criticized by several researchers as too restrictive and manipulative of students' responses, as well as not allowing students' meaning making (Wells, 1993). Based on the

IRE/F models, questions, response and evaluation prompts were suggested for classroom use. These closed questions memorized by the teachers were not engaging students in thinking or reasoning (Ruiz Primo & Furtak, 2007). In other words, they were limited to the “authoritative discourse” shaped by teachers’ questions and did not allow “dialogic discourse” necessary for the learning of scientific skills and understanding knowledge construction in science (Scott, Mortimer & Aguiar, 2006).

In Scott and Mortimer’s work on communicative approach identified four different types of talk in science classrooms: non-interactive/ authoritative, non-interactive/dialogic, interactive/authoritative, interactive/ dialogic. IRF sequences were observed in interactive discourses, mostly in interactive/authoritative type. In interactive/dialogic classroom type, Scott and Mortimer also found another pattern of discourse, I-R-F-R-F-… “where the elaborative feedback (F) is followed by a further response from the student (R), and so on” (2005, p. 401). Since I-R-F-R-F-… pattern was mostly observed in interactive/ dialogic type of classroom talk, they have been seen as an appropriate discursive pattern for dialogic instruction (Scott & Mortimer, 2005, Chin & Osborne, 2008).

IRF sequences have also constituted a basis for understanding the nature of questioning in science classrooms as these questions can serve for many purposes such as assessing student learning, engaging students to the lesson, and checking if students are listening at the moment. Chin (2006), in her review of studies on “teacher questioning and feedback to students’ responses” has drawn the following model of IRF sequence, including the purposes of using utterance (Figure 2-3).

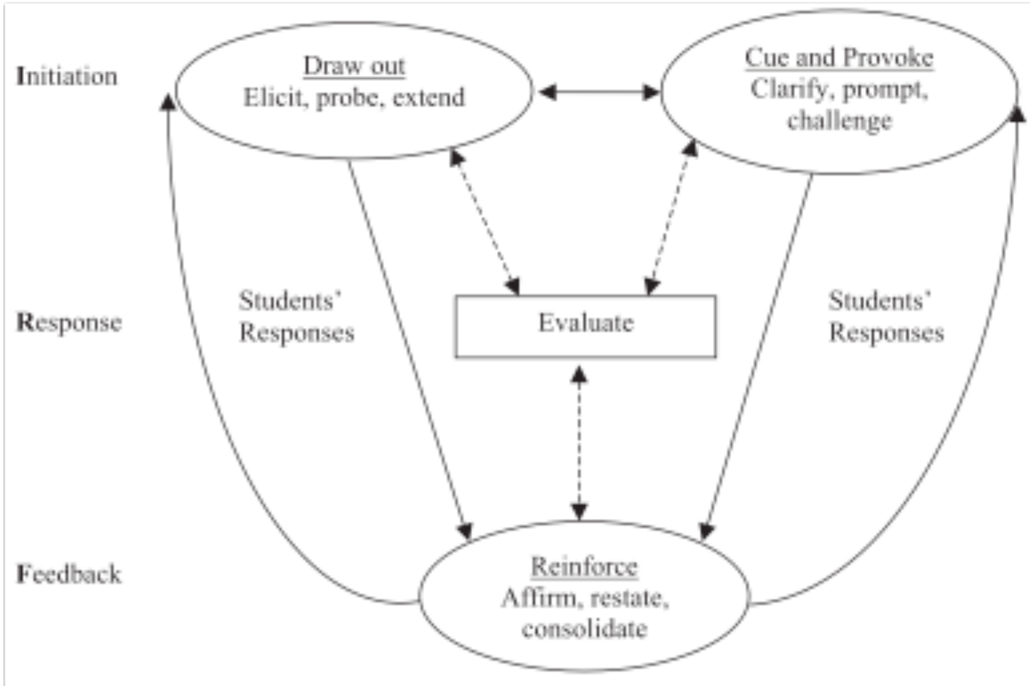

Figure **2-3**: Purpose of teachers' utterances during facilitative IRF iterations (Chin, 2006, p. 1337)

Referring to Figure 2-3, Chin recommended that evaluating students' ideas (e.g., ok, good, very good, wrong) should not be an end in the questioning cycle, rather teachers should give feedback to reinforce students' further thinking and reasoning.

IRE/F sequences first identified in applied linguistics inspired the studies in science education aiming to understand the classroom talk and the nature of questioning that mostly serves for assessing students' thinking and reasoning.

Assessment Conversation

To create an ideal model of assessment activities embedded into science teaching, Duschl and Gitomer (1997, 2003) studied on "Assessment Conversations." These assessment conversations have three parts: the teacher *(1) receives, (2) recognizes,* and *(3) uses* information provided by the students. Figure 2-4 gives the details about each of the three steps. To receive information, teacher arranges small group activities and tasks during which students can display their understanding. The recognition of student response involves teacher's careful analysis of student understandings by considering the conceptual goals of lesson and also working with students for the synthesis of the ideas. Finally, the teacher uses what has been learned in order "to evaluate previous efforts, meanings, and understandings, and performances" and to improve students' understanding, meaning making, and performances.

Duschl also tried to define what teachers need to know in order to facilitate assessment conversations that he sees as a way to improve scientific inquiry. These cycles were introduced to the teachers at the beginning of study as a way to assess students' scientific thinking. In their studies, Duschl and Gitomer (1997, 2003) explored challenges teachers faced and the results from their study revealed teachers obstacles related to science education policies, standards movements, and the nature of science content (teachers were using assessment conversations more during the activities and experiments).

Stage	Descriptions
Stage 1 – Receiving Information	Individual or group efforts on specialized tasks that by design bring about among students a diversity of responses and range of representations and ideas Teacher and students make explicit and publicly display via posters, presentations, charts, overheads, and so forth the diversity of students' efforts, representations of meanings and understandings, and performances on the tasks
Stage 2 – Recognizing Information	Teacher examines critically and makes an appraisal of the diversity of student efforts, meanings, and understandings, and performances and selects according to conceptual goals and employing criteria Teachers and students work toward a synthesis of comes to count as or stand for appropriate efforts, meanings, and understandings, and performances employing SEPIA [Science Education through Portfolio Instruction and Assessment] criteria
Stage 3 – Using Information	Applying what has been learned to an evaluation of previous efforts, meanings, and understandings, and performances or to the design of an investigation for advancing efforts, meanings, and understandings, and performances in the present domain of inquiry

Figure **2-4**: Stages of the Assessment Conversation

Informal Formative Assessments

In a more recent study, Ruiz Primo and Furtak (2007) studied "Informal Formative Assessments (IFA)" based on the studies of Duschl on Assessment Conversations. The term IFA has been first defined in the book *Formative Assessment and Science Education* (Bell & Cowie, 2001) as assessments that can be embedded in any type of student-teacher interaction and those assessments considering learning more than record keeping:

> *Formative assessment is responsive in that it can be informal.*
>
> The teachers referred to assessment as both formal and informal. In saying this they were usually referring to whether the information gathered was recorded and reported or whether it was used in classroom activities, without a written record being made. Formative assessments tend to be informal, with no written record of the information gathered. The information was used in the teaching and learning in the classroom and to build up a picture of the student learning by the teacher. (p. 63)

As this paragraph implies, IFA is a kind of formative assessment that means it is continuous through the instruction. However, it is informal that means it does not aim to report results officially. Furthermore, as mentioned by Ruiz-Primo & Furtak (2007), IFA "can take place in any student-teacher interaction and that helps teacher acquire information on a continuing basis" (p. 59).

Ruiz Primo and Furtak (2007) distinguished IFA from IRE/F cycles, IFA offer teachers freedom to formulate questions that elicit students' responses authentic situations, and to give importance to the way that teachers recognizes student responses. In their study, they introduced ESRU cycle to the three middle school science teachers at the beginning of the study. During these cycles, teacher *elicits*, student *responds*, teacher *recognizes* and *uses* the information related to scientific content (Figure 2-5).

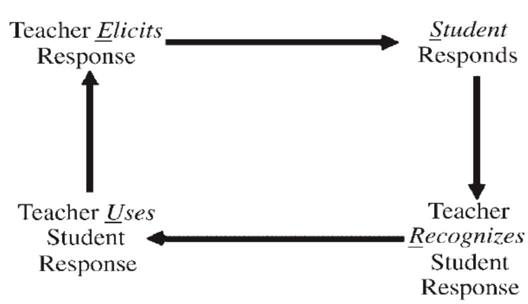

Figure **2-5**: The ESRU model of IFA (Ruiz-Primo & Furtak, 2007, p. 61)

In their article, Ruiz-Primo and Furtak also give examples to what teachers can do to elicit, recognize and use students' responses (Figure 2-6):

Eliciting	**Recognizing**	**Using**
Epistemic Frameworks		
Teacher asks students to: Compare/contrast observations, data, or procedures	Teacher: Clarifies/Elaborates based on student responses	Teacher: Promotes students' thinking by asking them to elaborate their responses (why, how)
Use and apply known procedures	Takes votes to acknowledge different students' ideas	Compares/contrast students' responses to acknowledges and discuss alternative explanations, conceptions
Make predictions/provide hypothesis	Repeats/paraphrases students' words	Promotes debating and discussion among students' ideas/ conceptions
Interpret information, data, patterns	Revoices students' words (incorporates students contributions into the class conversation, summarizes what student said, acknowledge student contribution)	Help students to achieve consensus
Provide evidence and examples	Captures/displays students' responses/explanations	Helps relate evidence to explanations
Relate evidence and explanations		Provides descriptive or helpful feedback
Conceptual Structures		
Teacher asks students to: Provide potential or actual definitions Apply, relate, compare, contrast concepts, Compare/contrasts others' definitions or ideas Check their comprehension	-----	-----

Figure **2-6**: Strategies for ESRU cycles by dimension (Ruiz-Primo & Furtak, 2007, p. 63)

We can see in the figure that considering epistemic frameworks and conceptual structures of scientific learning, authors provided different examples of teacher questions. According to the results of their study, IFA can provide more frequent feedback to the teacher to monitor the classroom activities and the effective use of these cycles (more complete cycles) results in better scores in formal written assessments.

For this study, I decided to use the term "Informal Formative Assessments (IFA)." Although the definition of IFA will be a synthesis of the previous studies, the initial model (Figure 2-7) will be different in two ways. First, the model will be a draft serving as a guide during the study and will not be introduced to the teachers at the beginning. For this reason, the model will be revised after observations on teachers' own routine informal formative assessment practices and teachers' reflections on their practices. Second, I will introduce the model to the teachers for discussion. Another difference of the model will be the detailed description of teacher and student actions during each step of the model. For example, when a student responds, this can be relevant, somewhat relevant or irrelevant to the scientific idea that teachers initiated. This differentiation in student responses can help us understand why teachers leave such sequences and redirect attention to another student response. The model also defines the way that teacher recognizes students' responses with the following actions: repeats/recognizes, corrects, gives evaluative feedback, takes votes to acknowledge, and clarifies or elaborates (Figure 2-7).

In addition, I am looking at the ways teacher recognizes student responses such as repeating, correcting, and elaborating. Looking at these different ways can give us information about how teachers are able to use the ideas from student responses to continue to the next step. Since I am looking at the effective implementation, the initial criterion for effectiveness will be completeness of the cycle (as suggested by Ruiz-Primo & Furtak, 2007). If the teacher leaves the cycle without reaching the specific objective of initiating the IFA cycle, I will call these as an ineffective IFA cycle. The possible occasions for leaving the cycle have been shown by red lines in the figure 2-7:

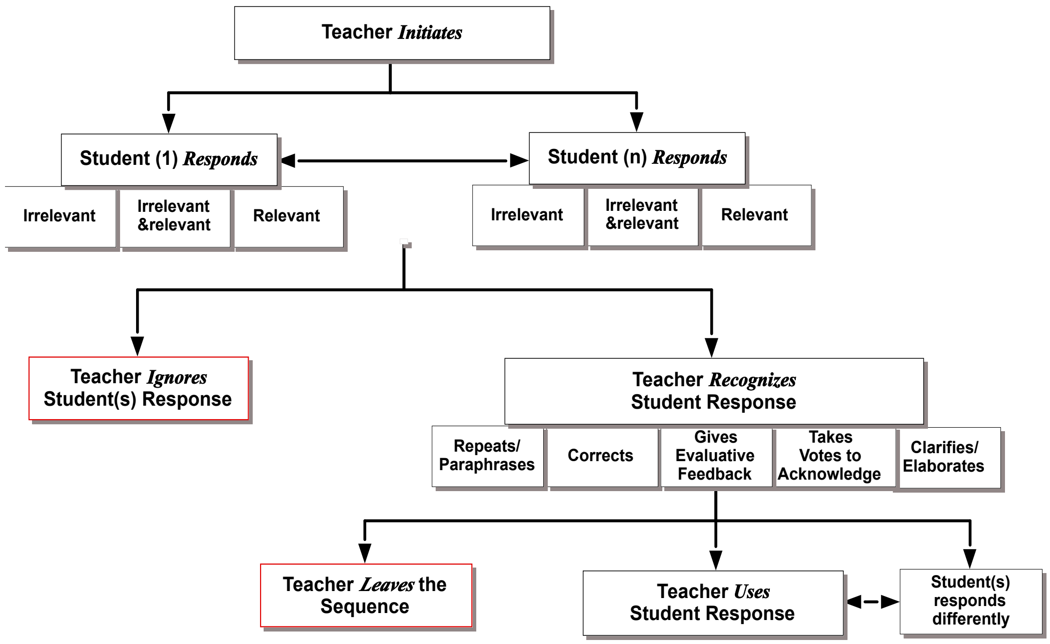

Figure **2-7**: Guiding Model for Informal Formative Assessment Cycle.

The initial criterion for effectiveness will only be used while selecting exemplary video-cases. This criterion will be revised after the discussions with the teachers.

Learning to Assess Through Reflection

The Place of Reflection and Reflective Practice in Teacher Education

The concept of reflection and reflective practice became a salient topic of professional teacher development research since it has been mentioned in the education literature in the seminal works of John Dewey (*How We Think*, 1910, *Democracy and Education*, 1916, *Experience and Education*, 1938). Reflective thinking and practice was not only a major issue in research articles, but also took its place in numerous standards documents in teacher professional development. For example, in 1987, *National Board for Professional Teaching Standards* stated how engaging in reflective thinking helps teachers understand their practice more thoughtfully and evaluate their practice for improvement as: “Teacher engages in reflective thinking in which he/she describes their practice accurately, analyzes it fully and thoughtfully, and evaluates ways to refine it.”

In the field of science, in 1996, *National Science Education Standards (NSES)* document emphasized reflection for the professional development of science teachers as: “Teachers should have opportunities for structured reflection on their teaching practice with colleagues, for collaborative curriculum planning, and for active participation in professional teaching and scientific networks” (p. 58). Reflection on instructional activities, materials and videos has also been suggested many times in *National Science Teacher Association Standards* (2003) document, and Standard 10 that is specifically about “professional growth” identified reflection as one of the musts for professional development: “To show their disposition for growth, teachers of science must demonstrate that they reflect constantly upon their teaching and identify ways and means through which they may grow professionally” (p. 30). These three documents show that the idea of reflection has gained more emphasis for the professional development of teachers through the years.

National Science Education Standards (1996) document also suggests the development of “courses and other activities” by which teachers will reflect on their learning:

> Courses and other activities include ongoing opportunities for teachers to reflect on the process and the outcomes of their learning. Instructors help teachers understand the nature of learning science as they develop new

> concepts and skills. Those who teach science must be attentive to the scientific ideas that teachers bring with them, provide time for learning experiences to be shared, and be knowledgeable about strategies that promote and encourage reflection (p. 63).

In addition to the importance and promotion of reflection during inservice teaching, the same standards document focuses on how reflection can be the part of preservice teacher education programs:

> Preservice courses must allocate time to teach prospective teachers techniques for reflection, and practicing teachers must be given opportunities to develop these skills as well. Many techniques for reflection on practice are available, and their use is becoming more widespread. Self-reflection tools such as journals, audiotapes or videotapes, and portfolios allow teachers to capture their teaching, track their development over time, analyze their progress, and identify needs for further learning (p. 69).

The above statements from NSES document clearly expresses the necessity of reflection for better curriculum planning and teaching activities, and the integration of reflection into preservice and inservice teacher education programs by using different techniques and strategies.

From the statements in all these documents, we can see that the focus on reflection for preservice and inservice teacher education is very obvious. However, what is meant by the concept of reflection is not very clear. There is a need for revisiting the definition of reflection by considering both the interpretations of the concept in teacher and science education research, and as well as the new directions proposed by socio-cultural frameworks for framing teachers' learning. Before going through the implementations of reflection and redefining it via new theories in educational research, I will summarize the ideas of Dewey and Schön for understanding the change after these seminal pieces.

What kind of thinking is reflective? Contributions of Dewey

Dewey approaches reflection as a cognitive process and sees it as one of the modes of thought that helps to make meaning out of an experience. He describes reflective experience as

> In discovery of the detailed connections of our activities and what happens in consequence, the thought implied in cut and try experience is made explicit. Its quantity increases so that its proportionate value is very different. Hence the quality of the experience changes; the change is so significant that we may call this type of experience reflective – that is, reflective par excellence (Dewey, 1916/1944, p. 170).

Once we make meaning from an experience, we can use this meaning as a reference for future experiences and so reflection makes it possible to connect our experiences and helps learning from experience. Therefore, reflection saves us learning through trial and error method each time. Dewey also differentiates reflective thinking from the other modes of thoughts: "consciousness, invention, belief" which helps teachers understanding the conventional, commonly accepted theories. For him, reflective thinking is "active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it and the further conclusions which it tend*s*" (p. 9).

Another contribution of Dewey was his description of steps for reflective thinking process. According to Rodgers (2002), Dewey implicitly defines six phases of refection in his books *How We Think* and *Democracy and Education.* Rodgers states these phases as (p. 851):

1. An experience
2. Spontaneous interpretation of the experience
3. Naming the problems(s) or the question(s) that arises out of the experience
4. Generating possible explanations for the problem(s) or question(s) posed
5. Ramifying the explanations into full blown hypotheses
6. Experimenting or testing the selected hypothesis

Dewey also emphasized that the reason for reflection upon experience is to share it with a community "A man really living alone (alone mentally as well as physically) would have little or no occasion to reflect upon his past experience to extract its meanings" (1916/1944, p. 6). That's why, for Dewey, community support was a key to efficient reflective practice. Finally, Dewey also considered affective characteristics for being a reflective thinker. For him, to be a reflective thinker, a person should possess the characteristics of whole-heartedness, directness, open mindedness, responsibility and readiness (Rodgers, 2002).

All in all, Dewey defined the concept of reflection as a cognitive act that also requires the improvement of affective characteristics such as whole-heartedness. Reflection process can occur in individual mind, but community is necessary to broaden the meaning from the experiences.

Connecting theory and practice in social science research: Contributions of Schön

Another important contribution for understanding the meaning of reflection was made by Donald Schön who is working on the development of professional knowledge for practitioners. He criticized the idea of "technical rationality" emerged from the positivist view of the early twentieth centuries. The followers of the idea claim the superiority of technical knowledge over practical knowledge and propose a direct application of theories into practice (Schön, 1983). According to Schön (1983, 1987), practitioners reflect *in* action while they are reaching professional artistry. For him reflection *in* action is active thinking during the action. Schön also describes the phases of reflection in action as follows (1987, p. 28):

- There, is to begin with, a situation of action to which we bring spontaneous, routinized responses.
- Routine responses produce a surprise-an unexpected outcome, pleasant or unpleasant, that does not fit the categories of our knowing-in-action.
- Surprise leads to reflection within an action-present.
- Reflection-in action has a critical function questioning the assumptional structure of knowing in action.
- Reflection gives rise to on-the spot experiment. (this can produce satisfactory results or may surprises that practitioner needs to go another reflection process).

By suggesting the concept of "reflection in action," Schön differentiates the concept of reflection into two, and he names the other kind of reflection suggested by Dewey as "reflection *on* action," an after the action process that requires deliberative thinking and more careful consideration and analysis of the practice. According to Schön, practitioners reflect on their action or their knowledge and they also reflect on their reflections in action to prepare themselves for the future cases. Griffiths (2000)'s interpretation on this connection between two types of reflections was that reflection-on action is the deliberative end of the sequences of reflection in actions. Thus, reflection on action becomes a strategy to learn from reflections in action and to improve reflections in action.

Critiques of Dewey and Schön

After Dewey and Schön's popularization of the idea of reflection, reflection has been an essential part of teacher education research. However, teacher education researchers criticized some aspects of Dewey and Schön's ideas.

First, these researchers focused on the issue that *teacher reflection as individual vs. social practice.* According to Zeichner & Liston (1996), Schön sees teacher reflection as a solitary process by neglecting the effects of social environment. Although Dewey stressed on the importance of community as a reason for reflections, he did not mention the importance of social factors during the process of reflection. On the other hand, Day (1993) claimed that teacher learning is a dialogic activity and therefore, reflections are dialogical as opposed to Schön's focus on reflection as an individual process.

Another dilemma about the concept of reflection is whether *cognitive / psychological* or *culturally mediated process.* Dewey and Schön' s definitions showed reflection occurring in the individual mind as a result of the cognitive conflicts during or after the experiences (Munby & Russell, 1989). On the other hand, with the rise of the socio-cultural theories, reflection has been interpreted as the part of teaching activity that is social and that can be influenced by the teachers' histories and cultural artifacts in the social context of the schools (Hoffman-Kipp et. al., 2003).

Finally, I want to focus on the change in the content of teacher reflections since Dewey and Schön. What are the issues teachers should reflect on? Should *teacher reflection only on technical matters* or should *teacher reflection* involve the *consideration of social, cultural, and political perspectives?* Following Dewey and

Schön, teacher education programs aiming to enhance reflection have been focused on reflection on technical matters (e.g., instructional strategies) by seeing teaching as a "rule-governed practice" (Hoffman-Kipp et. al., 2003). This was because other critical dimensions, such as the politics and policy behind educational practice, have not been emphasized in teacher education programs (Zeichner, 1990).

Towards More Comprehensive Definition of Reflection

Although Dewey and Schön were forerunners in use of the concept of reflections, there were other important attempts for defining the concept.

Cognitive Perspectives

Originated from Dewey and Schön's idea that reflection is different than routine thinking or action, some studies modeled reflection process systematically (e.g., Korthagen & Kessels, 1999, Korthagen et al., 2001, Korthagen & Vasalos, 2005). They used the framework in figure 2-8 which they named the "ALACT model of reflection" using the initials of each step. By using ALACT model, they studied where and how teacher actions become more systematic, i.e., different than routine actions. By taking a more psychological approach, Korthagen & Vasalos (2005) combined this model with an "onion model" describing the contents of reflection at different levels (Figure 2-9). Their claim was that when teachers' reflections are more systematic, their reflections become “core reflections.” In other words, the contents of teacher reflections reach to the "core” of the onion model (from reflections on environmental factors to mission level).

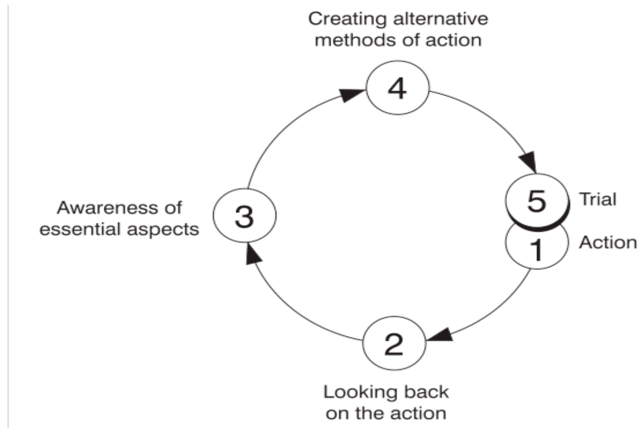

Figure **2-8**:The ALACT model describing a structured process of reflection (Korthagen & Vasalos, 2005, p. 49).

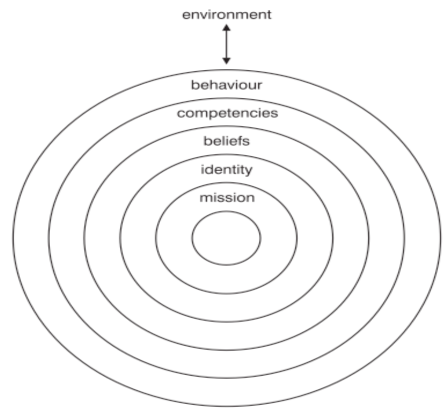

Figure **2-9**: The onion model describing different levels on which reflection can take place (Korthagen & Vasalos, 2005, p. 54).

Considering social and political dimensions

Max Van Manen (1977, 2007) for example, claimed that there are three kinds of reflections used for different aims. One is “technical reflection” a rational thinking about the underlying principles, theories and methods involved in the curriculum and designed to reach the objectives. On the second level, Van Manen defines “practical reflection” which considers the outcomes of the methods, strategies used for the students or teachers during implementation in classroom environment. Then, at the third level is critical reflection, which is on political, ethic, moral, and cultural aspects of practice.

Zeichner and Liston (Zeichner and Liston, 1987, Zeichner, 1993) claim that any kind of reflection should be “critical” in the sense that it should serve for the social equity and the establishment of "humane society." They also criticize the teachers' reflection that just justifies the current conditions. As this also appears in Dewey's writing, reflective thinking is not just approving the established theories and ideas. Reflection should be for improving these ideas and thus, reflective practices should help to improve instruction.

Following Zeichner and Liston, John Smyth, in his articles *Teachers' Work and the Politics of Reflection* (1992) attempted to describe "more socially, culturally, and politically reflective approach to teaching" (p. 75). Smith identifies four problems related to the concept of reflection. One is the assumption that teachers need to be naturally reflective practitioners. However, he thinks that teachers develop habits and see the process of teaching as a set of habits, which are "soothing, non-productive, and anxiety free" (Rudduck, 1984 as stated in Smith, 1992, p. 280). Thus, this may view may oversee the creative and dynamic nature of teaching activity and as a result, teachers' may not aim to improve their instruction. The second problem he sees is that although there are many different kinds of definitions of reflection, political aspects of the concept related to the nation and state descriptions' of good teaching has not been emphasized. The third problem is related to the individualistic and psychological definitions of reflection, which may put the teacher as the center of the problems and neglecting the social, cultural and political impacts. Fourth, Smyth criticizes the over-reliance on the pragmatic aspect of reflection, thus omitting giving enough emphasis on reflection on the social awareness of values. On the other hand, he also suggests four actions for teachers before going into the complexity of ideologies: These are (p. 298):

1. Describe (What do I do?)

2. Inform (What does this mean?)
3. Confront (How did I come to think or act like this?)
4. Reconstruct (How might I do things differently?)

Linda R. Valli (1993, 1997) focused on two dimensions of reflections: "content for reflection" about the themes discussed reflection and "quality for reflection." About the way assessing the reflection. In her article *Listening to Other Voices: A Description of Teacher Reflection in the United States (1997),* she determined five different times types of reflection by reviewing the literature and her empirical studies: technical reflection, reflection-in and on-action, deliberative reflection, personality reflection, and critical reflection. Valli specifies each type of reflection as:

Type	Content for Reflection	Quality of Reflection
Technical reflection	General instruction and management behaviors that are based on research on teaching.	Matching one's own performance to external guidelines
Reflection-in and on-action	One's own personal teaching performance	Basing decisions on one's own unique situation
Deliberative reflection	A whole range of teaching concerns, including students, the curriculum, instructional strategies, the rules and the organization o the classroom.	Weighing competing viewpoints and research findings
Personalistic reflection	One's own personal growth and relationships with students	Listening to and trusting one's own inner voice and the voices of others
Critical reflection	The social, moral and political dimensions of schooling	Judging the goals and purposes of schooling in light of ethical criteria such as social justice and equality of opportunity

Figure **2-10**: Content for Reflection and Quality of Reflection (Valli, 1997, p. 75)

Building on Bakthin's idea on inseparability of private and public theories, John Halliday (1998) thinks that private theories of teachers formed within their own conditions helps improve teaching via authentic reflective practice. Halliday (1998) looks at the differences between technicist and reflective practitioner from the perspective of "nature of authenticity." For Halliday (1998), authenticity occurs "when people take hold of the direction of their own lives without the direction of being determined for them by external factors" (p. 599). Then, reflection becomes more authentic if teachers are not assessing their teaching towards authoritatively determined criteria, which leads to more technical (standardized, inauthentic) reflection. Even though being technicist provides a standardization and certification of good teaching through specific guidelines and helps creating bonds between communities of practice, authentic account of the reflective practice leads to improvement through the emergence of fresh ideas from teachers' private conditions.

Considering the phases of reflection from Dewey and Schön, and also different types of reflections from Van Manen and Valli, some researchers developed matrices (e.g., Danielowich, 2007, Grunau, 2000). For instance, Grunau et al. (2000) developed a matrix to analyze teachers' reflections (see figure 2-11) to be able to see the reflection levels and contents of preservice science teachers and improve their reflections during a science methods course.

Forms of Reflection

		Introspection	Replay & Rehearsal	Enquiry	Spontaneity
Human Interests	Technical				
	Personal				
	Problematic				
	Emancipatory				

Figure **2-11**: Forms and Interests of Reflection (Grunau, Pedretti, Wolfe, & Galbraith, 2000, p. 49)

Analyzing Teacher Reflections:

Another way of analyzing teacher reflections have been an inductive qualitative analysis of the artifacts (e.g., written reflection, transcripts) based on Glasser and Strauss' grounded theory (1967). Researchers using this way of analysis determined categories emerged from their data (e.g., Abell, Bryan, & Anderson, 1998, Sadler, 2006). For example, Sadler (2006) created "taxonomy of challenges experienced during student teaching" and "taxonomy of successes experienced during student teaching" by using a constant comparative method of grounded theory. Sadler also explains the specific concerns related to challenges and specific accomplishment related to successes, as well as including typical examples from preservice teachers' reflections. According to these taxonomies, the challenges are: classroom and time management, institutional and job complexity, unengaged cooperating teachers, university requirements, and special-needs students. The successes were: relating well to students, individualized instruction, making content personally relevant, reflecting, and structuring inquiry.

Although it remained as a suggestion, cultural historical activity theory (CHAT) perspective was proposed to understand teacher reflection as a social and culturally mediated process (Hoffman-Kipp et. al., 2003). Originating from Vygotsky and his students' works during 1920s and 1930s, CHAT frames learning as a social and cultural activity affected by the backgrounds of subjects, mediated by social, cultural tools, involved in a community, necessitated the division of labor among subjects, mediating artifacts, and community, and rules to govern these relationships. These dimensions of CHAT will be explained in more detail in the following section on this chapter (under the heading “A Socio- Cultural Perspective for Understanding Teachers’ Learning and Practices: Cultural – Historical Activity Theory (CHAT).” With these dimensions, CHAT seems well suited for defining and analyzing reflective practice aligned with recent theories and questions in teacher education and science education research.

Strategies to Promote Teacher Reflection

Teacher education researchers used numerous ways of promoting reflection including action research, journaling, teacher narratives, teaching portfolios, reflective interviews, action research, using stories, teacher support groups, video records/video clubs, teacher book clubs, reflection roundtables, interactive reflective teaching seminars, and school-wide study groups (York-Barr, Sommers, Ghere, & Montie, 2006). In this section of the paper, the purpose is not to explain and review all of these strategies separately. I will rather try to select the most commonly used ones by looking at the literature I can reach. Then, I will explain these strategies and give examples from the teacher education research. Finally, I will mention some of these strategies commonly used specifically in science teacher education.

Journaling has been used in different versions. One kind of journaling is “Dialogue/Interactive Journal” which involves sharing of individual journals with another person or a group who will expand the views of the journal writer by sharing their ideas and making inquiries (Keating, 1993). Christensen et. al. (2004), for example, used interactive journaling by grouping master teachers and their interns. In this study, they have seen that interns are mostly focusing on classroom management issues, feelings about their successes or failures. Moreover, interns' reflections on content, pedagogy, and students were not as comprehensive, and interns' language was not as professional as master teachers. After sharing journal writings, master teachers give their thoughts and inquiries on interns' journals.

Interactive journals can also be in the form of "structured reflection logs," which includes questions, question sets, cases, and videos to guide teacher reflections. Kolar and Dickson (2002) used structured reflection logs with special education preservice teachers and through guiding questions, scenarios, and video cases, they asked preservice teachers to reflect on their experiences with disabled people. According to the findings of the study, preservice teachers thought using structured reflection logs were very beneficial for connecting what they have learned, their present experiences and their future considerations.

Another kind of journaling that has been suggested especially for the cohort of first year teachers is "Online Directed Journaling" (York-Barr, Sommers, Ghere, & Montie, 2006). This strategy has been previously studied with practitioner nurses who are trying to learn their professions in different places and in cooperation with other nurses. These nurses have been asked to write weekly journals and every week they had 24 hour access to a web site that they post their reflection journals and also reviewed and commented on other journals. Findings of this study showed that nurses found this experiences as an easy and encouraging way of learning (Daroszewsky, Kinser & Lloyd, 2004).

Action research methods also provided a medium for teachers' reflections. As defined by Reason and Bradbury (2001), action research is (p. 1):

> A participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is merging at this historical moment. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities.

As is obvious from the above definition action research aims to connect “action and reflection” and just like the purpose of reflective practices, action research aims to connect “theory and practice” while participating in a community.

According to Zeichner and Wray (2001), using *portfolios* for teaching are beneficial for more qualified reflections. Teaching portfolios are “purposeful collection of any aspects of a teacher’s work that tells the story of a teacher’s efforts, skills, abilities, achievements, contributions to students, colleagues, institution academic discipline or community” (Brown & Wolfe-Quintero, 1997, p. 1). These teaching portfolios can improve reflection during the process of preparing them, which is expected to involve reflective thinking (Bailey et al. 1998). For example, in a study conducted in Israel with two mentor teachers during an inservice teacher training course, Orland-Barak (2005) used process and product portfolio to explain evidence of reflection in portfolios. According to the findings of the study, both process and product portfolio included reflective language while more dialogic reflections has been found in product portfolios. Although portfolios were found to be useful for fostering dialogic reflections, the portfolios did not show critical reflections that would consider the social, moral and political dimensions of teaching.

Not surprisingly, advancements in technology led teacher education researcher to use technological tools to promote reflections. Recently, using *videotaped cases* of teaching practices in reflection studies is appealing to many researchers attempting to understand and encourage teacher reflections (e.g., Chen, Schewille, & Wickler, 2007, Finn, 2002, Sherin, 2000). These studies, individually, found some positive influences of using videotaped cases for the quality of reflections, mainly because video records give teachers the opportunity to remember and review details of experience. By working with 15 inservice teachers, McConnel et al. (2008) compared the reflection practices of teachers while using two different media: text and video. They collected the data through pre and post-STEBI (Science Teaching Efficacy Beliefs Inventory) surveys and teachers' videotaped presentations on their reflections of their experiences with their colleagues. Their main conclusions were (p. 10):

1. Teachers who use video are more likely to use evidence to guide their instructional decisions, and
2. Teachers who use videos to support their reflections gain confidence in their ability to help students to learn science.

Another way of using videotapes to promote reflection is the formation of "video-clubs." According to Sherin (2000), video-clubs give teachers opportunity to review their practices with their peers and to focus on their reactions. In his study, Sherin arranges teachers of small groups (4 teachers in each group) to watch and reflect on 10 minutes episodes from teaching practice. As a result of the study, teachers stated that they have "not only increased understanding when reflecting on video, but also paying more attention to students' responses during instruction" (p. 37).

In science education, as in teacher education research in general, most studies on reflection were designed with preservice teachers. Researchers working with preservice teachers integrated the previously mentioned strategies (e.g., journals, guided interviews) for promoting reflection to "science methods courses" with a focus on improving reflection (e.g., Abell and Bryan, 1997, Abell, Bryan & Anderson, 1998, Bryan & Abell, 1999, Van Zee & Roberts, 2001). These studies concluded that science methods courses are effective to improve reflective practices of preservice teachers. There have also been some studies on inservice teacher education designed to facilitate refection for professional development and solve their difficulties (Bond, 2001, Monet and Etkina, 2008, Orland-Barak, 2005). As in the study by Monet and Etkina (2008), journal writing was utilized as a way to improve self-reflections of science teachers during an inquiry-based professional education program. They resulted that science teachers learned more about inquiry process through their written reflections on their journals.

Reflective practice was also the part of lesson study research originated in Japan and popularized in the US after the studies on the video cases of teaching from the Third International Mathematics and Science Study (1999) and became the focus of numerous research (e.g., Lesson Study Research Group, 2004, Lewis, Perry, Hurd, 2004). Lesson study involves the planning of the research lesson after studying the curriculum by a group of teachers and then implementation of this research lesson by one members of the group while the others are collecting data. A post-teaching discussion follows this process where teachers are reflecting on their video-cases (Figure 2-12).

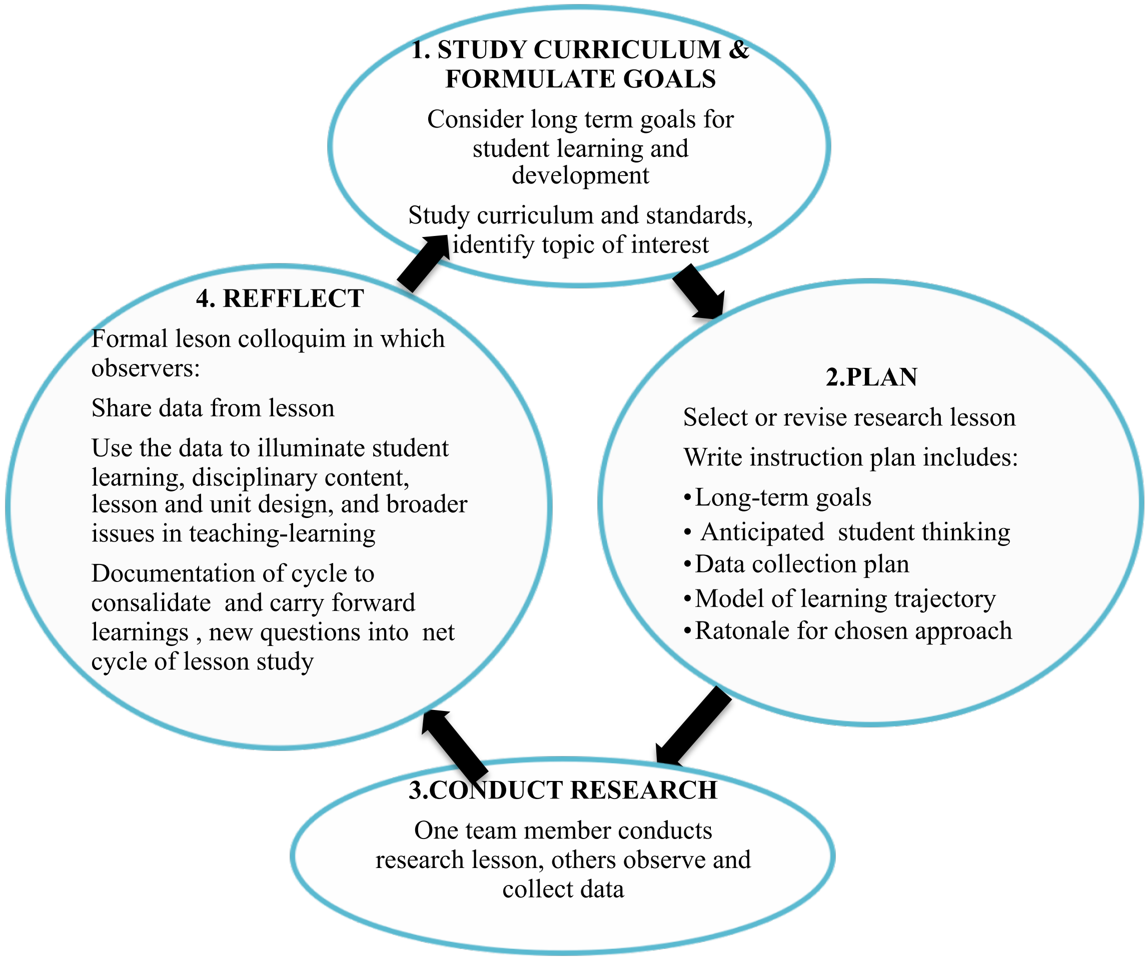

Figure **2-12**: Lesson Study Cycle

After the reflections, the lesson plans, goals and teaching methods are revised and the cycle starts again. Due to collaborative nature of the lesson studies, teachers share their ideas on student thinking by looking at live lessons and improve the lessons by division of labor in their communities of practice (Perry & Lewis, 2008).

When we look at the recent research in science teacher education about reflection, growing interest in using video cases to promote reflection is apperant (e.g., Abell, Bryan, & Anderson, 1998, Finn, 2002, Roth, 2003, Roth & Chen, 2007, Wang & Hartley, 2003). For preservice teachers, analyzing and constructing video cases helped them to improve their understanding on professional science teaching. Moreover, preservice teachers engaged in observing the different aspects of their teaching activity like student reactions and context of the teaching activity (Calandra, Gurvitch & Lund, 2008, Roasen, et. al., 2008). Experienced inservice teachers, on the other hand, already have a professional vision of science teaching (McDonald & Kelly, 2007). However, video cases were still found to be very useful for science teachers especially when they have been introduced to new ideologies, methodologies, or strategies of teaching practice (Sage, 2001) or improving their scientific content knowledge (Lundeberg et. al., 2008). While working with 27 science teachers, Lundeberg et al. (2008) compared science teachers' reflection on (1) TIMMS video-cases (2) teacher's own video-case (3) video-cases of teachers' colleagues. They concluded that although all these video –cases have different advantages and disadvantages, inservice teachers found reflecting on TIMMS video cases as the "least beneficial" for their improvement in scientific content.

Re-defining the Concept of Reflection in Teacher Education

Reviewing studies on teacher reflection showed that both the definition and implementations of the concept has gone through significant changes. Despite many different ideas on how to define, promote and analyze teacher reflections, we can see a pattern towards viewing reflection as social practice influenced by the cultural and historical artifacts and state policies. Another trend that can be realized from the literature is using video cases to integrate reflective practice in preservice and inservice teacher education programs.

Through the synthesis of the ideas mentioned above, I will define teacher reflection that can be more consistent with recent theories of teacher learning (i.e. socio-cultural theories): Teacher reflection/reflective practice that requires deliberate and critical thinking in/on actions is a *sine qua non* for meaningful connection of theory and practice in educational settings. Moreover, it should be through careful analysis and sharing ideas with colleagues on educational practices embedded in social, cultural and political milieu of context (e.g., school, classroom) and historical backgrounds of the participants.

In my definition, I agree with Dewey's idea of seeing reflection as a special mode of thinking, which is deliberate and critical. However, I disagree with the cognitive views (such as Korthagen and Vasalos, 2005) that trace reflection on missions, beliefs, and competencies of people. These constructs are very complex to analyze and difficult to change. Rather, my definition of reflection is more concerned with what teachers can explicitly state in the discourse of reflective practice as they carefully analyze their practice and share ideas with their colleagues or other people within their community.

As inspired by Schön, I defined reflection as a way to connect theory and practice. Through reflection, I aim to connect teachers' models of IFA and models from science education literature. Studies on inservice teacher education also showed the potential benefits of reflection for the professional development of teachers when they have been introduced to innovations (Sage, 2001). The type of assessment activities in this study "Informal Formative Assessments" is also different than the traditional assessment activities including multiple-choice tests and quizzes. Therefore, reflection can be a beneficial tool for helping teachers to understand this relatively new assessment strategy.

Deviating from Schön, I think teachers' reflection may include social and cultural dynamics affecting assessment practices (Hoffmann Kipp et al., 2003). For this reason, I defined the teachers' histories and context in the methodology. Another concept proposed by researchers was 'critical reflection' that considers the social and policy issues related to teaching practices (e.g., Max Van Manen, 1977, 2007, Zeichner, 1993). For this study, to understand teachers' challenges for implementing IFA, the researcher will encourage teachers to talk about obstacles due to the requirement of the school board, district and state school boards, and the educational policy documents.

Redefinition of the concept of reflection leads us to question the appropriateness of the existing analysis frameworks. The use of CHAT framework (Figure 3-1) can be a way to understand social and cultural dynamics of the context of this study. Moreover, by considering the literature showing the effectiveness using teachers' own video cases to promote reflection, I will also select exemplary video cases of teachers' own practice as a way to promote reflection.

A Socio- Cultural Perspective for Understanding Teachers' Learning and Practices: Cultural – Historical Activity Theory (CHAT)

The Emergence of the Theory

CHAT originated from the works of Vygotsky during 1920's and 1930's when he started to look at human development not only as a psychological process but also as a social process. For him, development of abilities first occurs in an "intra-psychological plane" and reaches its maximum potential through mediating artifacts in the inter-psychological plane. One of the artifacts that he commonly focused in his studies was "language" (Vygotsky, 1962). Following Vygotsky, his students Luria and Leont'ev continued to work on the social artifacts and Leont'ev come up with the idea of looking at the triadic relationship between subject, objects and mediating artifacts. These relations, according to him, appear in activity systems, which can be the unit of analysis. In his writing, Leont'ev (1978) states this as:

> We always must deal with specific activities, each of which answers a definite need of the subject, is directed toward an object of this need, is extinguished as a result of its satisfaction, and is produced again, perhaps in other altogether changed conditions.
>
> …*the concept of activity is necessarily connected with the concept of motive.* Activity does not exist without a motive…(p. 62)

Leont'ev (1978) sees an *activity* directed towards an *object* (or *motive*) and composed of *actions* directed towards *goals* and consist of *operations* that connects the activity to real world by defining the actual behavior to accomplish the goals of actions. According to Leont'ev, activities are abstract; we can observe them through goal directed actions. For differentiating actions from operations, he says that operations are routine actions that have been practiced many times. Leont'ev (1981) also focused on sharing responsibilities in an activity system that will appear as "division of labor" in Engeström's reformulation of the theory.

In this second generation, Engeström adds new dimensions to the triadic relationship of the activity system (see Figure 2-13). The new dimensions he added to the system are *community* (the group of the people in which subjects belong), rules, either explicitly or implicitly stated (regulating the social interaction in the community of which the subject belongs), and *division of labor* (shared participation of responsibilities in the activity determined by the community members). There is always an *outcome* of the system - that is, the resulting product of the activity system. The inclusion of these new elements to the activity system would, according to Engeström, have more focus on "the societal and collaborative nature" of the actions.

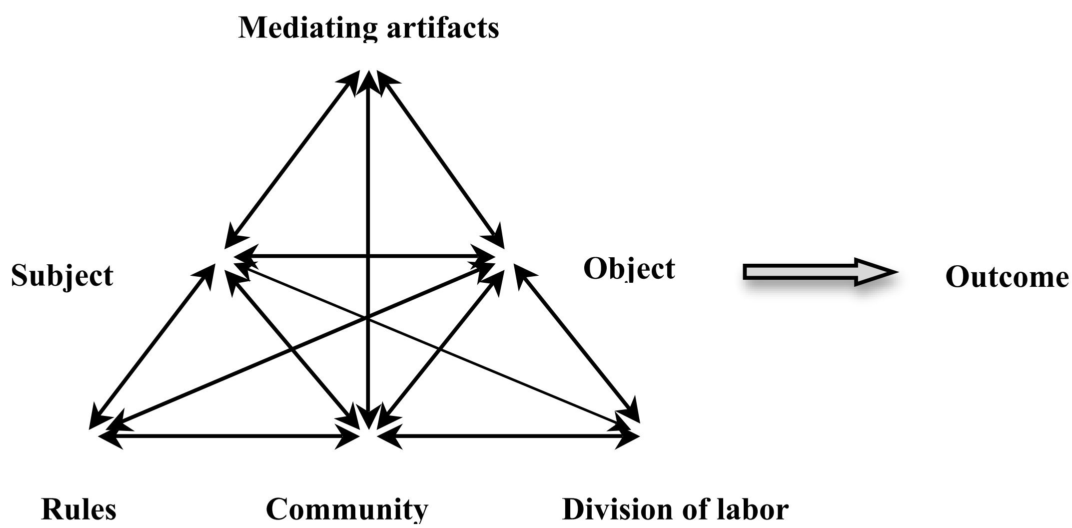

Figure **2-13**: A Complex Model of an Activity System (Engeström, 1987)

In order to understand the interactions between activity systems, Engeström proposes a third generation of the CHAT (see Figure 2-14). This third version of the activity theory model aims to look at dialogues between different activity systems from multidimensional perspective and improve conceptual tools to understand these international dialogues (Daniels, 2004).

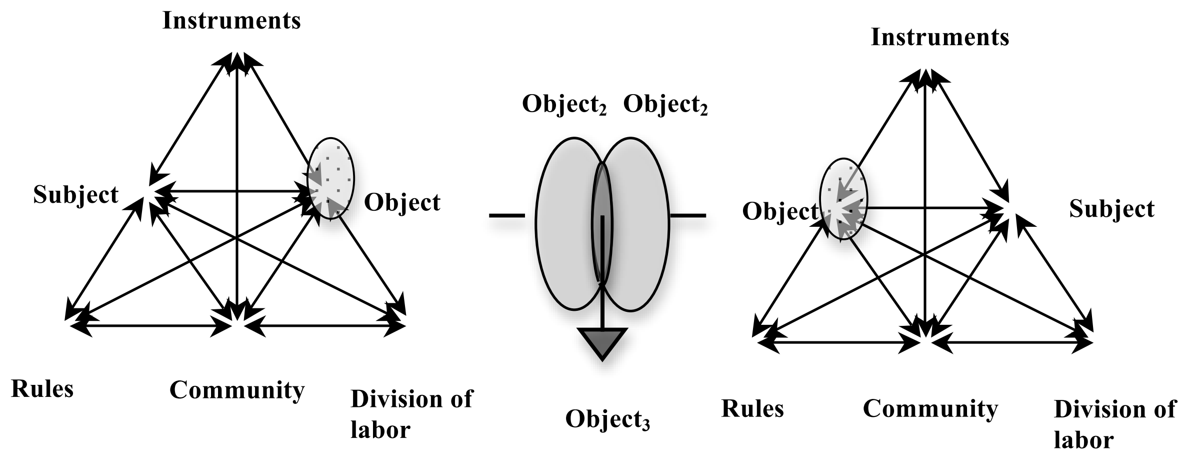

Figure **2-14**: Activity systems as min. model for the third generation of activity theory (Engeström, 2001)

Studies from Applied Linguistics: Discourse as a Mediating Artifact in CHAT?

What is the role of discourse in the activity theory and why have discourse analysts started to use the theory in their studies? Discourse has important roles within the activity theory. First, it can be described as a mediating artifact/tool for subjects to reach their objects (Mercer, 2004). For example, students who are working as a group to complete a flower model for their science projects need to communicate and use scientific discourse. Second, discourse can be the object of the activity system if the aim is to establish an appropriate discourse (Gee and Green, 1998), such as to carry out a physics experiment or discuss U.S national economics. Another role of discourse in activity theory is based on seeing activity as a “dialogic inquiry” (Wells, 2002). According this view, discourse is used in the formation of dialogues between the subjects of different activities involved in the same community. As is seen in figure 2-15, discourse has the role as the tool of the tools i.e. it helps the creation of material and semiotic artifacts as outcomes of the joint activities within the same community.

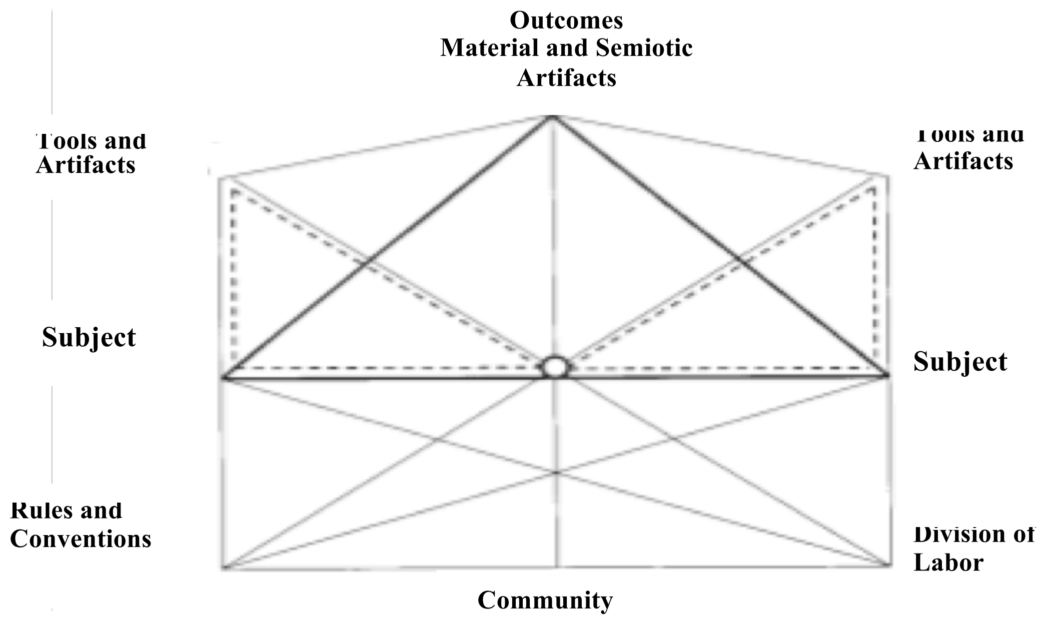

Figure **2-15**: Discourse as tool in the joint activity system (Wells, 2002, p.59)

Wells (2002) also considers the role of inter-subjective dialogues in the case of zone of proximal development of Vygotsky where novices have been assisted by more experienced peers or adults. He claims that the variations in the levels of participants lead to different contributions on the formation of mediating artifacts of the joint activity system. Therefore, in another model (see figure 2-16), he shows inequality of contributions from different activity systems when the subjects have different roles or authorities. Figure 2-16 shows inter-subjective dialogues between two activity systems; one having experts as subjects and the other has novices.

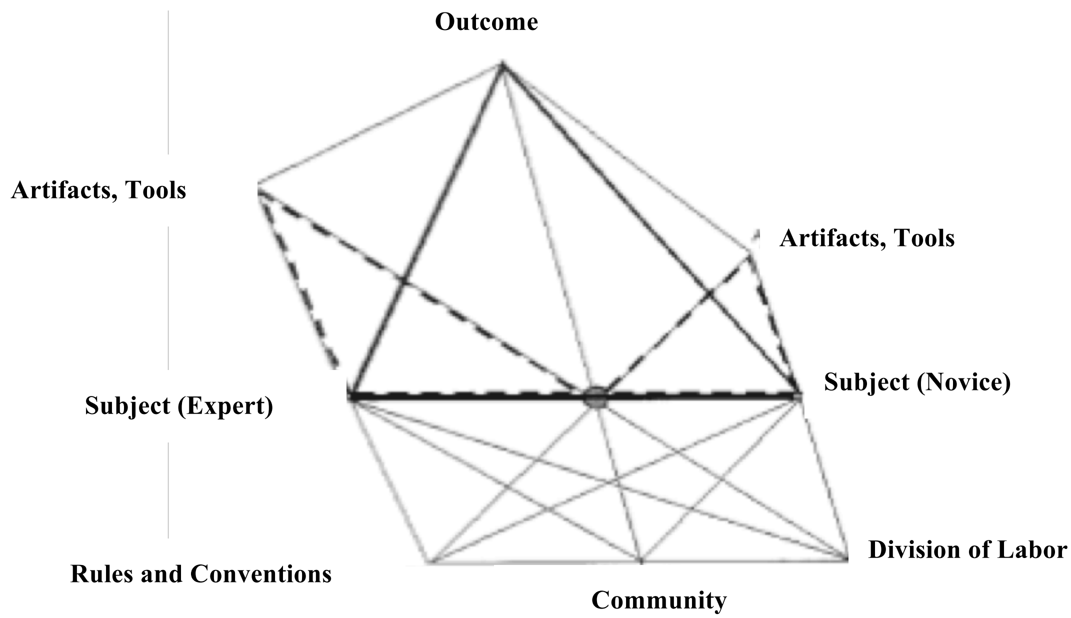

Figure **2-16**: Discourse in the zone of proximal development

This dialogic approach has also been mentioned in the writings of Lektorsky (1999) as he used the term "inter-subjective relations." However, Lektorsky's point is somewhat different than Wells' description of dialogues in joint activity system. He states that

> The so-called inner world (and all processes connected with it) arises as a result of the outer activity of a subject mediated by intersubjective relations. In order to create or change "inner" or subjective phenomena, it is necessary to create some objective thing. The process of objectification is a necessary presupposition for the existence and development of the inner world. Thus what is important about the features of human being is that these features are not naturally given. (p. 67)

Here, intersubjective relations or dialogues make the change through activity systems visible from outside and thus objectifies these changes. Only then, the activity systems alter the inner world of the subjective individual.

Studies in applied linguistics (Gee & Green, 1998; Mercer, 2004; Wells, 2002) used CHAT to understand the role of discourse in activity systems. Through CHAT, these studies identified varying roles of discourse within activity systems (i.e., discourse as mediating artifact, object of the activity system, tool to form dialogues between activity systems).

The Popularization of the Theory in Educational Research

Originating as a theory of psychology, CHAT has influenced the research on computer education (e.g., Kaptelinin, 1994; Kuutti, 1996; Nardi, 1996), and work place education (e.g., Bardram, 1997; Engeström, 2001). These researchers have generally looked at the mediating artifacts that are most of the time physical tools (i.e. technological tools). CHAT has also evoked an interest among educational researchers aims at understanding the nature of teaching and learning in sociocultural context (e.g., Moll, 1990; Russell and Schneiderheinze, 2005). This has been mainly because of the shift in theories of learning from an individual meaning making perspective to the construction of knowledge through social interactions (Leach & Scott, 2002).

CHAT as a tool to understand the social construction of activities through looking at the elements of its culture (e.g., rules, mediating tools) provided a framework for educational researchers to understand the activities within school or classroom context (e.g., McDonald, Le Higgins, & Podmore, 2005, Roth et. al., 2004). In the following paragraphs, I will explain some examples of using CHAT framework in language education, teacher education and science education. One way of using activity theory was through Leont'ev's tri-stratal description of activity, action and operations (as has been discussed in the previous section). Wells (1996) operationalize the actions of the activity through discourse analysis. For this reason, he first describes a skeleton for "The Enactment of Educational Practice" (see figure 2-17):

'ACTIVITY'	(Motive)	'ACTION'	(Goal)	'OPERATION'
Practice of Education	(a) Cultural reproduction (b) Development of individual potential (c) Fostering of communities of inquiry	Curricular Unit	Increasing mastery of: (a) Content knowledge (b) Discipline based practices (c) Tools & artifacts (d) Metacognition (e) Collaboration	
		Curricular activity	Outcome related to (a)-(e) above	Use of semiotic tools, including spoken discourse e.g., Curriculum genres (cf Christie, 1993)
		Task	Completion of a component of an activity outcome	E.g., Co-construction of episode of discourse
		Step	Contribution to outcome of task	E.g., Co-construction of sequence of discourse, using a micro-genre, e.g., triadic dialogue

Figure **2-17**: Enactment of Educational Practice (Wells, 1996, p. 88)

When we look at figure 2-17, Wells divides the activity of "practice of education" into actions as curricular unit, curricular activity, task, and step. Then, he attempted to define specific operations for the actions that can be observed and analyzed in educational data. It is also important to notice that although he defines general motives or object for the activity, he defines more specific goals for the actions. Following this, Wells attempts to integrate two episodes of discourse from 4th and 5th grade elementary school science classrooms to this skeleton (see figure 2-18).

	Example 1	**Example 2**
Curricular Unit		
Topic:	Understanding the Weather	Life Cycle of Butterfly
Teachers' Dominant Goals	(a) Content knowledge (b) Practices of inquiry (c) Collaboration	(a) Practices of inquiry (b) Collaboration (c) Self-Evaluation (d) Content-knowledge
Activity		
Stage in C.U.:	Early: before starting inquiry	Late: after observing caterpillars
Teachers' Goal:	Plan organization of C.U.	Continue self-selected inquiries
Object:	Not yet decided	Chrysalis
Mediating tools:	Spoken discourse, lists of individually generated questions	Magnifying glass, etc.; reference books; spoken discourse
Task		
Preceding Task:	None	T's directions to generate questions
Teacher's Goals:	Generate suggestions for planning curriculum unit	Students generate questions for study of chrysalis
Participant's Goal:	Generate suggestions for planning curriculum unit	Generate questions' for groups' further inquiry
Mediating Tools:	Spoken discourse	Spoken discourse
Community:	Teacher with whole class	3 students with visiting teacher
Division of Labor:	T. controls topic and turns	Shared control of topic and turns

Figure **2-18**: Discourse Episodes in Activity Systems in Two Classrooms

Through the analysis in figure 2-18, Wells tried to understand the differences between two different examples that shared the same goals of teaching content knowledge, practicing inquiry and collaboration. As can also be seen from the figure 2-

18, students in two different classrooms started the activities from different stages. For understanding the weather project, students entered the curriculum unit with no experience on the content knowledge while for Life Cycle of Butterfly, students started after observing caterpillars. In the first example, the object of the activity was unknown at the beginning since the planning of the unit continued during the activity. In the second example, the object was set as Chrysalis. In terms of mediating artifacts, the first example only used discourse whereas in the second classroom teacher facilitated from instructional materials along with discourse. When the author looked at the specific task (Figure 2-18), the goal of the first classroom was planning the curriculum unit while the goal of second classroom was generating questions about the content. Another important difference was seen in the size of community of the classroom and the shared authorities between the teacher and the students (Wells, 1996).

Chavez (2007) used the activity theory in order to understand how participants (teachers), motives, and goals influenced the tasks and how "specific classroom speech community" and rules changed in three classrooms with teachers having different motives and goals. She studied the "orientation of language use practices" when second year college students learning German through peer work in class. From the selected excerpt of her data, she specifically looked at (a)The use of slang and profanity (b)Student disengagement with the task (c) The use of the first language in relation to teachers' motives or roles. Although Chavez used the three-variable approach like Wells (1996), Chavez used a more holistic approach for determining the activity/motives and actions/goals of teachers by looking at the excerpts of paragraphs rather than line-by-line analysis used by Wells (1996).

Mercer (2004) studied activity theory based on the assumption that dialogues helps the formation of further activity systems. By using a conversation analysis approach which looks at the meanings of linguistic structures and each turn, Mercer tried to address the following:

(i) the nature and functions of teacher-student dialogue as a means for guiding children's joint activity and learning;
(ii) the quality of children's talk during group-based activities as a medium for joint problem-solving and learning;
(iii) the relationship between teacher-student and student-student dialogues, focusing on such issues as if/how teacher-student dialogue can be seen to inform students' subsequent group activity and whether their group talk shows that they have been inducted into specific forms of discourse;
(iv) the relationship between the quality of students' engagement in classroom dialogue and learning outcomes;
(v) designing ways for teachers to improve the quality of classroom dialogue as an educational process.

Mercer’s use of activity theory was actually the first generation, which has been mentioned in Leont’ev’s book. Therefore, the study basically made a detailed analysis of the language-in-use (discourse).

Recently, science education researchers have started to base their research to CHAT. For example, Roth et al. (2002a) analyzed a collective teaching and learning paradigm which they call “coteaching /cogenerative - dialoguing” during the lesson on the Dihybrid Cross. These authors defined two activity systems. The participants of the first activity system are the authors of the article: university student, new teacher, supervisor, researcher, and methods professor. In the second systems, the participants are the high school students in the class. Their analyses showed how each participant interact, i.e. their contradictions and accomplishments of their responsibilities (activity system 1), what students learn from these interactions (activity system 2), and the effects of individual histories of each participant on their interaction and student learning. The study shows the potential of this research approach to contribute to research in science education grounded in a social epistemology.

CHAT framework also provides an analysis of contradiction and tensions in activity systems to understand the gaps between objects and outcomes of the activity systems (Engeström and Escalante, 1996). In another study, Roth and Tobin (2002b) focused on determining the tensions during a teacher education program at an urban school. By looking at the activity systems of the preservice teachers' student teaching experiences at an urban school, they noticed problems like inappropriate pedagogy, middle class language (tools), lack of respect and participation (rules), unruly students, low expectations at school (community), and hierarchical relation to cooperate with supervisors and method professor (division of labor).

More recently, Forbes, Madeira, Davis & Slotta (2009) used third generation of CHAT framework in two studies of science teacher education. First, they attempted to explain preservice elementary teachers' curriculum design and capacity to implement inquiry into classrooms. Second, they tried to understand secondary education science teachers' PCK (pedagogical content knowledge) development through involvement of activities such planning, reflection, and etc. In the first study, they used the to identify the process of curriculum design for inquiry. For this reason, they tried to determine the nodes of the CHAT triangle for curriculum planning and curriculum enactment (e.g., tools-proposed models of inquiry, community-co-curriculum developers and detached supporters). In the second study, they used CHAT to explain the PCK development where they adopted the PCK framework into CHAT framework by identifying the nodes of the triangle (e.g., community- social group, mentor and teacher, digital community, classroom, school, object-development of PCK). In the study, they have also mentioned the challenges teachers faced during these activity systems. Although they mentioned in their paper that they used CHAT frameworks to analyze their data collected through interviews, reflective journals, observations, lesson plans, and instructional artifacts, they did not show how they have done the specific data analysis.

Although there is a growing interest to the use of CHAT in different fields of education, the model has obstacles for the educational researchers aiming to analyze practical teaching and learning environments. Currently, there remains work to be done sorting through the meaning and applications of important constructs in activity theory such as community, rules, and outcomes.

Chapter 3

Method of the Study

In order to create a guiding practical model of IFA and ways of analyzing teachers' practices of and reflections on IFA, this study focuses on a case of four local middle school teachers while teaching science. Therefore, the study is designed as a *qualitative case study,* which uses ethnographic data collection and analyses methods, i.e., *passive and active participant observations* of middle school science classrooms, *ethnographic interviews* with teachers, *field notes* taken by the researcher, and *discourse analysis* with an *ethnographic perspective.* Moreover, *Cultural-Historical Activity Theory (CHAT)* is also introduced as an alternative data analysis framework for understanding the role of division of labor among the elements of the community on the challenges and the outcomes of IFA practices. The following paragraphs will explain these methodologies and strategies together with the reasons for selecting them.

Design of the Study

As Bell and Cowie (2001) stated, one characteristic of Informal Formative Assessment activities is that they are constructed through the classroom talk, more specifically everyday conversation between teachers and students. Qualitative Case Study Design was commonly used in previous studies in science education about assessment activities embedded into the classroom talk including assessment conversations (Duschl

& Gitomer, 1997, Duschl, 2003), teacher questioning and feedback (Chin, 2006), and Informal Formative Assessments (Ruiz-Primo & Furtak, 2007). Their studies usually selected limited number of cases from their long-term projects involving larger populations. Due to the need for detailed, extensive analysis of classroom discourse, my study designed as a qualitative case study. This study examines the case of four local middle school teachers who teach science as part of their curriculum and reflected on their use of IFA through video cases from their own teaching. Case study, according to Yin (1994, p.13),

- is an empirical inquiry investigates a contemporary phenomenon within its real-life context, especially when
- the boundaries between phenomenon and context are not clearly evident.

My research on IFA is consistent with these descriptions of case study. First, I looked at IFA practices in today's science classrooms with an aim to observe the authentic (real-life) implementations of IFA. Second, unlike controlled laboratory experiments, I did not attempt to exclude the variables that may exist in the context of the study and that might have influence on change in science teachers' practices and perspectives after their reflections on video cases. For example, involvement in this project may influence teachers' affective characteristics. However, these variables were not a concern in this study. For this reason, I defined the context of my study in detail in a subsequent section.

Another reason for selecting case study design is related to the theoretical frameworks selected for the study. Drawing from the socio-cultural approach of Vygotsky and his colleagues, a classroom has its own culture that produces its own discourse through interaction between participants, i.e. teachers and students. Histories of the participants, the established community of the school, and the mediating artifacts in the social environment can also affect the formed culture of the classroom. For this reason, instead of generalizing the findings to a universe of all other middle school science classrooms, this study is concerned about contextual understanding of IFA activities and science teachers' reflective practices. Yin (1994, p.13) also stated that case inquiry

- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion, and as another result,
- benefits from the prior development theoretical propositions to guide data collection and analysis.

This study relies on different data sources, i.e., field notes and audio and video recordings of classroom practices and reflections. Moreover, pervious research on IFA and theoretical frameworks for data analysis guided the study.

Unlike ethnographic studies, the IFA model created and the data analyses methods used during this case study were aimed to guide related studies in science education and science teacher education. However, this case study adapted an ethnographic perspective. Originating from the cultural anthropology, ethnography attempts to make a "detailed description and interpretation of a cultural or group system" (Creswell, 1998, p. 58). An ethnographic perspective requires long-term observations and researchers involvement in the research and shared the culture with participants to better make sense of the "behavior, language and interactions" within the culture. Therefore, the description, interpretation and analysis of the group sharing the same culture are important phases of ethnographic research. The researcher tries to come up with an *emic* (including actor's views) or an *etic* (including researcher's interpretation) perspective "holistic cultural portrait" which is an overview of different aspects of the culture (Creswell, 1998). Harry F. Wolcott, in his book *Ethnography: a Way of Seeing* (1999, p. 61) described the research with ethnographic perspective as a study that

> can be conducted by one individual, does not require one to be trained or licensed, its problem… can either be taken to the field or uncovered there, relies essentially on a human observer to observe humans, provides rich database for further research and writing, emphasized working with people rather than treating them as objects, [its] end product results in a contribution to knowledge, and [requires] a long-term commitment is assumed and there is no specified minimum.

Educational Setting

The data of this study were collected at a local charter school, a public school serving to grades from 5 to 8 and located at Northeast of the US. One characteristic of the school is a project-based curriculum. The curriculum is divided into real-life projects like civil war, medical school, the institute of neurology, finance, and so forth. Students are involved in independent work, one to one meetings with their teachers, guided practice in small groups, and small or whole group discussions and lecturing. During the projects, teachers assess students' work via different formative and summative assessment methods such as small pop quizzes, project posters presentations, and journals. Another characteristic of the school is that it is technology-intensive. Each student is provided a laptop to use while preparing projects. Students prepare project web sites, create videos related for their homework, and share their documents on web-based environments with their classroom friends and their teachers. Teachers are also provided laptops. By connecting their computers to the smart board, teachers benefit from some websites while lecturing and assessing student knowledge with quizzes on these websites. This school defines itself as small and nurturing. The school has only four classrooms, two of which are 5/6 grades and the other two are 7/8 grades. Each classroom has two teachers, one lead teacher and one assistant teacher. Occasionally, special education teachers visit the classrooms to work with special education students.

This study was carried out in two classrooms of this local charter school. One is a 5/6 grade with main teacher Charlotte and assistant teacher Daniel. Charlotte has a BA degree in Psychology and a dual Master of Education degree in Elementary Education and Moderate Special Needs. Charlotte took a few courses in biology, earth science, and chemistry while working on her Bachelor's degree. She did not take any science related course during her graduate work. She has 18 years of experience of teaching at high school and middle school in different subjects including science.

Daniel has a BS in Meteorology with an emphasis in Earth Systems. He then was certified as a middle school mathematics teacher. Daniel has 8 years of experience of teaching at middle schools in different subjects including science.

The other classroom is a 7/8-grade class with a main teacher Sawyer and assistant teacher Kate. Sawyer holds Bachelor's degrees in English and Adolescent Psychology, a Master's degree in Curriculum and Instruction, and a PhD in Instructional Systems. Sawyer took a few applied science courses while working on her Bachelor's degree. He did not take any science related course during his graduate work. Sawyer has 20 years of teaching experience at University's Upward Bound Math and Science Center, high schools, and middle schools in different subjects including science.

Kate has a B.S. in Environmental Interpretation and Outdoor Recreation Education with a minor in English. She also has a M.Ed. and her teaching certification in English. As required by her B.S. degree, she took applied science courses. She did not take any science related course during her graduate study. Kate has 6 years of experience of teaching at middle school in different subjects including science.

Table **3-1**: The Design of the Research

		Science Teachers	
		Charlotte & Daniel	Sawyer & Kate
Scientific Projects	Scientific Project #1	Human Body	Institute of Neuroscience Designing Scientific Research
	Scientific Project #2	Oceanography	Physics Laws in Action

Procedures

The procedures of the study involved five main steps (see table 3-2): one was the observation of the first scientific project that included researchers' videotaping the whole class time and taking field notes about IFA practices (to answer research question# 1). During this time, researcher took an *etic* perspective and did not talk about the specific aims of the study with the teachers. The second phase involved videotaping science teachers' guided reflections on their video cases during the first researcher-teacher meetings (to answer part of research question# 2). The video cases were selected before the first meeting by the researcher. To select these video cases, the researcher determined IFA sequences among all video records of everyday classroom during three-month long science project. These were the sequences starting with a teacher initiation (mostly a question) and have the aim to assess students' understanding, thinking, reasoning of scientific ideas, explanations, phenomena, theories, and so forth. The initial guiding model of IFA helped for this selection. I, as the researcher, considered three other criteria while selecting the IFA cases: reaching the aim of the cycle, different phases of the projects (e.g. engage, elaborate, sum-up), and approved participants in the IRB process.

The third part of the study was the science teachers' development of their IFA models during the second researcher-teacher meetings (RTMs). Forth was the observation of second scientific project where I again audiotaped and videotaped the whole class and took field notes. As different from the first part of the study, I was more interactive occasionally guiding the teachers during their practice. Final phase was videotaping of science teachers' reflections during the third researchers-teacher meetings (RTMs) arranged after the second set of observations on second scientific project.

Researcher-teacher meetings (RTMs) were designed so that teachers could have a closer look into their practice through selected video cases, reflect on their practice under researcher's guiding questions, and develop an effective model of IFA practice, and express their challenges or problems for using an effective IFA cycle. Researchers and teachers held three meetings of about one-hour long. Two of these meetings were right after the first set of observations on teachers' IFA practices and the final one was at the end of all classroom observations. The researcher met the group of 5&6th grade teachers

(Charlotte & Daniel) and the group 7&8th grade teachers (Sawyer & Kate) separately due to different timelines and subject matter in their science projects.

The first meeting " Reflection on Video-Case Samples" included the researchers' brief introduction to the concept of IFA, teachers' perspectives on the concept of IFA, watching different video cases of IFA practice, and teachers' reflections on their own practices of IFA through guiding questions (Appendix B). After this meeting, teachers were given a paper that summarizes the theoretical IFA models prepared by the researcher (Appendix C) and an article by Ruiz-Primo and Furtak in a journal of which the audience is middle school science teachers (*Science Scope*). These materials were used for the discussion during the second meeting.

The second meeting "Developing a Practical Model of IFA with Teachers" included discussion on theoretical models of IFA and use of the teachers' draft IFA diagrams to improve an IFA model. The third meeting "Revisiting Teacher's Perspectives on IFA and Challenges of Using IFA" included teachers' perspectives on the concept of IFA after their reflections on video case, researchers' revisiting IFA models, and a discussion on teachers' challenges of using IFA.

Table **3-2**: The Sequential Phases of the Study

Phase 1	Observation 1 on Scientific Project 1 Teachers' own way of using informal formative assessments (IFA)	Research Ques. # 1 In what ways do middle school science teachers use IFA prior to having opportunities to engage in video case reflections regarding their assessment practices?
Phase 2	Researcher-teacher meeting (RTM) #1 after Scientific Project 1 Teacher reflections on IFA in general Watching video cases Teachers' reflection on their own video cases selected by the researcher on their use of IFA	Research Ques. # 2 What are the middle school science teachers' reflections on their use of IFA?
Phase 3	Researcher-teacher meeting (RTM) #2 Teachers' reflections on IFA literature (Ruiz Primo paper and summary) Teachers' development of IFA models	Research Question 3 What models of IFA do teachers develop?
Phase 4	Observation 2 on Scientific Project 2 Teachers' way of using IFA after meeting with the researcher and developing their own model through reflection	Research Ques. # 4 In what ways do video case reflections on assessment activities change middle school science teachers' IFA perspectives and practices as stated by teachers?
Phase 5	Researcher-teacher meeting (RTM) #3 after Scientific Project 2 Teachers' reflection on their video about the way that they are using IFA after meeting with the researcher and developing their own model through reflection	Research Ques. # 5 What are the challenges middle school science teachers faced during the implementation of IFA?

Data Collection Methods

The data of the study were from three main sources. First, the middle school teachers were given a teachers' history and current practices questionnaires (Appendix A) used to define the context of the study. Second, the data to understand the practices of and reflections on IFA came from the observations on the classroom interaction during science related projects. The third data set came from teachers' reflections on their video cases through interviews during researcher-teacher meetings.

Data Collection to Understand the Practice of IFA

Yin (1994) suggested *observation* as one of the methods for collecting data during case studies. Collecting data through observation provides a detailed picture of the case and serves as a source of evidence. According to Yin (1994), observations can be *direct* or *participant*. Using direct observation, the researcher/observer makes meaning of the field during his/her visit times about events, behaviors, physical environment, and so forth. On the other hand, during participant observation, researcher/observer is involved in the context in different roles, such as working in the organization worked on, being a part of the culture studied, or being in interaction with main participants of research through meetings, interviews, and other interactions. Through Participant-observation, researcher can make sense of the events as "insider" (emic perspective). However, this advantage can also be seen as losing the objectivity of the observer. Another problem is that the observer may manipulate some behaviors or events by interacting with main participants (Yin, 1994). Spradley (1980) uses the term "nonpartcipant observation" instead of "direct observation" as mentioned in Yin's book (1994). Spradley divided the participant observation into levels - passive, moderate, active and complete participations - according to how much the researcher influences the context of the study.

Since I intended to conduct a detailed analysis of informal formative assessments constructed through everyday discourse of the science classroom, I used observation as a data collection method for my study. The method of observation was participant. During the first scientific project, I was passive and hardly interacting with teachers or students. On the other hand, starting with phase 2 (Table 3-2), I used active participant-observation method as I was meeting with teachers, interviewing them, and guiding their reflections.

According to Stake (1995), record keeping is a crucial part of observation during a qualitative case study. For him, a good record keeping, "provide[s] a relatively *incontestable description* for further analysis and ultimate reporting" (p. 62). For this research, I used two ways to record IFA practices of teachers. One way was taking field notes that helped to have the general picture of these practices and capture the important sections related to the aims of my study. The other way was video recording of every minute during the observation, which provided a data source for details of the practice.

The video records capture every detail of our observations, however, they are useful when we know what to look for on these video records. The field of ethnography provides some suggestions. One aspect of the scenes that ethnographers pay attention to is the social structures, "the social practices and routines that produce and reproduce the group or organizations' culture" (Gobo, 2008, p. 163). The context of this study was the middle school classrooms during science lessons and therefore, I looked at the practices and routines related to educational and scientific practices in the classroom.

Understanding of the conventional assessment practices or collecting scientific evidence in this studies context can inform us about how IFA are appropriate or challenging to the classroom culture. In ethnography, researchers also listen to the talk to make meaning from the signs and discursive practices. Observations of behaviors or actions in the practices may not help without understanding their meaning. Therefore, I used discourse analysis to comprehensively look at the meanings of the talk and actions. Ethnographers also look at artifacts that can be technological, cognitive, and organizational. Since these artifacts can be supportive or unsupportive of certain assessment activities in the classroom, I looked at the mediating artifacts in the assessment activity by using the cultural-historical activity theoretical framework as a data analysis tool.

Data Collection to Understand the Teacher Perspectives and Challenges

Interviews have been suggested as another important data source for case studies (Stake, 1995, Yin, 1994). Interviews can be in different formats according to how structured the questions are, i.e., structured, focused, and open-ended interviews (Yin, 1994). For case studies, interviews are suggested to be open-ended during which the questions can be about the views, opinions, ideas of interviewees' on the events. Another set of data for this study was collected during researcher-teacher meeting where teachers reflect on their video cases about selected IFA practices. These meetings involved open-ended interviews with open-ended stimulating questions to guide middle school teachers' reflections.

The epistemic stance of the interviews used in this study is inspired the view that knowledge is constructed in the social communities. Accordingly,

> The research interview based on the conversations of daily life and is a professional conversations; it is an inter-view, where the knowledge is constructed in the inter-action between the interviewer and the interviewee. An interview is literally an *inter view,* and inter-change of views between two persons conversing about a theme of mutual interest (Kvale and Brinkmann, 2009, p. 2).

The interviews of this study depended on the sharing of ideas between teachers and the researcher on IFA, and through work to construct a new model of IFA through this interaction of the two parties (not two persons as in the definition of Kvale and Brinkmann, 2009). The role of the interviewer was like a "traveler" as defined by Kvale & Brinkmann (2009). According to their definition, interviewer-traveler "walks along with the local inhabitants, asking questions and encouraging them to tell their own stories of their lived world…" (p. 48). Along the journey, the interviewer-traveler tries to unfold the meanings of the interviewee's responses by interpreting them. "The journey may not only lead to new knowledge; the traveler might change as well" (p. 49). In this study, although the researcher (interviewer) determined the focus of the interview, the researcher had an aim to learn and change ideas after listening to teachers' ideas drawn from their experiences.

The interview approach chosen for this study also had the characteristics of "ethnographic interviews" used in ethnographic research as an ancillary method to clarify the interpretations from the observed data. In ethnographic interviews, "the interviewer and the interviewee already know each other and previously talked together. This gives rise to a different emotional climate between the two parties" (Kvale and Brinkmann, 2009, p. 191). During the first set of observations of this study, I needed to get close with the teachers to be accepted to their classroom culture. We had discussions on learning theories, assessment practices, and scientific explanations. This may have led to a different climate during interviews. During ethnographic interviews, just like in this study, the interviewer asks the reasons for particular actions, scenes and so forth, because the interview is used together with observations and not the only data source to answer all research questions of the study (Gobo, 2008).

During ethnographic interviews, the questions should try to avoid conditioning the interviewee's responses as much as possible (for the interview questions of this study, see appendix 2). Verbal (e.g., "really," "interesting"), para-verbal (e.g., "mm," "ha") or non-verbal (e.g., shaking head) probes can be used "to encourage interviewees to talk, break down their defenses, help them make themselves clear, check that the ethnographer has correctly understood the replies, and get the interviewee to elaborate on stereotypical answers" (Gobo, 2008, p. 196).

Recording interviews via technological devices by asking the permission of interviewees are also very helpful for further reference to the data. These records, of course, should not be thought as replacements of careful listening the conversation during the meeting (Yin, 1994). Researcher should pay attention to the interviewee's responses because the following question may depend on the response of the interviewees and researcher may catch important points while listening. Another concern can be about distractions caused by technology problems. The researcher needs to be careful while setting up the technological equipment (Yin, 1994). For my study, I used a video-camera for recording interviews after taking the permission of the teachers as my University's Research Protection Office required. During the interview, I also took notes to guide my further questions and help me see the important sections of the conversation during the interview.

Data Analysis Approaches and Frameworks

As mentioned before, this study used two different ways of analysis: discourse analysis with an ethnographic perspective and an analysis by using the framework of cultural-historical activity theory (CHAT).

Discourse Analysis

Discourse Analysis (DA) has a long history that cuts across many countries and disciplines (Luke, 2002, Maingueneau & Angermüller, 2007, Traynor, 2006). Moreover, discourse analysis of all types comes from fields outside education, and much of it is tied to linguistics in one way or another (Rogers, Malancharuvil-Berkes, Mosley, Hui, & Joseph, 2005). This study used ethnographic approach (e.g., Gee and Green, 1998; Kelly and Chen, 1999) to analyze the classroom discourse to be able to construct a model of IFA by analyzing the interaction between students and teachers.

The data were handled by using analytical tools from sociolinguistics: transcripts and event maps (Brown & Spang, 2007; Kelly & Chen, 1999) of teaching practice and reflective sessions. As Gee and Green (1998) stated " two key tasks facing ethnographers are central to understanding an ethnographic perspective on discourse analysis: exploration of part-whole, whole-part relationships and the use of contrastive relevance." (p. 126). Since ethnographic perspective requires looking both to the details of the whole and seeing the whole from the parts, this study used event maps to see the whole-part and part-whole relationships while identifying the assessment culture of the classroom. For this reason, event maps (Brown & Spang, 2007; Kelly & Chen, 1999) of the whole data collection period and the scientific projects from which the IFA cases selected were created to see where, when and how IFA moves have been used more effectively in the whole picture.

The analyses provide examination of the discursive moves of the teachers using informal formative assessment strategies. The transcripts of teaching practice were constructed by turns of each speaker (teacher-student). Then, the next level of the unit of analysis was each IFA cycle during interactions. IFA cycle (figure 2-7) that has been developed for the study guided the determination of these units. This schema was improved during the observations of practice and as science teachers developed their own models of IFA through reflection on their practice. The coding of each IFA cycle involved looking at discursive features as well as the content and meanings embedded in the discourse. First, I looked at the subject who initiated the cycle (teacher vs. student initiated IFA). Then, the content and the meaning of students' responses were checked against the teacher's initiation to understand the relatedness of the response to the task. If the content of the students' responses matched with the teachers' initiation question, then the response was coded as "on task". After students' responses, I checked the cycles to see a sign of teachers' recognition of the students' responses. As in guiding model 2-7, these can either be in the form of approval (e.g., okey, nodding the head), or feedback (e.g., cool, great idea), or taking votes from other students (e.g., what do you think about Rory's idea?, raise your hands if you agree with Jason.). In order to decide if the cycle was connected or non-connected, teacher moves after student responses were checked to see students' words or words with a synonymous meanings with students' ideas. For example, during an IFA cycle on the introductory microscopy lab, a student Rory attempted to explain what microscopes were used for: "Well, I know what it's used for/ It's used for looking at stuff closer than what the eye can see by itself", then another student Grace uses the concept "cells" to answer the same question "Umm like if you wanna see cells or from very underneath and look at that and it's like really figures. You can actually see it." Before moving to another IFA cycle on microscopes zooming into small objects, the teacher uses Rory's idea on "what the eye can't see by itself" and the concept of "cell" from Grace's explanation to make a connection to his lesson: "Ohhh so a cell is an example of something that really small that we wouldn't necessarily be able to see with our naked eye or just our eyes. Ok."

The data involving teachers' reflections were coded by using the categories used to create the guiding interview questions for the Researcher-Teacher Meetings. Initially, the main categories were (1) reasons for using effective IFA, (2) evaluation and justification of teachers' own use of IFA, (3) changes in IFA practice (4) challenges for effective implementation of IFA. Then, I used a building task of language "connections" (see Gee, 2005) for relating the emerging themes on the discourse of reflection to the main categories. According to Gee (2005, p. 12), " we render certain things connected or relevant (or not) to other things, that is to build connections or relevance." Therefore, I looked at the whole set of reflection transcripts to see how the themes were related to the other themes and to the main categories. These themes were also checked against the reflections before and after researcher-teachers' meetings to understand the change in the teachers' perspectives and the problems they may face while implementing IFA.

The transcripts from the videorecords of the researcher-teacher meetings were coded the initial categories and by looking at the meaning of the teachers' responses, I took note on the subcategories (e.g., the aim of IFA- engaging students, evaluating students responses as right/wrong). The subcategories formed for meeting# 1 were used to understand the changes occurring under the same category when checked against the transcripts of the researcher-teacher meetings #2 and 3 and thus helped understanding the change in perspectives either within the subcategory or main category. During the coding process, another main category on the meaning of the concept of IFA emerged and was checked against meanings used in different meetings regarding the concept of IFA. Table 4-4 gives the list of final main categories after the coding of teachers' reflections.

A Cultural-Historical Activity Theoretical Perspective

Cultural-Historical Activity Theory (CHAT) as was explained in Chapter 2, has been studied by researchers in the field of applied linguistics and education. As I discussed before, even though scholars of applied linguistics provided some examples of analysis, use of CHAT framework for analysis of data from science classrooms is not yet available. Therefore, in this study, this framework was used as a complimentary to the analysis mentioned before. By using this model, the study aims to introduc a socio-cultural framework for modeling the challenges of teachers due to the way the roles distributed in their community.

This study used Cultural Historical Activity Theory (Engeström, 1987) to look at how challenges or opportunities teachers may have due to the division of labor among the participants of the classroom community. Figure 3-1 describes the IFA activity system in the context of this study. As is seen in the figure, the possible ways of dividing the labor can be between classroom teachers, among students, between teachers and students and among teachers, students and scientific authorities. In Chapter 5, I will exemplify cases where these division of labor can be a challenge or an advantage as teachers trying to reach the objects of the activity system. The objects that of this activity system were determined based on teachers' reflection of the aims of IFA in their classroom.

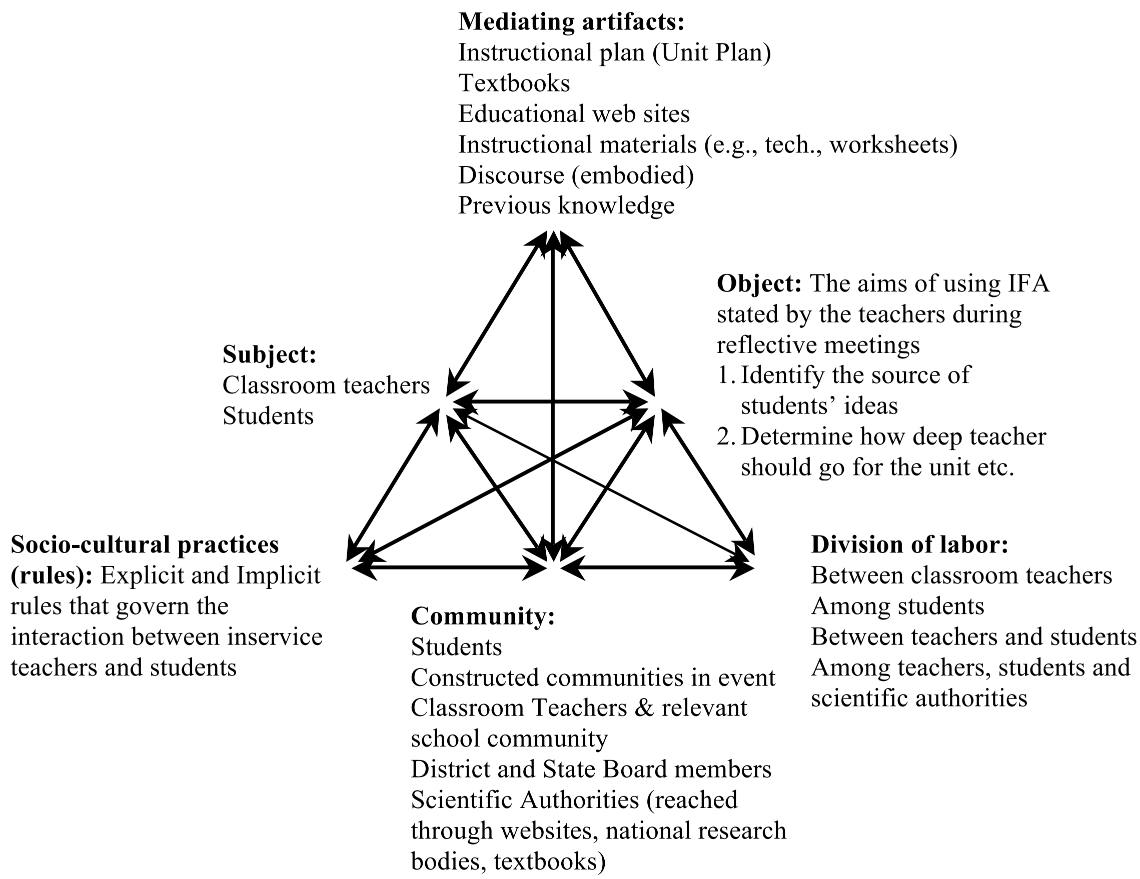

Figure **3-1**: CHAT Diagram of the Informal Formative Assessment Activity

Chapter 4

Analyses and Findings

Overview

This case study in a local middle school with four teachers having different levels of teaching and science teaching experiences attempted to understand the authentic assessment practices during teachers' conversations with the students (through video-records of science classrooms) and teachers' reflections on their practices and literature based models of assessing classroom conversations (through guided interviews during researcher-teacher meetings). The analysis of the transcripts from the video-records of the classroom observations before researcher-teacher meetings (RTMs) revealed three main different cycles of assessment: connecting cycles (where teachers connect the students' ideas to the aim of the lesson during the sequence), non-connected cycles (where teachers closes the sequence either with an evaluative feedback or agrees/disagrees and continues to lecture), repeating cycles (where teachers repeats their questions for different students and closes the sequences either with an evaluative feedback or sums up students ideas).

Prior to teachers' interactions with Informal Formative Assessments (IFA) video –cases and related academic literature, term IFA was briefly defined to the teachers. Then, teachers were asked to share their ideas on how and why IFA should be used in the science classrooms. The analyses of the transcripts from the interview data showed that teachers defined IFA as "on the fly questions" that "video-films students' progress." At this phase of the meeting, teachers emphasized that these assessments do not require any planning. Teachers explain the aims of using IFA as evaluating students' knowledge or ideas (right/wrong), activating prior knowledge, and making connections between scientific ideas, and engaging students to scientific discussions, activities, or projects. Teachers also commented on the effectiveness of IFA that depends on the attainment of the aim of the cycle, the different identities and disabilities of students, time limits in their planning, and the type of student response (on task/off task).

Researcher-teacher meetings (RTMs) provided some mediating artifacts for teachers to re-think their reflections on IFA. These mediating artifacts were the selected video-cases of their assessments practices and assigned readings of IFA literature prepared for the teachers (see Appendix C). During their discussions teachers also used their experiences from earlier years. After the interactions with these artifacts, teachers started to focus on the idea that IFA is "really an assessment tool" in that, although it's not as explicit as other formal assessment activities, they need to use IFA often to understand if they are moving towards their goals. Teachers also changed their ideas about IFA being on the fly. They recognized that IFA are connected to their curriculum planning. The meetings also resulted a discourse switch between the researcher and the teachers. Just as I was trying to adapt teachers' language, teachers started using the academic language. When they are asked about their reflections on IFA after using these artifacts, teachers focused on the aims of IFA and for them, IFA are used for engaging students, understanding individualized ideas/explanations of students, understanding the level of student understanding of particular scientific concepts (teachers decides on the depth that they can teach), improving critical thinking skills, identifying the source of students' ideas, checking how well students learn from the teacher explanations.

Three researcher-teachers meetings (RTMs) conducted with each group of teachers (one is 5-6th grade teachers and the other is 7-8th grade teachers) were also a forum for discussing and developing a practical model of assessments constructed through the classroom discourse and identifying the potential challenges for teachers' effective assessment of classroom conversation during science lessons. As shown in previous research, teachers talk about time efficiency and the lack of subject-matter knowledge as challenges. Upon watching their practices, they also mentioned the conflict in the authority of the knowledge (challenges or advantages of division of labor among the participants of the classroom community) and the limitless scientific knowledge and its availability through online resources. The following paragraphs will explain these findings in detail after sketching the assessment in the learning culture of the classrooms used as the cases of the study.

Assessment in the Learning Culture of the School

The type of assessment used in a classroom environment is dependent on the learning culture created by the members of the classroom (Shepard, 2000). My field notes during the six months of observing two classrooms helped me to ascertain how teachers arranged science learning in their classroom culture and how different kinds of assessments embedded in students' learning processes. I used "mapping"-a qualitative method to summarize the one-year overall ethnography of the two classrooms videotaped as the partial data of study during 2009/2010 academic year (Table 4-1 & Table 4.2). As Powell (2010) pointed out:

> Typically, maps are thought of, and used, as a directional tool, a graphic means of representing places that are held to particular conventions of scale, scope, symbol, and legend. But mapping as a methodological tool has taken many forms, pushing past its use as an orientation device. In the fields of geography, planning, child development and psychology, sociology, and anthropology and education, maps have been used to document and analyze socio- and psycheographic notions of place, social relationships, and/or cognitive processes (pp. 539-540).

In this study, mapping was used to analyze the conceptual sequence of scientific units and designed classroom events (activities) for the attainment of the learning goals of the scientific units. These maps are called as "event maps" in the current study as is in the previous studies of Brown & Spang (2007) and Kelly & Chen (1999).

Event Maps: An Overall Look at Assessment Practices in Science Classrooms

The event maps (figure 4-1 & 4-2) show how the content was sequenced in terms of projects and then divided into smaller units. The selection of the projects to videotape was based on the respective relevance to science content relative to researcher's background in science. All units were recorded; however, the ones involving teacher-student interactions were chosen for analysis. The figures 4-1 & 4-2 give information about the description of every unit recorded and daily activities selected for data analysis. Since the focus of this study is to look at the assessment activities constructed through conversations between teachers and students, the daily activities that allow more interactions between students and teachers were chosen for data analysis. The units involving activities based on independent work of the students were not analyzed and in the event maps, they were labeled as "No IFA case selection."

Project title	Date	Units	Unit title	Dates	Content of the Unit	Description of the daily event from which IFA cases selected	Dates
Civil War	09/08/09 - 11/25/09	No videotaping –No science content					
Medical School	12/02/09 - 03/05/10	1	3-D Cell City	12/02/09 – 12/15/09	Cell structures & organelles	Microscope Laboratory: How to use a compound microscope?	12/08/09
		2	It is all in the Genes	01/04/10 – 01/08/10	DNA & Mendelian Genetics	Role play on how traits pass through generations & Whole class discussion on recessive &dominants genes	01/04/10
		3	Gross Anatomy	01/11/10 – 01/15/10	Known body parts- common conditions & diseases	No IFA case selection	
		4	Human Body Systems	01/18/10 – 02/12/10	All body system in detail (e.g. circulatory, respiratory,..)	Whole-class circle discussion on how heart-blood, oxygen is related.	01/22/10
						Whole-class circle discussion on circulatory system	01/27/10
						Online Activity on reviewing glands in the human body	02/02/10
						Whole class circle-Review of what has been learned about skin	02/09/10
		5	Diseases & Conditions	03/15/10 – 03/05/10	Diseases in the Human Systems-symptoms, diagnosis, treatments	No IFA case selection	
Oceanography	03/15/10 – 05/28/10	1	What in the World?	03/15/10-04/09/10	Oceans on the World	Presentations on different oceans of the world	03/26/10
		2	What puts the Ocean in Motion?	03/15/10-04/09/10	Waves, tides, currents	Experiment on Water waves	03/16/10
						High vs Low Tides Lab activity	03/29/10
		3	Ocean Exploration	04/12/10-05/03/10	Previous & current scientists' research on Oceans	No IFA case selection	
		4	Ocean Ecosystems	05/03/10-05/28/10	Coral Reefs, Ocean Food Chains	A video on the Great Barrier Reef & students reflect on the video .	05/04/10
						Explanation of Kelp Forests Whole-class circle discussion Kelp Forest	05/12/10

Figure **4-1**: Timeline of the Overall Ethnography for Charlotte & Daniel's Classroom (2009/2010)

Project title	Date	Units	Unit title	Dates	Content of the Unit	Description of the daily event from which IFA cases selected	Dates
Finance	09/08/09 -	No videotaping –No science content					
Institute of Neuroscience	12/2/09 - 02/1/10	1	Introduction to the Nervous system	12/02/09 – 12/15/09	The need for nervous system & the basic parts of the nervous system	Whole-class discussion & brainstorming on the need for nervous system & parts puzzle	12/02/09
		2	Functions of the Nervous System	01/04/10 – 01/08/10	How nervous system helps the functioning of other human body	Watching movie & Whole-class discussion on the functions of the nervous system	01/04/10
		3	Brain	01/11/10 – 02/01/10	Parts of the brain and how brain works	Brain modeling & one to one brain talks	01/20/10
Designing Scientific Research	02/02/10- 04/16/10	1	The Concept of Variables	02/02/10 – 02/12/10	Defining & exemplifying independent & dependent variables	No IFA case selection	
		2	Research Questions and Hypotheses	02/16/10 – 02/26/10	Writing research questions and hypothesis	Falling object exp. & whole- class discussion on formulating questions	02/27/10
						Whole-class brainstorming on writing hypothesis & independent research	02/17/10
						One–to-one questioning on writing hypothesis & independent research	02/25/10
		3	Scientific Method	03/15/10- 04/09/10	Making decisions on the methods used in scientific research	No IFA case selection	
		4	Reporting Results from Scientific Research	03/03/10- 04/16/10	Conducting the designed experiments and reporting the findings	No IFA case selection	
Physics Laws in Action	4/16/10 – 5/28/10	1	Gears, Gearing, and More Test	04/17/10- 05/05/10	Constructing cars and testing gears to physical processes	No IFA case selection	
		2	Trebuchets	05/05/10- 05/28/10	Understanding how trebuchet works and	Teacher's modeling of trebuchet and discussion on physical laws to show how it works	05/05/10
						Students' construction of trebuchets in small groups	05/12/10

Figure **4-2**: Timeline of the Overall Ethnography for Sawyer & Kate's Classroom (2009/2010)

In the two classrooms used in this study, scientific content was arranged as projects that are connected to the real life practices. As shown in Figure 4.1, Charlotte and Daniels' 5-6th grade classroom completed three main project during 2009/2010 academic year: Civil War, Medical School, Oceanography. The researcher recorded Medical School project for understanding the authentic assessment practices of teachers and after two Researcher-teacher meetings, Oceanography project was recorded to collect evidence on teachers' reflections of the changes they experience on their IFA practices after the meetings.

Figure 4-2 shows the overall ethnography of Sawyer and Kate's classroom, i.e., how they sequenced the contents during 2009/2010 academic year. As shown in the figure, they had four main projects: Finance, Institute of Neuroscience, Designing Scientific Research, and Physics Laws in Action. To understand the authentic assessment practices of the classroom, I videotaped Institute of Neuroscience and Designing Scientific Research. After two researcher-teacher meetings, the project "Physics Laws in Action" was videotaped as an evidence to support teachers' reflections on the changes they experience in their IFA practices.

The assessment artifacts collected from these two classrooms showed that teachers used spoken and written artifacts to evaluate the progress during each project. For example, at the end of the medical school project, Charlotte and Daniel required students to prepare a medical fair. For the medical fair, each student was required to prepare "large format poster, public service announcement, comic book or coloring book (geared for our community's younger siblings), hands-on demonstration/experiment, list of local resources, a virtual patient." The fair made available to parents and visitor from the town. Students presented the diseases they prepared to the visitors. As a written artifact, each student also prepared a report about the disease that they are working on. In two of the classrooms, teachers used varied formative assessment strategies to understand student progress at the end of each unit. One type of assessment was short-answer essay exams. The question below exemplifies the type of assessment:

> Give the following information for each system:
> 1. Circulatory System
>   definition of system -
>   name of one part -
>   function of that one part –

Another type of assessment at the end of the units is asking students to prepare models (e.g., brain models, cell city models, wave models). During the units, teachers used different types of formative assessments. They assessed students' inferences from their observations during experiments. Below is an example of an observation table used by teacher to assess student inferences during the beginning of the Oceanography project in 5-6th grade classroom.

Record the amount of salt needed to float each item.

Item	Amount of Salt (teaspoons)
egg	
apple	
marble	
rock	

Other than summative and formative assessments, teachers in this study were using IFA during most of their teaching activities, except the independent work times where students study on their own.

Teachers' Use of "Informal Formative Assessments (IFA)" in Science Classrooms

As evidenced in the cases from previous studies (e.g. Carlsen, 1991; Chin, 2006; Duschl, 1998; Furtak and Ruiz Primo, 2007, 2008), teachers create discussion environments to assess student-learning processes. As the inquiry mode of learning has been well accepted for science classrooms, research started to focus on how teachers should guide inquiry activities. As Duschl (2003) stated "engaging students in kit-based science and lab investigations in and of itself is not inquiry." For an effective inquiry environment, teachers have an important role to guide student engagement in argumentation and scientific discourse during the scientific investigations. To be able to guide students, teachers should frequently assess students' ideas, thinking processes, improvement in learning during scientific investigations, confusions, and so forth, so that teachers can make prompt changes in the activities when necessary. In the two classrooms observed for this study, I observed these kind of assessments constructed during daily conversations, which I refer to as Informal Formative Assessments (IFA). At the beginning of my study, I wanted to identify the ways IFA were used by the four experienced inservice teachers aimed to create inquiry environments through their projects. For the set of data from these lessons, studiocode (a software to analyze video) was used to identify IFA cases for each lesson (Figure 4-3).

A timeline window (see the bottom on figure 4-3) was created for every science lesson decided to be used for data analysis and then, by using a code window (right hand side of the figure 4-3), researcher coded each IFA case as the lesson plays on the screen. Then, IFA cases were selected for researcher-teacher meetings and detailed analysis.

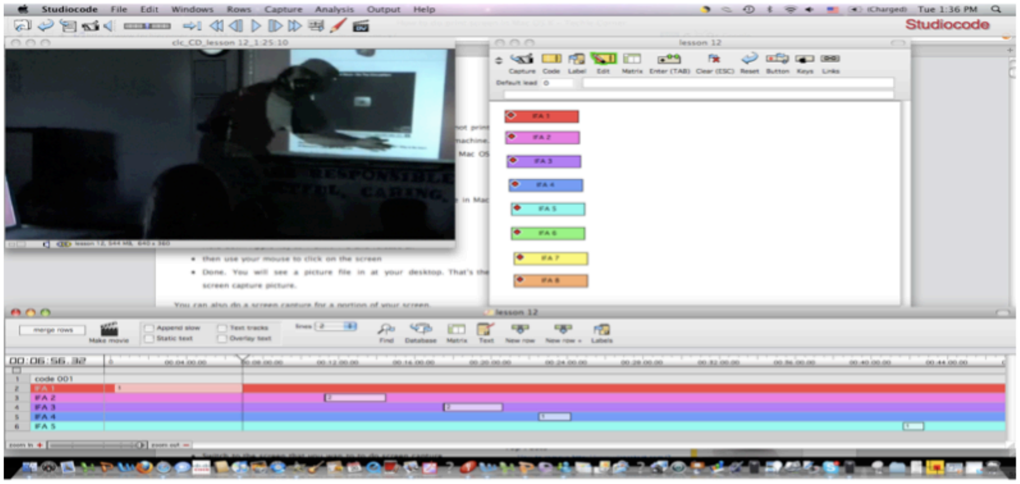

Figure **4-3**: Timeline of the IFA case#1 Selection from Charlotte & Daniel's Classroom (2009/2010)

The figure (4-4) shows the process of IFA case selection from the main project, its unit, sub-units, and teacher planned daily activity.

Project Titles	Civil War	**Medical School**	Oceanography
Dates	09/08/09 - 11/25/09	**2/02/09 - 03/05/10**	03/15/10 – 05/28/10

Units	**1**	2	3	4	5
Unit title	**3-D Cell City**	It is all in the Genes	Gross Anatomy	Human Body Systems	Diseases & Conditions
Dates	**12/02/09 – 12/15/09**	01/04/10 – 01/08/10	01/11/10 – 01/15/10	01/18/10 – 02/12/10	03/15/10 – 03/05/10
Goals of the Unit	**Cell structures & organelles**	DNA & Mendelian Genetics	Known body parts, conditions & diseases	All body system in detail	Diseases in the Human Systems-

Sub-Units	Tim and Moby movie intro to cells	**Part One: Learn About Cell Structures**	Part Two: Build a Cell

Description of the daily events	Explanations of cell structures and organelles	Discussion of how cells are related to tissues and organs	Self-evaluation on learning about the organelles	**Microscope Laboratory: How to use a compound microscope?**	Microscope Laboratory 2: What cells look like under a compound microscope.
Dates	12/03/09	12/04/09	12/07/09	**12/08/09**	12/09/09
				IFA Case 1: What are the microscopes?	

Figure **4-4**: Timeline of the IFA case#1 Selection from Charlotte & Daniel's Classroom (2009/2010)

The selection of IFA cases was based on three criteria. First, the guiding model (figure 2-7) was used to check if the IFA cases were complete, i.e., teachers, after initiating a cycle, take students' responses and show that they recognize students' answers and then teachers integrate student response to their next step in the instruction. The second criterion was the phases of the lessons (e.g., engage/introductory activity, evaluate/review session, and etc.). Finally, the researcher eliminated the cases including students who were not approved by their parents to be video recorded. Table (4-1) shows the selected IFA cases for the researcher teacher meeting (RTM) with Charlotte and Daniel (5-6th grade).

Table **4-1**: IFA cases for the Researcher-Teacher Meetings for Charlotte & Daniel

Case label	**Type of IFA**	**Description of the daily activity**	**Phase in the Project**	**Total # of IFA per activity**
A	Connected	Microscope Laboratory: How to use a compound microscope?	Engage/Guided Practice	27
B	Connected	Whole class circle discussion on recessive & dominant genes	Explain in large group discussion	9
C	Connected	Whole-class circle discussion on how heart-blood, oxygen is related.	Elaborate in large group discussion	12
D	Non-connected	Whole-class circle discussion on circulatory system	Explain in large group discussion	17
E	Non-connected	Online Activity on reviewing glands in the human body	Review	8
F	Repeating	Review of what has been learned about skin	Review	19

As shown in the table 4-1, 6 cases were selected from Charlotte and Daniel's classroom (A-F). The type of the cycle was identified as "connected," if the teachers use student responses to continue the following cycle or activity. These cycles identified as "non-connected" when teachers did not use students' responses during their subsequent step. Another type of cycle identified as repeating cycles where teachers used the same question again and again to initiate consecutive cycles. Table 4-1 also shows description and the phases of daily activities from which the cases selected as well as the total number of IFA cases per activity. In a similar way, Table 4-2 shows IFA cases (A-F) selected for research-teacher meetings (RTMs) with Kate and Sawyer (7&8th) together with the types of these cases, description and phase of the activity and the number of IFA cases per activity.

Table **4-2**: IFA cases for the Researcher-Teacher Meetings Kate & Sawyer

Case label	Type of IFA	Description of the daily activity	Phase in the lesson	Total # of IFA per activity
A	Connected	Whole-class discussion & brainstorming on the need for nervous system & parts puzzle	Engage/brainstorming of initial ideas	22
B	Connected	Whole-class discussion on the functions of the nervous system	Engage	32
C	Non-connected	Brain modeling & one to one brain talks	Guided Practice	7
D	Non - connected	Falling object experiment & whole- class discussion on formulating questions	Guided Practice	16
E	Repeating	Whole-class questioning on formulating hypothesis & independent research	Review	14
F	Non-connected	One–to-one questioning on writing hypothesis & independent research	Guided practice	8

Coding the Transcripts of IFA Practice: Identifying the Ways of Using IFA

After the selection, the cases were transcribed to analyze the discourse of the interactions during IFA. By using the guiding model of IFA (figure 2-7) for the study, the researcher identified different patterns on teachers' use of IFA in their classrooms. Below is an example of the transcripts and the coding to analyze the IFA practice:

	Time	Speaker	Line #	Transcription	Code
IFA Cycle 1	00:33:81	Daniel	1 2 3 4 5 6 7	These are the microscopes (*Pointing to the microscopes on the table*)/ I wanna know what you know about microscopes? Either what they're used for or if you know any parts on the microscope and the technical names of the parts or how do you go about using the microscope?	Teacher initiates-asking questions
			8	So, thank you for raising your hands. Rory?	
	00:53:81	Rory	9 10 11	Well, I know what it's used for/ It's used for looking at stuff closer than what the eye can see by itself	Student responds-on task
	01:05:30	Daniel	12 13 14	Coool, yup.	Teacher recognizes-gives evaluative feedback
			15 16 17	Grace?	Teacher recognizes-takes other student's response
	01:07:80	Grace	18 19 20	Umm like if you wanna see cells or from very underneath and look at that and it's like really figures. You can actually see it.	Student responds-on task
	01:12:70	Daniel	21 22 23 24	Ohhh so a cell is an example of something that really small that we wouldn't necessarily be able to see with our naked eye or just our eyes. Ok.	Teacher uses student response-to explain the use of microscope
IFA Cycle 2	01:19:30		25 26	But microscope might help us to see something like that, Grace?	Teacher initiates-checking student understanding
	01:18:26	Grace	27 28	Yeah	Student responds-on task
	01:32:80	Daniel	29	Cool	Teacher gives feedback- evaluation

The transcript above is from the video record of the beginning of an introductory microscope laboratory lesson, a part of 3D Cell City Unit and right before students are beginning to learn about basic structures (e.g. membrane, cell wall) and the organelles (e.g. nucleus) of cells (see Figure 4-1 for the timelines of the unit in the event map). Transcripts were constructed by the turn of speaker and coded by using the steps in the guiding model figure 2-7 together with explanations of the reasons of teachers' actions. As shown in lines# 21-24, Daniel uses (summarizes) student responses "to explain the use of microscope." Moreover, a transcript convention (Appendix D) was used for showing the expressions of the talk. Cycles were separated and labeled as a different cycle when the teachers initiated another cycle (see lines# 25-26 when Daniel asked a question to check student's understanding) or started lecturing independent of the students' responses.

Considering the exemplary cases of IFA selected from the data of the study, the use of IFA varied among different teacher, classrooms, and the phases of the lesson, yet they can be categorized under three types: connected, non-connected, and repeating cycles.

IFA Cycle Type# 1: Connected Cycles

Studies by Duschl (2003) and Ruiz-Primo & Furtak (2007) focused on the importance of using student responses during the flow of the lesson for creating inquiry environments and promoting student learning. In my study, I use the word "connect" instead of "use" based on the teachers' preference. The transcripts from the data of two classrooms in the local middle school showed that teachers use IFA cycles when they connect student ideas to continue their discussion. For example, the transcript below is from the lesson right after students' role play about personal traits that we carry through our genes (see event map for the daily activity "Role play on how traits pass through generations," on 01/04/10in figure 4-1). In this role play, students were exploring their unique personal traits that may come from their families and distinguish them from their friends in the classroom. In the following lesson, Charlotte (5&6th grade teacher) was elaborating on how traits pass through generations through classroom discussion. She had the aim to teach the concepts of "recessive" and "dominant" genes. In the IFA case below, without using the scientific terms, she initiates with a question (lines# 1-4) to understand how student are reasoning about passing of traits from generation after generation. Upon getting an on task response from student 1 (lines# 5-12), the teacher gave evaluative feedback to encourage more students to share their ideas by saying "Whooow. Dr. Mendel is back. That's cool!." Right after the acknowledgement, teacher doesn't close the cycle. Instead she attempts to integrate student 2's explanation to her following question while she is asking for more ideas. Charlotte does so by saying "Did you understand what he was saying? What do you think? (lines# 16, 17). The cycle continued with an explanation from student 2 and then the teacher used the word "dominant" to connect student 2's response to the follow up question and if other students could relate their ideas to the scientific terminology. Student 3 (Stu) gave an example to recessive gene that shows an understanding of the concept. Then, teacher used eye color example to go to the next sequence that will be on how scientists can predict passing of traits based on dominant and recessive genes.

Time	Speaker	Line #	Talk	Code
00:00:00	Charlotte (Teacher)	1 2 3 4	Your great great great grand father, great great great great great mother, get passed generation after generation after generation after generation. Which traits won't get passed on? Great mysteries of life! What do you think Mike?	Teacher initiates-asking questions
00:23:81	Mike	5 6 7 8 9 10 11 12	I would think how trait was stopped is uuumm someone marries someone else trait stops. Like if I have some wife and then I have a kid and he marries someone else, his kid will not have the same traits as me. Because his uumm wife's traits will have some of his traits and his traits will go. So, they'll go into the kids. So, it'll be different or it could he could have a dominant gene or she can have a dominant gene so it's just two dominant gene.	Student responds-on task
00:54:31	Charlotte (Teacher)	13 14 15	Whooow. Dr. Mendel is back. That's cool!	Teacher recognizes-gives evaluative feedback
		16 17 18	What do you guys think? Did you understand what he was saying? What do you think? What? I'm open to all hypothesis or hypotheses. Tell me what do you think?	Teacher recognizes-takes votes to acknowledge
01:08:81	Walter	19 20 21	Well like if Ryan (*pointing to his friend)* like marries some girl with blue eyes and he has brown eyes, and then they have a kid, their kid probably have brown eyes.	Student 2 responds-on task
01:17:81	Charlotte	22 23 24	So, and is it just like, I'm just guessing fifty fifty. How do you know?	Teacher recognizes-elaborates on student response
01:22:81	Jackson	25 26	Brown eyes are usually dominant gene.	Student responds-on task
01:24:81	Charlotte (Teacher)	27 28 29 30 31 32 33 34 35 36 37	What whoow okey. I'm hearing like you guys are like on the same sort of level of thinking about genes and passing on and passing on and you have this idea of dominance and stuff. Talk to me Stu, what are you thinking? (*Stu is raising his hand*)	Teacher recognizes-gives evaluative feedback Teacher connects-uses the term dominant from student 2 response Teacher recognizes-takes votes to acknowledge
01:34:81	Stu	38 39 40 41	Well I, I was kinda with that but uumm with the brown being the dominant genes but uu since green is really unlikely, they don't ever know if it's gonna be dominant oor recessive. So, I have no you really no green eyes.	Student 3 responds-somewhat on task
01:54:81	Charlotte (Teacher)	42 43 44 45 46 47 48 49 50 51	So, maybe some of the traits that we can use to differentiate individuals. For example, eye color, maybe you're saying that some of them we can predict somehow and maybe some of them are just totally random. You can't tell. So maybe that's true and if that's true, you think maybe uumm scientists are working on trying to figure out how something could be figured out. Braining on this kind of bothers us, doesn't it. We can not figure things out. Sort of the way we're wired, we're inquisitive, inquisitive that way.	Teacher connects-teacher includes student examples to her statement that will open up the next sequence

This was one example of a connected cycle where Charlotte (5&6th grade teacher) both evaluated the level of her students understanding about recessive and dominant genes and integrated their ideas into further action. This can be seen when Charlotte said "What whoow okey. I'm hearing like you guys are like on the same sort of level of thinking about genes and passing on and passing on and you have this idea of dominance and stuff" (lines# 27-30). This may have helped teacher to tailor her closing explanation (lines# 42-51). Moreover, the teacher may make the conversation familiar to students by adding the examples that they used in their explanations (e.g., eye color).

IFA Cycle Type# 2: Non-Connected Cycles

Another main type of cycle appeared in IFA examples was non-connected cycles where teachers initiates the cycle usually by asking a question, students responds and then teacher either shows the recognition of the response and then starts another cycle or continues with his or her own explanation related to the idea. Below is a transcript from Sawyer (7-8th grade teacher)'s class on the Nervous System. Sawyer's class started the Nervous System project by watching a movie about disfunctioning of the brain and the nerves as a previous activity (see the event map for the daily activities on 01/04/10 in figure 4-2). Right after, Sawyer asked his students to give him a "basic, concise definition of the function of the nervous system." At one point during the conversation, students mentioned now neurons help us to feel through our senses. Following this idea, student (Andrew) mentioned neurotransmitters (lines# 1, 2) and then explained the relation between neurotransmitters and feeling pain in the body (lines# 6-9):

Time	Speaker	Line #	Talk	Code
08:04:78	Andrew	1 2	Uumm neurotransmitters like serotonin and dopamine, they like like carry information.	Students responds-on task
08:10:77	Teacher (Sawyer)	3 4 5	Yup	Teacher recognizes-agrees with student response
08:11:76	Andrew	6 7 8 9	And uumm the more of each uumm each uummm like substance there is like the stronger the pain like stronger the signal, like there is more like like milder strong pain.	Students responds-on task
08:26:26	Teacher (Sawyer)	10 11 12	Uh-hum.	Teacher recognizes-agrees with student response
08:26:76	Andrew	13 14	The more neurotransmitters there is, the stronger the sensations.	Students responds-on task
08:30:26	Teacher (Sawyer)	15 16 17	Good. Serotonin and dopamine.	Teacher recognizes-gives evaluative feedback

As is seen in the transcript, the teacher recognizes student response, agrees with him (lines# 3, 10), and then gives him an evaluative feedback “Good.” (line# 15) as an ending line of the IFA cycle. Following this feedback, the teacher goes back the model of nervous system on the smart board to talk about the parts of the nervous system. Sawyer did not connect the student response to his definition of the function of the nervous system or he did not explain the student how his knowledge is related to their topic. Therefore, this IFA cycle was labeled as non-connected cycle.

Another example to non-connected cycles is when Daniel (5&6th grade teacher) was explaining about how immune system defends our body against harmful microorganisms. Daniel wanted to use antibiotics to familiarize the subject to the students. Before, using the example, he wanted to see if students know what “antibiotics” are.

Time	Speaker	Line #	Talk	Code
00:00:04	Daniel (Teacher)	1 2 3	...medical establishment we worry about because you have germs that when you have antibiotics,... Raise your hand if you have taken antibiotics before.	Teacher Initiates-asks a questions
00:08:48	Students	4 5	Ummm weeelll (most of the student are raising their hands)	Students response-on task
00:08:98	Daniel (Teacher)	6 7 8	Probably most of you, probably have it one time or another and antibiotics are...	Teacher recognizes student response – agrees with students
		9 10 11 12 13 14	It's some sort of uummm chemical oooorr uumm that helps your body destroy the particular germ. Penicillin is, was the first antibiotic and it was derived from orr orr done from uumm from the yeast orrr mold I'm sorry, from a mold and that's were they were they…	Teacher explains what antibiotics are and leaves the cycles

In this cycle, when students raised their hands (line# 4, 5), Daniel recognized that the students were familiar with antibiotics. Then, instead of using a follow up question (in order to use students' experience or knowledge on antibiotics) to understand what students knew about antibiotics and how antibiotics work, Daniel just used his own explanation and then left the cycle.

IFA Cycle Type# 3: Repeating Cycles

Another type of cycles appeared in my data were repeating cycles, which can be either connected or non-connected cycles. For example, in one of her lessons on human body systems (Daily activity on the event map: "Whole class circle-Review of what has been learned about skin02/09/10 in Figure 4-1), Charlotte (5 &6th grade teacher) was reviewing sensory system by using online readings and activities. Students were taking turns reading the story about sensory system on the smart board. After they finished each paragraph Charlotte asked a question to see if students were learning any new or interesting information from the online reading. In the following conversation, Charlotte asked the question “Raise your hand if you learned something new from that paragraph” (lines# 1, 2). Then Charlotte repeated the question by saying “Something new?”(line# 8) and What else? (line# 14):

Time	**Speaker**	**Line #**	**Talk**	**Code**
00:00:00	Teacher (Charlotte)	1 2 3	Raise your hand if you learned something new from that paragraph. So, Wendy? Yeah	Teacher initiates- asking question
00:08:99	Wendy	4	From confession of the sense we like it	Student responds
00:11:49	Teacher (Charlotte)	5 6 7	Umm himmm those, very cool	Teacher gives feedback- encouraging feedback
		8 9	Something new?	Teacher repeats the question
00:14:48	Betsy	10	Certain parts went through your ear	Student (2) responds
00:18:48	Teacher (Charlotte)	11 12 13	Yeah that's cool. We would not know that right? Good Betsy	Teacher gives feedback- encouraging feedback
		14 15	What else?	Teacher repeats the question

In this case, Charlotte aimed to encourage more students to attend and help the teacher to summarize all the ideas at the end of the lesson. Like Wendy and Betsy (line# 4, 10), other students mentioned their new knowledge about sensory system as Charlotte kept asking, what is new, something new? Anything else? What else?. At the end of the class, she connected all student responses to summarize what they have learned today and in previous lessons about sensory system. In another case below, Sawyer (7&8th grade classroom) was questioning students’ understanding of how to write hypothesis in scientific research (see the event map for the daily activity on “Whole-class brainstorming on writing hypothesis & independent research” on 02/17/10 in Table 4-2).

Here, Sawyer asked the same question “Come up with an hypothesis” or “Give me a hypothesis” again and again to find the correct response, correct way of formulating a hypothesis given the variables of eating chocolate cake vs. vegetable soup on running.

Time	**Speaker**	**Line #**	**Talk**	**Code**
00:00:00	Teacher (Sawyer)	1 2	Chocolate for lunch as compared a nice vegetable soup	Teacher initiates-describing a case
00:09:55	Students	3	Euuuv he was kidding.. They don't	
00:14:05	Teacher (Sawyer)	4 5 6 7 8 9 10 11 12	impact how well how fast you run? So, how does eating chocolate, chocolate, how does eating chocolate cake for lunch as compared to eating a nice eating a nice vegetable soup, notice I said nice vegetable soup impact how well you run? How fast you run? NOW.. COME UP WITH HYPOTHESIS and I expect more than one or two hands. I'm gonna give some time cause I wanna pick somebody different. I am gonna pick Marisa	Teacher initiates-describing a case
00:49:05	Marisa	13	Maybe we eat some chocolate and some chocolate	Student responds –on task
00:51:55	Teacher (Sawyer)	14	Ok.	Teacher ignores
		15 16	Give me a hypothesis	Teacher repeats the question
00:53:05	Marisa	17	Uuummm sugar	Student responds-on task
00:55:55	Teacher (Sawyer)	18 19	GIVE ME A HYPOTHESIS	Teacher repeats the question
00:55:55	Marisa	20	Okey Okey	
00:57:54	Teacher (Sawyer)	21 22 23	I wish you listened me. Here is the hypothesis. (*pointing to the hypothesis sentence on the smart* *board*)	Teacher repeats the question
01:02:04	Marisa	24 25	UUmmm if you if you eat chocolate for lunch and then go for go for fun, you might run faster.	Student responds-on task
01:15:54	Teacher (Sawyer)	26	Then, when you?	Teacher recognizes student response-asking a complimentary question
01:17:54	Marisa	27	uuuu, if you eat chocolate instead of vegetable soup	Student responds-on task
01:24:04	Teacher (Sawyer)	28 29 30	All right. So, if you eat, if you eat?	Teacher recognizes student response-asking a complimentary question
01:30:54	Students	31	chocolate cake	
01:31:54	Teacher (Sawyer)	32 33 34	If you eat chocolate cake for lunch, you will run faster than if you eat a nice vegetable soup and again it's a nice vegetable soup.	Teacher leaves the cycle-giving the correct response

As is seen in line# 14, 15, 18, Sawyer ignored the student responses since he was not satisfied with the responses Marisa was giving. Finally, the teacher left the cycle by formulating the correct hypothesis.

Teachers' Reflections on Their Use of IFA

Coding the Transcripts of Researcher-teacher Meetings:

The analyses of teacher reflections were done by using Gee (2005)'s discourse analysis method of looking at the building tasks of language. One building task of language that will be used in this study is "connections." According to Gee (2005), one way to look at the discourse of the interview data is to search for "themes, motifs, or images that co-locate (correlate) with each other; that is themes, images, or motifs that seem to "go together." Such related themes connect diverse parts of the interview together and give it a certain overall coherence and "texture" " (p. 153). The texture of the interview data from the researcher-teacher meetings (RTMs) was first constructed through the guided interview questions. These questions formed the phases of three meetings arranged with 5&6th grade and 7&8th grade teachers separately. As stated by Kelly (2004), "phase units represent activities marking the ebb and flow of concerted and coordinated action among participants, and reflecting a common content focus of the group (Green & Wallat, 1981; Kelly & Brown, 2003; Santa Barbara Classroom Discourse Group [Floriani, A., Heras, A. I., Franquiz, M. Yeager, B. Jennings, L., Green, J. & Dixon, C.], 1995)." Thus, the phases of the meetings are constructed under a common action or content focus (e.g. challenges of effective IFA implementation, reflections on video cases). The first meeting involved the phases of

1. Researcher's introduction of the focus and the aim of the study
2. Teachers' reflections on IFA prior to watching video cases from their own practices with a focus on students' knowledge and learning processes

3. Teachers' reflections on IFA prior to watching video cases from their own practices with a focus on teachers' knowledge and learning processes
4. Teachers' watching of video cases
5. Teachers' reflections on IFA after watching video cases from their own practices
6. Researchers' introduction of IFA literature to teachers and handing the files containing the paper, which is the summary of literature and Ruiz-Primo & Furtak articles on IFA written for middle school teachers and published in the Journal *Science Scope* as well as the empty sheets for teachers to write & draw their ideas about their own IFA model.
7. Researcher's explaining and clarifying the aim of the study on model development and initial ideas from teachers for their model.

The second meetings had the following phases:

1. Teachers' reflections on a paper on the previously developed models of IFA prepared by the researcher (Appendix C) and an article by Furtak & Ruiz-Primo (2005) article in Journal *Science Scope.*
2. Teachers' comments and critiques on the guiding model of IFA (figure 2-7)
3. Teachers' working on their own IFA models

The third meetings had the following phases:

1. Teachers' reflections of IFA related to the changes in their perspectives and practice after completing another scientific project
2. Researcher's revisiting practical IFA models with the teachers

3. Teachers' reflections on IFA in terms of challenges due to internal (inside the classroom) and external (outside the classroom) factors

Table **4-3**: Coding Researcher-Teacher Meetings

Phase #	Phase description	Speaker	Talk	Code
2	Teachers' pre-reflections on IFA related to students and student learning	Sawyer	Uuuuuum it's through informal questioning or questioning, I think you can hold in on student need. You can also uuuum holding on student interest where if you're talking about today we're talking about bioms. If a student has particular interest, you can begin to tailor a lesson, tailor a project, tailor a specific activity to the interest of that student and hopefully engage them more. There is much educ... much of what we do is working towards engaging the students, through the student, taking their interest.	The aim of IFA- -Engaging students through -Understanding students' needs and interests - Tailor a lesson, a project, a specific activity to the interest of the student
		- -	- -	- -
3	Teachers' pre-reflections on IFA related to teachers and teacher learning	Sawyer	Yeah that's trying to tease out that they know a lot more and also put it in terms that they understand input and output. Uuuummm and really help them to see, **begin** to see that there is a lot there but it's also fairly simple thing going on at one level as an input and output [to the brain], but you know it takes a way to do it.	Justification of leaving IFA Cycle-When the aim is just start the talk about scientific concepts
		- -	- -	- -
5	Teachers' reflections video cases	Kate	Right. It's something comes up like the Brady thing. You know Sawyer question that [Brady's question on electrodes]. "What are you talking about? Tell us **more** about that [what you understand from pickle things]. OHH **okey** are you talking about this? Oh that's right. You know how body works, you know we use there is electricity and chemicals. You know that make up the way our body functions and yeah.	The aim of IFA-Understanding student reasoning of scientific concepts
		- -	- -	- -

Table 4-3 shows an example of how the data from researcher teacher meetings (RTMs) were coded. These data were from the first researcher teacher meeting with Sawyer and Kate (7&8th grade classroom teachers). First column shows the number of the phase and the second describes the phase (e.g. Phase #2 is during "Teachers' reflections on IFA prior to watching video cases from their own practices with a focus on students' knowledge and learning processes"- see the list of the phases mentioned above). Within each phase, every turn (by speaker: Sawyer or Kate in Table 4-3) was coded to look at the common themes within and across the phases of the meetings. The code contained a main category (e.g. The aim of IFA) and a subcategory (Understanding students' needs and interests).

Table **4-4**: List of the codes of the data from the Researcher-Teacher Meetings

Timing(meeting#)	Code	Typical Example
Prior to watching video cases (1st meeting)	The aims of IFA	Evaluating
	The meaning of the concept of IFA	Informal questioning
Right after watching video cases (1st meeting)	The effectiveness of IFA	Student's identities/disabilities
After watching video cases and being familiar with academic literature (2nd and 3rd meeting)	The aims of IFA	Communicating inferences during scientific investigations
	The meaning of the concept of IFA	Assessment tool
	The effectiveness of IFA	Related to curriculum planning
	Change in Teachers' IFA practice	Improving "Reflection-in-Action" during IFA practice

Table 4-4 above shows the main codes and typical examples appeared (a) Prior to watching video cases (1st meeting) (b) Right after watching video cases (1st meeting) (c)

After watching video cases and being familiar with academic literature (2nd and 3rd meeting).

Prior to watching the video-cases and reading the literature on IFA, teachers were given a brief description of IFA and they were asked why and how they should use these assessments in the classrooms. When the researcher looked at the interview data before teachers see the video-cases and literature on IFA, all four teachers stated that they use IFA for the purposes of "Evaluating students' knowledge or ideas (right/wrong), activating students' prior knowledge, and making connections between scientific ideas." Sawyer (7 &8th grade teacher) also mentioned the need of using IFA to engage students as:

> Uuuuuum it's through informal questioning or questioning, I think you can hold in on student need. You can also uuuum holding on student interest where if you're talking about today we're talking about bioms. If a student has particular interest, you can begin to tailor a lesson, tailor a project, tailor a specific activity to the interest of that student and hopefully engage them more. There is much educ... much of what we do is working towards engaging the students, through the student, taking their interest. (Sawyer, RTM#1, 4/7/2010)

According to Sawyer, IFA are "informal questioning or questioning" used by teachers to make changes in their activities or project when students have "particular interests" to a certain topic (e.g. bioms) in order to engage students more.

Based on the emerging themes from the coding of the transcripts of teacher reflections right after watching the video cases at the first meeting, teachers mentioned ideas about the effectiveness of the IFA. Accordingly, the effectiveness of IFA depends on:

- The phase of the lesson – different phases of the lesson (e.g. engagement, exploration, guided practice, individual research time, one to one conversation with teachers) requires different type of cycle. During exploration, for example, teachers may not immediately connect student responses.

During the discussion on the previously developed models of IFA at the second meeting with Charlotte and Daniel (5&6th grade teachers), teachers started talking about incorrect or naïve student responses and how they can handle these responses. Although they were both in agreement about helping students to find or move towards a valid or correct explanations by themselves, Charlotte also mentioned that there are sections of the lesson she would prefer to correct whereas in others she would not. She says that

> So, I would not correct in the brainstorming section, but I would correct somewhere else.
>
> …
>
> Uahh it would not necessarily because of a time pressure, it would be because of the section of the lesson that I'm in. So, if I was introducing the new information, that's probably where I want that information to go out crystal clear. (Charlotte, RTM#2, 4/8/2010)

From this quote, we can see that Charlotte made decisions on correcting or guiding students' ideas based on the phase of the lesson, e.g., she prefered not to correct during "brainstorming" section.

- The attainment of the aim through student responses

As is seen in the second transcript example to non connected cycles, where Daniel was checking to see if most of the students are familiar with antibiotics, he did not choose to use students' knowledge or experience with antibiotics. Rather, he gave his own explanation. During our discussion on this case at the first meeting, Daniel mentioned that despite the benefits of using students' experiences with antibiotics, he just thought, "my purpose is to check if they are familiar" (Daniel, RTM#1, 3/5/2010).

- "Who I am talking to" (Identities/disabilities/)

During meeting#1 with 5&6th grade and 7&8th grade teachers, both teacher pairs mentioned specific students who had special needs, and for those students, they used IFA sometimes to "encourage their participation." Thus, they left some IFA cycles incomplete if the students were feeling "uncomfortable" continuing. Moreover, some students (called as "talkers" by teachers) sometimes took over the whole group conversations, and in these cases, teachers may have prefered to leave the cycle.

- Time limits

While teachers are commenting on the previously developed IFA models at the second meeting with 5&6th grade teachers, Daniel mentioned that

> …what situations would it be you know where you just correct student response where that would be just more time efficient response or you know almost in my mind is like instead of correcting when I was trying to think (...) I just correct the students or rather I tried to get them lead them to the right answer like kinda getting them back into instead of correcting (Daniel RTM#2, 4/08/2010)

Thus, teachers sometimes need to have time limits on guiding students' ideas during IFA. Teachers may just choose to correct students' response and leave the cycle to manage the time as time has been mentioned as a challenge in previous research and in this study.

- Type of student response (on task/off task)

Students' responses that were not relevant to the task at the moment were cases where teachers prefer to leave the cycle.

To conclude, prior to watching video cases and academic literature on IFA, teachers did not clearly see IFA as an assessment tool, but as a questioning strategy with an aim to evaluate the right or wrong students' responses. At the beginning of the study, based on what has been learned from the literature, effectiveness of these cycles was mainly evaluated by looking at the completeness of the cycles. However, teachers' reflections on the effectiveness of the cycles showed the factors that need to be considered for evaluating the effectiveness of the cycles.

Teacher Reflections and Practices after Second Scientific Project

Change in Teachers' Perspectives

Through video cases and the summary of articles on IFA, teachers changed some of their initial perspectives on IFA. First, as opposed to seeing IFA only as "questions that teachers ask on the fly," all four teachers started saying, "IFA is really an assessment/ and assessment tool."

The second change was related to the aims of IFA. When teachers were asked to explain the aims of IFA after video-cases and reading literature, they added new aims to their previous list. When teachers were asked for the aims of IFA at the third meeting, their list included:

- Understanding individualized ideas/explanations of students
- Improving students' critical thinking skills
- Identifying the sources of students' ideas – are students ideas from the valid sources such as national geographic websites, observations with University professors, or invalid sources such as "my mom told so" and Wikipedia.
- Evaluating students' engagement to scientific reasoning
- Communicating inferences during scientific investigations or experiments
- Checking how well students learn from the teacher explanations

The third change concerned interpretations of how teachers use IFA. As Daniel mentioned during RTM#2, understanding how well students learn from teachers' explanations can also help teachers to determine the level they can teach on particular scientific concepts. He said

> Uumm I further worked on depth of knowledge and breadth of knowledge like to start "uu oo" maybe other series where this concept fits into the big picture.
>
> Or you can go deeper into that one concept and really understand it. So, I was thinking in my you know in this depending on where the student responds is and as you are trying to bring it to like uuu you know certain level of understanding. (Daniel, RTM#2, 4/8/2010)

Thus, based on his assessment, Daniel made decisions about the depth he could go or breadth that he could connect a particular concept to the broader scientific ideas. The change in teachers' thinking related to different aims of IFA might also be the result of teachers' involvement in academic discourse through reading the literature and connecting it to their practices.

The fourth different idea was about IFA being connected to their curriculum planning. Charlotte (5 and 6th grade teacher) said the following during second meeting:

> what I do is… review the old stuff, activating prior knowledge, tell them what I'm gonna teach them about today and and introduce that topic and then through guided practice using that knowledge to gather as a group or in smaller groups whatever appropriate to do that and then uumm independent practice of what that is. When you're [students are] getting on there and then rap it up with a summary of what we have covered which actually reconnects to step 1 which was reviewing prior lesson and then moving on.
>
> …so that's one thing that [the structure of curriculum] I think is important to frame where my head is on through the questioning cycles. (Charlotte, RTM#2, 4/8/2010).

The transcripts above and the new aims increased teachers' thinking about IFA shows evidence that teachers changed their ideas after watching IFA video-cases, reading academic literature, and interacting during researcher teacher meetings (RTMs). Even though it was difficult to see if there was a change in teachers' practices within the same academic year that teachers started learning about the concept, in the following paragraphs, I used evidence from interview data on how teachers perceived the change in their practice during the implementation of the scientific projects after two research meetings (Oceanography and Physics Laws in Action, see event maps in figures 4-1 and 4-2).

Change in Teachers' Practices

As mentioned before, after two research meetings and reflections on practice and the literature, teachers implemented other new scientific projects (Oceanography and Physics Laws in Action- see event maps figures 4-1 & 4-2). During meeting#3, teachers were asked to describe the changes in their practices. For the more experienced teacher, the change was more related to her training of the preservice teachers about how to use IFA. Charlotte (5&6th grade lead teacher) responded to the question as:

> Sometimes it's the case [Luke doesn't listen to the student response]. Sometimes, Luke did a really nice job:) But sometimes Luke would just, he just cut, but that's too rough by the way. Like he had no tolerance for uum at times. So, I use these ideas we're discussing here. I explain him these assessments. Then, sure! These models help me to give suggestions to my intern. (Charlotte, RTM#3, 5/14/2010)

Thus, for her, reflections and readings helped guiding the preservice teacher who was an intern and teaching some of the lessons during the Oceanography project. Charlotte also mentioned that understanding IFA concept through video cases and readings is a useful tool to help the interns during our informal conversations while I was recording the second project.

On the other hand, assistant teachers in both 5&6th and 7&8th classrooms mentioned the change in terms of the improvement in their "reflection in action" during their IFA practices after our meetings. Daniel said "Uumm you know the funny thing is I now typically think about it [IFA] in the moment."(Daniel, RTM#3, 5/14/2010). Similar to Daniel's experience on "think about it [IFA] at the moment," Kate mentioned that she was more conscious as

> Uuuhhmm I feel like in uumm in a lot of ways uuummm I am conscious of it now so, I am very conscious of how we got into students. Do you know what I mean like before I just it's just what happened, but now like oohhh I feel like I almost kind of see these, I'm just a very visual person so, I almost like see these boxes [the steps of IFA] ooohh I'm going, I'm going this way you know what I mean you know what I mean or this way (*pointing on the model*)…(Kate, RTM#3, 5/12/2010).

Later at the third meeting, Kate also mentioned the word reflections and explained how she thinks she experiences an improvement in her reflection during the practice as

> Uuuummm I guess I don't know if there is like a pure I don't know if I, I guess there is sort of reflection, there is sort of reflection that How did you know? Did I do the right thing? Did I guide them in the right direction? How did that conversation go? Uuuumm could I have asked a different question?, could I have asked something maybe more appropriate? you know, but so I mean there is, there is certainly is a reflection there. (Kate, RTM#3, 5/12/2010).

From Kate's explanation, we can say that Kate reflected on her IFA practices more after our meetings and she evaluated her use of IFA by asking herself questions like "could I have asked a different question?, could I have asked something maybe more appropriate?"

Furthermore, Daniel also stated an improvement on how he uses IFA with students after our meetings as:

> But I think since talking about it, it's become more ingrained. You know …more of those types of assessments. You know I'm putting out different types of questions and uumm reflecting back what students have said. That's definitely I've added that a little bit more uumm since our conversations" (Daniel, RTM#3, 5/14/2010).

Therefore, as he became more aware IFA, he was trying to use IFA more and asks "different types of questions" to "reflect back on students' responses."

Considering what teachers mentioned, we can conclude that video case reflections and introducing the academic literature on IFA can help improve teachers' reflection-in-action during their IFA practices. Moreover, these reflections can guide experienced inservice teachers for explaining effective IFA implementation to their interns.

Practical Models of IFA developed by Teachers

When the idea of reflection was popularized by Schön's seminal pieces, he suggested teacher reflections as a way to connect theory and practice. In this study, researcher teacher meetings (RTM) provided a forum where teachers reflected on the previously developed models assessing classroom discourse, which are driven by the sociocultural and social constructivist theories of learning. As discussed previously, teachers were given a literature-based model (see figure 2-7 & 4-5). This model was a summary and the combination of the models that attempted to assess the classroom conversation or questioning. In this study, this model as a guide to the researcher to analyze IFA and discuss the concept with teachers. As mentioned in the methodology chapter, the model was not shown or used as a script that needs to be followed step by step, but as an illustration of an assessment constructed though the dynamic interaction between teachers and the students in the classroom.

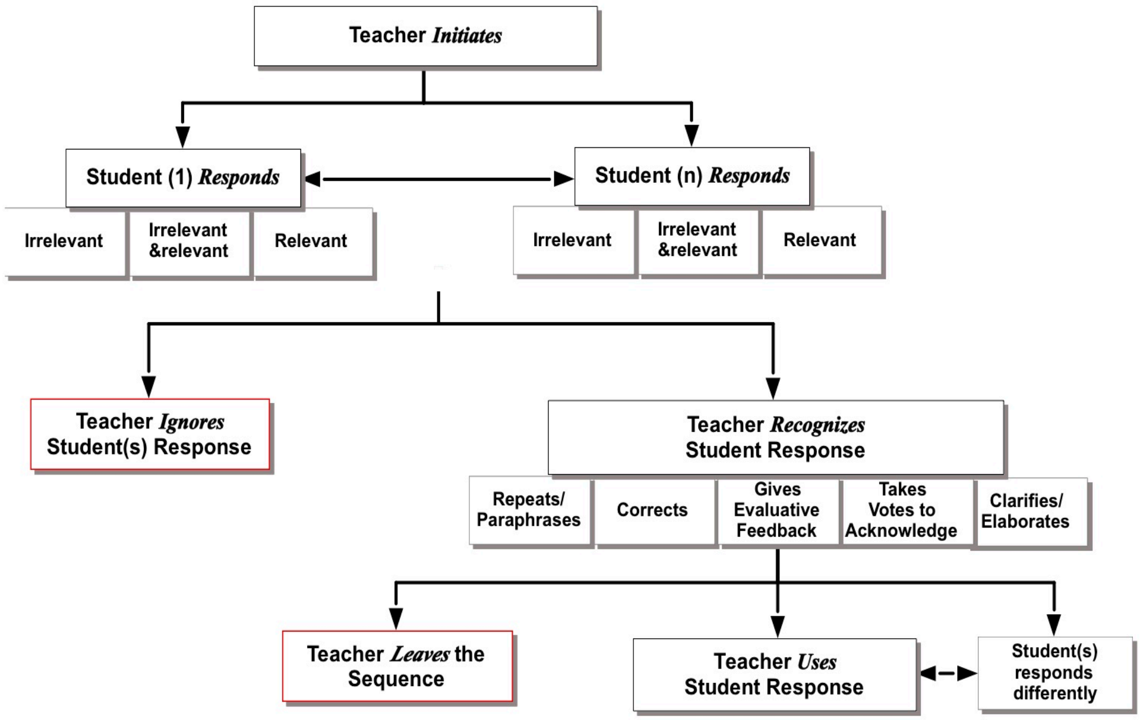

Figure **4-5**: Guiding Model for Informal Formative Assessment Cycle.

Teachers' reflections on the model was guided by two main artifacts: video-cases of their classroom assessment practices and papers summarizing the academic literature of the assessment models developed by science education researchers based on their classroom research. At the end of the first RTM, teachers were given two papers (Appendix C) were given to the teachers and asked them to read for the discussion during the following meetings and empty sheets to write and draw their ideas on an effective IFA model. At the second and the third researcher teachers meetings, teachers discussed the previous models and requested changes on the guiding model. At the second meeting, teachers were also asked to create a new model by using the literature, and what they have learned from the video cases and their teaching experiences. The process of discussing other models and creating teachers' own model were not limited to the meeting settings. Teachers were discussing their models during the breaks in their teams and ask questions to researcher.

Based on the transcripts from the interview data, I present some of the requested changes and comments by the teachers on the guiding model as they are working on their models.

- Re-considering the question of "why do teachers leave the cycle"?

Considering that every IFA has a purpose or was embedded in a lesson, which had specific intended essential knowledge or practices to be achieved, the moves where teachers left the cycles (figure 4-7) may not be due to teachers' ignorance of students' response. Rather, teachers may reach the expected outcome through the specific IFA cycle. However, by showing teachers on the model, they may recognize if they ignored the instance, or if they have a reason to leave the cycle as they are reflecting on their practice. That's why these moves have been labeled with exclamation marks in the detailed on the final model (figure 4-7). By looking at the points with exclamation marks while watching their practices, teachers can evaluate their actions and reflect forward for the similar occasions. These exclamations marks will be the points where teachers ask " why do I need to leave the cycle?" "Will it be better if I connect?", and If I need to connect, what can be the ways?" Thus, the model gives a space for teachers to discuss and reflect on their practices and not just assumes that leaving cycle means teachers ignore the student' responses.

- Considering the "performance expectations" and "expected outcomes"

Sawyer (7&8th grade lead teacher) and Charlotte (5&6th grade lead teacher) mostly focused on the need for showing the "goals" or "objectives" of the assessment activity so that the teacher could understand if they were "moving towards or away from what they want to accomplish" (Sawyer, RTM#2, 4/15/2010). Thus according to Sawyer "If you, when you look through this [the guiding model in figure 4-5], I think you oversee goals or objectives… this needs to be towards goals and objectives" (Sawyer, RTM#2, 4/15/2010). Charlotte also mentioned the importance of knowing purpose of the section as

> What's the purpose of this section of the lesson will guide you the kinds of questions I will ask? how I reinforce what's and how to direct stuff. So, if I don't want to cut out… uumm this information, I might have asked a question about it. (Charlotte, RTM#2, 4/8/2010)

For Charlotte, knowing the purpose helped her determine if she needed to follow up on the conversation or cut the conversation. Later, during my discussions with the teachers as they were working on their models in the breaks, we came up with an idea of IFA cycles helping the alignment of instructional goals with outcomes based on Sawyer's sentence on knowing "what they want to accomplish." Then, we changed the language as "essential knowledge and performance expectations" instead of goals and outcomes considering the academic literature used for the researcher teacher meetings (see figures 4-6 and 4-7).

- Explaining the complexity of the interactions during IFA (alternative ways of following up on student response)

Another comment by the teachers was on all of the models previously developed. For the teachers in my study these models failed to show the complexity of student-teacher interactions. For example, Sawyer said:

> I think it describes one sense, one aspect of interaction, but it simplifies interactions…
>
> I think it's OVERLY simplifying what's going on uuumm of teachers using it. (Sawyer, RTM#2, 4/15/2010)

Daniel also mentioned the simplicity of the models with an emphasis of IRE and then he sees IRE as a frame to build on it.

> you know that the IRE was simplistic. You know it's nice to go on and see it's good to build of off that. Two you know the cycle that they have and then onto your flow chart which definitely expands that that more to you see more see the complexity of it Daniel, RTM#2, 4/8/2010)

While working on their models, especially the assistant teachers with less teaching experience (Daniel and Kate), the teachers suggested alternative ways of handling student responses. In the detailed final model (figure 4-7), I included the alternative ways suggested by the teachers.

- Considering student-initiated cycles

At the end of the third meeting with Kate and Sawyer, I asked if they wanted to add anything else to the final model and Sawyer asked, "can the students initiate?" I as a researcher, and Kate as an assistant teacher, agreed with Sawyer's idea. I later mentioned the idea to the 5&6th grade teachers and they strongly agreed considering examples from their experiences. Thus, we changed the models as either initiated by teachers or initiated by students (figures 4-6 & 4-7). If students initiate IFA cycles, it directly connects to "teacher recognizes" step on the model.

- Correcting the visual appearance of the model (e.g. circle to represent the continuing cycle)

When teachers started to look at the guiding model before and during the second meeting, they talked about some of their confusion. For instance, Daniel said "so this happen and it could be kinda connected but a new idea or could just be coming back to this you know where you can go back to these five" (Daniel, RTM#2, 4/8/2010) and Charlotte added to that "So, you're saying you can go back to here or you can move back to here" (Charlotte RTM#2, 4/8/2010). To eliminate this confusion, teachers wanted to show the model as a circle and the final step of one cycles connected to the beginning of the cycle. This change has been done as can be seen in figures (4-6 and 4-7).

- Clarifying the meaning of the words (e.g. using on task, off task instead of relevant & irrelevant)

Another source of confusion was due to the word choice in the guiding model. Sawyer commented on the relevant vs. irrelevant students' responses as

> …we are not gonna define specific relevant questions, but let's say relevant questions on task relevant questions
>
> Off-task relevant questions. Cause that does a teacher spend a lot of time doing. They are relevant questions but are they relevant to that moment? (Sawyer, RTM#2, 4/15/2010).

Therefore, we decided to change the words relevant and irrelevant to on task and off task (figures 4-6 and 4-7).

Final Model

Figure 4-6 (simplified version) and figure 4-7 (containing the passive examples for each step of the cycle) show the models developed by the four participant teachers of the study after their reflections on video cases and academic literature on IFA. According to figure 4-6, IFA cycles were shown to connect the essential knowledge to be taught and performance expectation to be aimed, and each cycle should achieve and expected outcome. This is because teachers mentioned that they use IFA cycles to reach their instructional goals (essential knowledge and performance expectations) and they can evaluate how well they reached their aims by looking at the outcomes at the end of using IFA cycles. Then, to foster inquiry environments, during each IFA cycle, teachers should recognize and then connect students' responses (by using the suggested ways in figure 4-7). The cases that teachers did not complete and left the cycle are shown in red boxes with exclamation marks. This may not show ineffectiveness, but the moves should be considered while teachers reflected upon their practices.

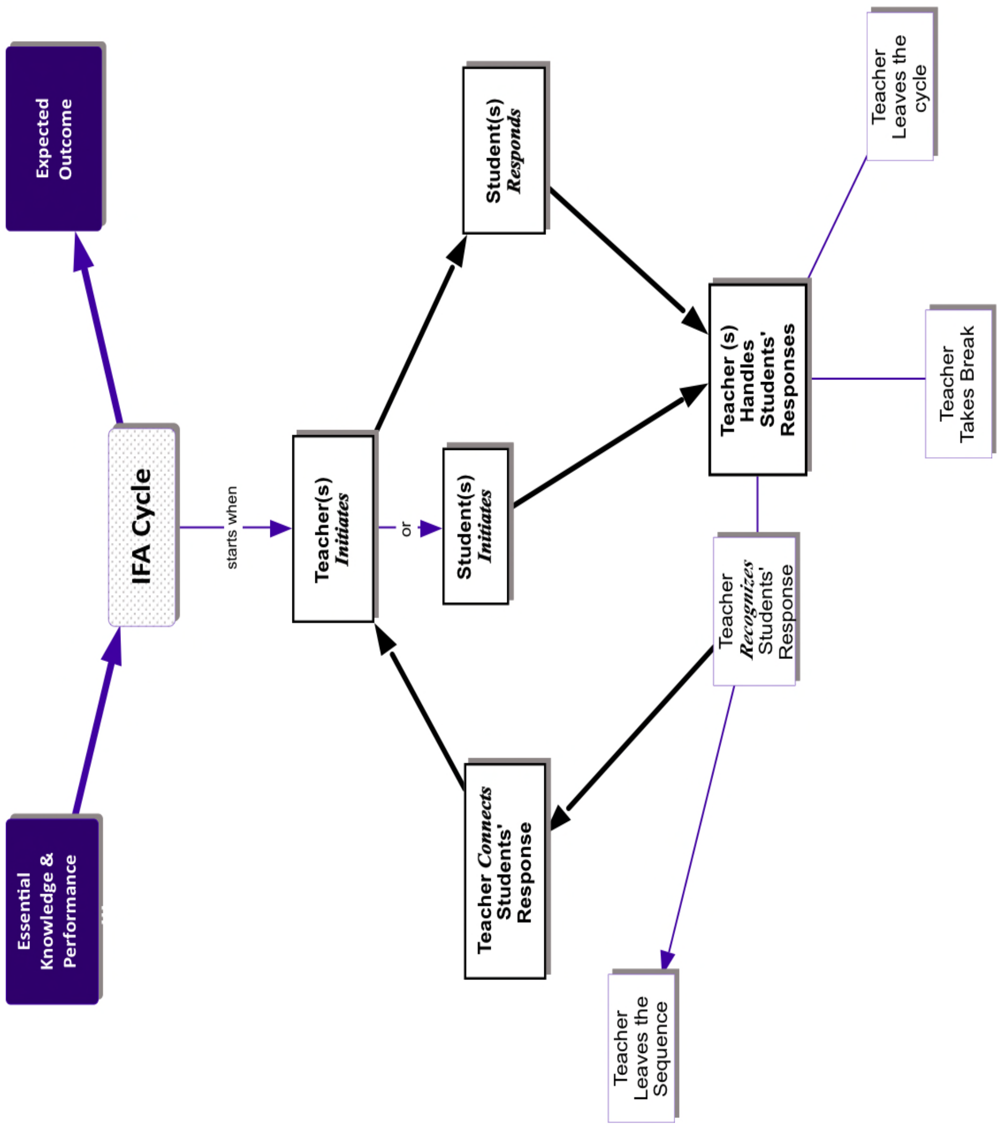

Figure **4-6**: Simplified Final Model for Informal Formative Assessment Cycle After RTMs

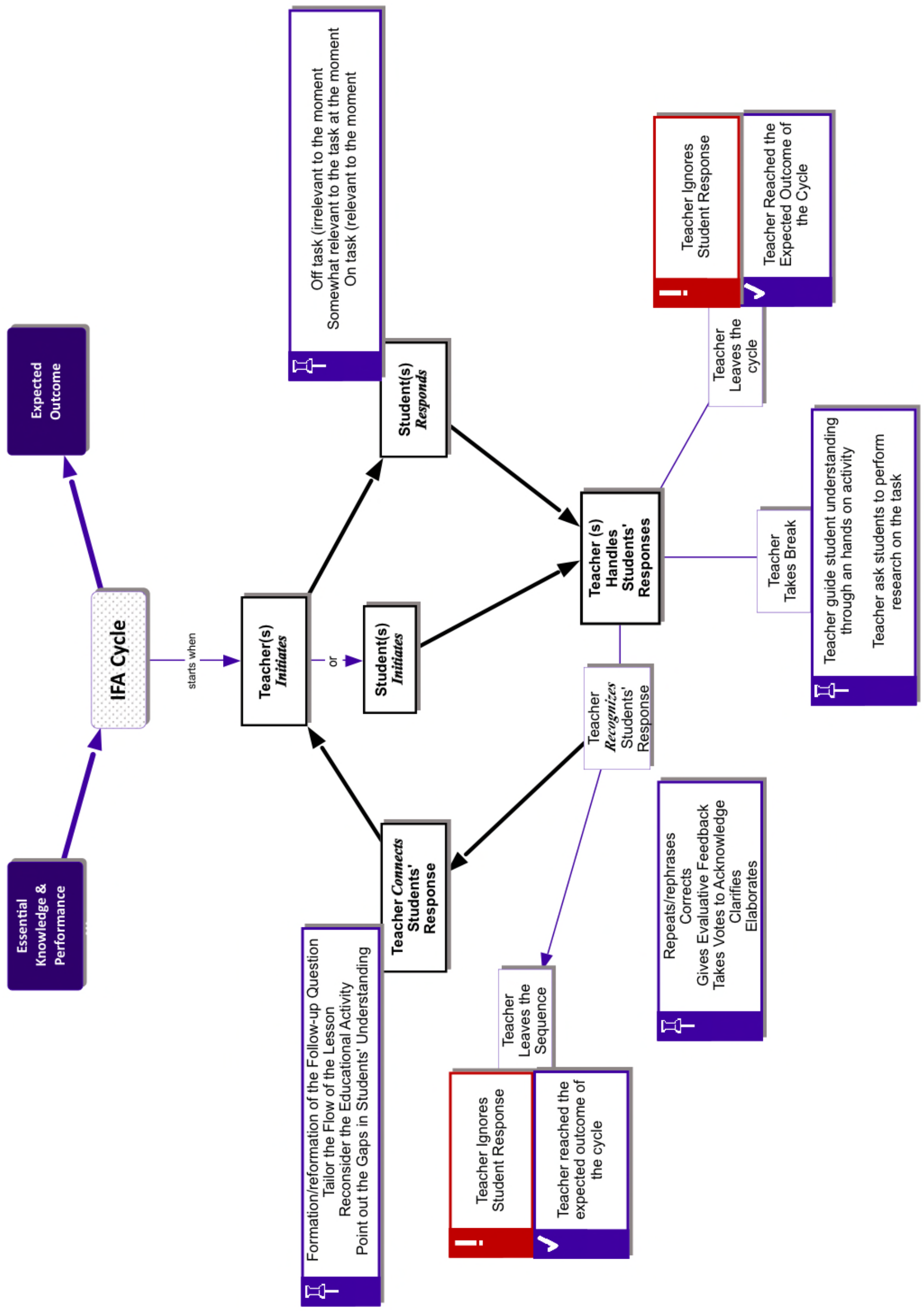

Figure **4-7**: Detailed Final Model for Informal Formative Assessment Model After RTMs

The Challenges Teachers faced during the Implementation of IFA Practices

One of the interview prompts for the researcher teacher meeting (RTM)#3 was about the challenges of effective implementation of IFA. Although talking about challenges planned to be a phase of meeting #3, the discourse analysis of the first two meetings showed that challenges of using IFA appeared as a theme for coding. As stated in previous research on effective questioning in classrooms and assessment conversations (Chin, 2006; Carlsen, 1993; Duschl, 1998), “time” is considered important to manage by teachers and thus can also be a challenge for the effective use of IFA. During every meeting, teachers repeatedly mentioned time efficiency, e.g., “Time is the thing. I think it's quite important for teachers. I think (Sawyer, RTM#3, 5/12/2010).” Daniel (5&6th grade teacher) explained where they can be more flexible in terms of time and where they can’t as:

> That's what I was gonna say too. There are serious time constraints. That's why I have to theorize what's going next. It's first circulatory system is one of the first systems so there is a little bit more time…there is always different organs working together in this system. So, I think there is that's why there is a lot more time put into that [circulatory system] and it's that was the first system so that the just see what was out there whereas any system can work with one of the last ones and time was shorter so it's that was (Daniel, RTM#3, 5/14/2010).

Thus, it seems that teachers may have more time to guide students’ responses and help them discover when they are at the introductory units of their projects such as in the case above of the circulatory system within all human body systems (see event map in figure 4-1).

Another challenge that was also mentioned in previous studies is related “subject matter knowledge.” Daniel explained this as

> I think we may have mentioned it before but… if a teacher is not knowledgeable on the subject that they're trying to go deeper ummm like they can still be effective but they could be doing more harm than good if you have students putting out mis-information, if you have the teacher putting out the mis-information, I mean I've worked with teacher before that you know whoow you know they teach to kids something that isn't, is not true (Daniel, RTM#3, 5/14/2010).

For Daniel, lacking subject matter knowledge may be a challenge to a teacher when the teacher is trying to go to the depth of the topic, and then if the teacher just uses mis-information, it might be a disadvantage for students. Following this explanation of Daniel, Charlotte and Daniel started discussing the danger of simplifying concepts as:

> You've (*looking at Daniel*) thought me that when I simplify things I need to be really careful. Because it's easy to simplify things to an incorrect level. (Charlotte RTM#3, 5/14/2010).
>
> Yeah yeah:)) and I had a professor that same thing that was one of his things was bad science and remember he had a bad science web site where it was all about all these concepts that are taught in elementary schools, that are incorrect (Daniel RTM#3, 5/14/2010).

Another finding of the previous studies is the challenge due to external-standardized tests. Therefore, I asked teachers about these tests and what they think on how these tests can affect the effective implementation of IFA. All of the teachers mentioned that these tests are not necessarily a challenge for the use of IFA in the classrooms. For example, Charlotte said:

> But the idea is this is making us a better teacher, right? That goes back to the talking to the wall if you're not using this type of informal formative assessment as you instruct, who you're teaching? YOU DON'T KNOW:)) So, how do you how do you meet those PSSA goals if you're not:)) having this dynamic interactive teaching experience with kids (Charlotte, RTM#3, 5/14/2010)

And following Charlotte, Daniel added:

> Yeah, I don't I don't. It would be a challenge to a teacher if they thought this wasn't effective in preparing kids for standardized tests. Then, and then, a teacher would think ohhh this is a challenge because I can't do this cause I need to prepare only for PSSAs or as you almost have to not necessarily worried about PSSAs orrr you're using this in the context of comparing for the PSSAs. Like it's not as this would get in the way if anything because of such an effective way of teaching. As a matter of what we're using for is going to enhance whatever you're doing umm so yeah even though it's not a standardized methods, still help for standardized tests. (Daniel RTM#3, 5/14/2010).

As is seen in his response, IFA are helpful for students to be ready for these tests such as PSSAs since teachers can “enhance” their teacher teaching through use of IFA. For him, PSSAs can only be a challenge if teachers are concerned about the test preparation process or comparisons.

Until this point, I focused on the challenges stated previously. The teachers in my study also mentioned some challenges that have not been the focus of the previous study. One of these challenges is related to the authority of the knowledge. This can be related to the relationship between teachers and students. Daniel said:

> Yeah, it's so it's so it's really I think inspiring to kids to realize how whoow you know I've researched something I, I know this information, I can teach my teachers about it. My teachers are humble to know when you know it's it's the kids know more than that and and orr they see that the teachers are like curious about the subject, so they'll see us going "ohh whoww" "Ohh I really, I wish I knew that and then you know they see us going and learning information and and come back and say ohh cool, look this what I've found orr inspiring the kids to "ohh we should go do research, learn more about that and then come you know let me know because I'm as curious as you are and so we can learn this you know you can teach me, so all those things I think can be a challenge but then at the same time if done whowwfully can be a positive. (Daniel, RTM#3, 5/14/2010)

According to Daniel, sometimes, teachers should make the students feel that students know better, “they can teach to their teachers about their research,” i.e., they have the authority on the particular topic. As will be discussed in more detailed in the following chapter, teachers may be challenged by the students who want to manage the conversations most of the time and those who are “shy” or have less interest in science.

In addition, Charlotte and Daniel also talked about the case where the limitless sources of scientific knowledge have challenged them. In one of the lessons during circulatory system (see event map in figure 4-1), Charlotte was using the circulatory system model to review how the system works. Students raised a question about blood being blue. Charlotte and Daniel wanted say that blood is blue only in the figures, but then they asked students why do they think blood could be blue. This question led to responses as “I saw it in the laboratory,” “My father told me so,” “I saw in the restaurant that the lobster had blue blood” and so forth. Then, Charlotte stopped that cycles after the responses. Charlotte said “identification of these sources of scientific knowledge was a challenge” and she explain the reason why she left the cycles as:

> And all I know is that that was risky because it perpetuated the knowledge in kids actually accepted that as a fact. In my training, I have been told that if you learn something incorrectly, you have to learn it correctly over-learn it correctly twenty times to compensate for the one time that you learnt it wrong. So, there are times that I'd rather children absorb the knowledge correctly. It's a very first time, so they don't have to unlearn the other things. Do you know what I mean?...
>
> So I would have cut off the blue thing so can you start going with it? So I am not messing with that and I thought we'll have to regroup for other day and we did I think we did have a clear explanation (Charlotte, RTM#2, 4/08/2010).

Therefore, in the case where the teacher couldn't handle the resources, she preferred to stop that day and then get the response to the student after she carried out a research on the color of the blood.

This section introduced the challenges the four teachers of the study may have during the effective implementation of IFA. Time efficiency and subject matter knowledge were the challenges for science teachers in the previous studies on classroom-based assessments. Different than previous studies, external, standardized tests were not mentioned as a challenge in this study. This finding also aligns with Ruiz-Primo and Furtak (2007) study that finds statistical evidence for effective use of IFA leading to better scores in summative assessments. This study also introduced two new challenges which were not the focus of previous studies on classroom assessments: authority of the knowledge, which will be discussed in terms of CHAT perspective in the following chapter, and limitless sources of scientific knowledge, which is available in nature, in the laboratories, through media, and online resources.

Chapter 5

Using CHAT Framework to Explain the Division of Roles during IFA

At the beginning of chapter 4, I described the analysis of cycles of Informal Formative Assessments (IFA) constructed through classroom discourse. I used the analytical tools of sociolinguistics (event maps and transcripts) to show the daily educational activities during which IFA cycles were created and how these IFA cycles can be varied (i.e. connected, non-connected, repeating) in a case of four middle school teachers at a local charter school. In this chapter, I will look at IFA cycles as "activity systems" as defined by Activity Theory of Vygotsky, Luria, Leontev (1978) and Cultural Historical Activity Theory of Engestrom (1999) (see chapter 2 for the review these theories).

I mean by an "IFA Activity System" is the cumulative participants, actions and artifacts of all single IFA cycles, which is part of teaching and learning practice in the classrooms. Based on the data from the four teachers in my study, IFA Activity System is constructed by two groups of subjects (classroom teachers: lead and assistant teacher; students: either in 5&6th grades or 7&8th grades). While constructing the IFA, classroom teachers and the students use spoken discourse as a main mediating artifact of the term IFA in this study. This discourse involves the moves, i.e., teachers or students' initiation (such as a case scenario or questions), students responses (on task or off task), teachers' recognition of student responses (such as giving feedback, taking votes from other students) and teachers' connecting students responses to the following explanation, cycle, or activity (see IFA model developed by teachers in figure 4-7 for the details of the discursive moves). Other than the main artifact-discourse, during IFA Activity Systems, subjects sometimes use other mediating artifacts to make decisions about the way they want to use IFA or decide how to initiate an IFA cycle. For example, as mentioned in Chapter 4, during their reflections, teachers said that they use the plans in their curriculum to decide when to connect (to follow up) on students' responses. Thus, I consider instructional planning as a mediating artifact for the construction of IFA. Another instance can be when students use the online educational websites to decide how to initiate a cycle (what to ask on the topic that they carry out research for classroom assignments). Like these two examples, I observed that textbooks, instructional materials and students' previous knowledge (see figure 5-1) could also mediate the construction of IFA.

The sociocultural rules constructed in the classroom (e.g., when to raise hands to respond to teachers, and wanting friends to think about their ideas) can also affect the nature of the IFA Activity System. The school community (e.g., the members of the charter school board, administrators, teachers, parents) and the community of scientific authorities (e.g. NASA) shape how IFA Activity System is constructed via determining the educational philosophies of the school, and thus the learning and assessment culture. Division of labor between the subjects and the participants of the community would help the effective operating of the activity systems (Leontev, 1978). The roles of the two teachers and different students during IFA may also determine how teachers want to handle students' ideas or questions (i.e., will the ideas or questions be important to follow up on?). Moreover, the roles of scientific authorities in the classroom can also affect how teachers act on students' ideas or questions. The IFA Activity System also has objects that teachers want to achieve each time they are using an IFA cycle. As seen in figure 5-1, these objects can be identifying the sources students' knowledge or the depth of concept the teacher should explain (for the full list, see chapter 4 on aims of using IFA).

By defining the details of the IFA Activity System in this chapter, my aim is to look closer into the division of labor between the participants of the classroom community. The reason for this analytic focus is that teachers mentioned tensions, due to the roles created by students, when asked about the challenges of using IFA effectively. Considering this challenge, I wanted to analyze how the roles are distributed among students as they are participating in IFA cycles. Moreover, in a previous study by Wells (1996), he found evidence from his analysis of the discourse in 4&5th grade elementary science classroom that how teachers followed up on students' responses were also determined by the distribution of roles between teachers and students. In his paper, he defines two different levels of teaching:

> The first of these emphasizes the goal of cultural reproduction-the transmission of successive generations of the currently valued resources of the culture so that the young of today will be able to contribute productively and responsibly, in their turn, as members of the work force and of the larger society. In the second, on the other hand, the goal that is emphasized is the development of individual students in such a way that each is enabled to achieve his or her full potential as a human being and to make original, and possibly divergent, contributions to the society of which she or he is a member. (p. 82)

Thus in the first one, new members entering to a community of practice in a culture are responsible for the continuation of the culture and in the second one they are expected to contribute to the progression of that community of practice. According to Wells (1996), these two views are interrelated in terms of socio-cultural perspectives and so he sees the schooling as an “apprenticeship into semiotic practices-the ways of meaning making- that are valued in the culture, and that teaching-and-learning involves and essentially dialogic relationship” (p. 83). However, teachers have different roles than students, as they are the ones making decisions on how to guide the classroom conversations. With this theoretical framing, teachers who want to encourage students’ full participation to meaning making processes through dialogic interactions expand on students’ ideas or questions during these conversations. Thus, I also looked at the cases where the division of labor creates tension or becomes advantage during IFA “Activity Systems.”

In the following sections, I will explain the tensions caused by the division of labor between teachers and students and among students that challenge teachers to reach the objects of IFA. Then, I will also show the cases where division of labor among the classroom participants (teachers, students, and scientific authorities), when formed differently, may become advantage to reach the objects of IFA.

Division of Labor as a Tension During IFA Activity System

Figure 5-1 shows the IFA Activity System based on the case of my study - four teachers’ 5&6 and 7&8 charter classrooms in a local charter school. The highlighted sub-categories under division labor shows the types of relation between participants where the division of labor may become a tension during the discursive moves of the IFA Activity System.

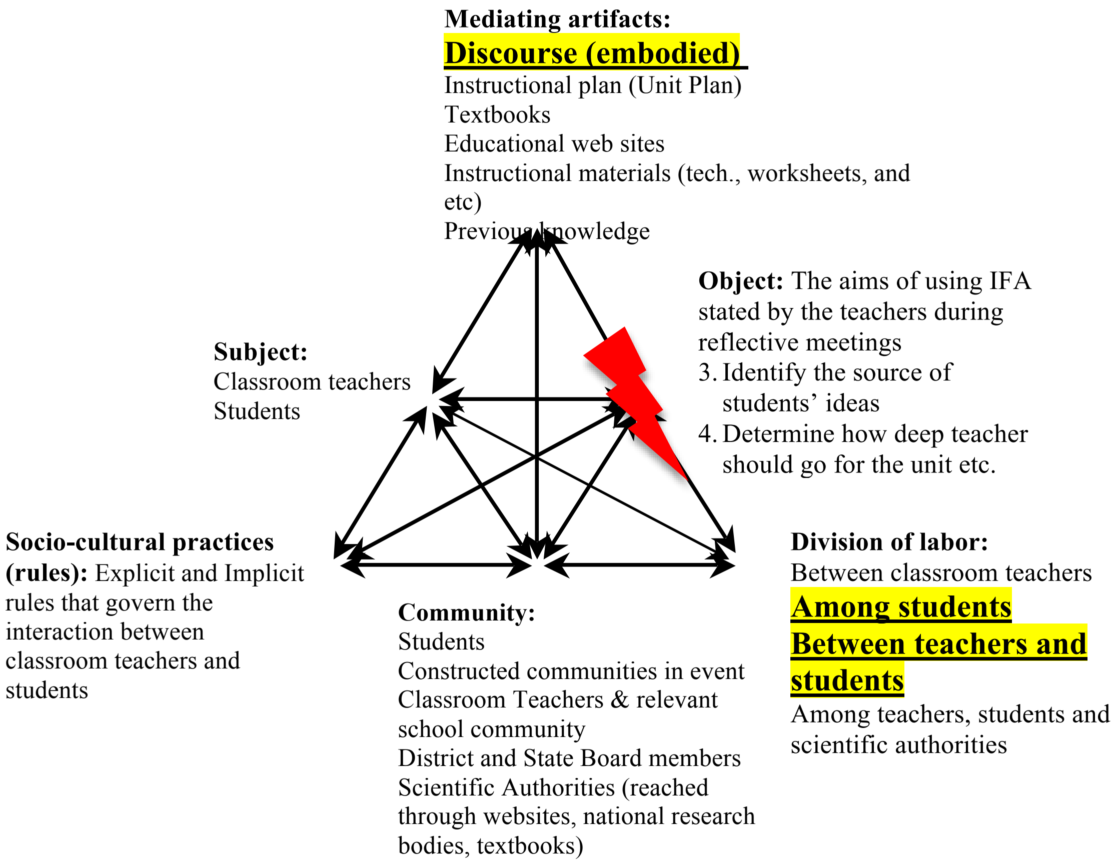

Figure **5-1**: IFA Activity System Representing the Tensions due to Division of Labor

I will now explain the cases where the division of labor during an IFA cycle created a tension for the teacher and then I will explain how the division of labor between teachers and students can also create tensions during IFA cycles.

<u>Tension Case 1:</u> Division of Labor Among Students

One of the challenges that were mentioned by the teachers was about the different roles or characteristics of the students. During the third meeting, when asked about the challenges of using IFA, Daniel explained that:

> I mean you can have a bunch of shy kids then you know where may that conversation may not happen or not naturally… you know I think that's one thing that's I guess the one draw back is maybe you do have you know those five or six kids that are really reluctant or just you know maybe not reluctant but they're just content, they just sit there and listen and you know they amused they were entertaining maybe they're in their own little world and :)umm but it you know engaging those kids you know is sometimes a challenge because then you have kids that Jason's you know have the hand up every time and when he gets going you know and you really talked about trying to not let him dominate, not take that role as I know everything, and so like Gareth in the one, Gareth start to give his explanation and looked at Jason for confirmation:):) like right? what is what I 'm saying correct? you know professor right?:) (Daniel, RTM#3, 5/14/2010)

In his response, Daniel was trying to explain the difficulty of engaging students who might be "shy" or "content." Then, he thinks that the reason for this challenge is the students like Jason who "have the hand up every time" and Daniel feels that he needs to "not let him dominate, not take that role as I know everything,..." The example that he is giving here about Gareth and Jason was from an IFA case showed to teachers during their first meeting with the researcher.

Figure **5-2**: Screen shot from the video record of 5&6th grade Introduction to Microscopy Lab

Above is the screenshot from the scene where Jason is trying to dominate the conversation and Daniel is trying to remind him that it's still Gareth's turn.

The following is the transcript of the conversations happening at the time scene above. As is seen in line # 8, the teacher directed the question to Gareth. When Gareth started responding, he also looked at Jason for approval. Jason started evaluating Gareth's response (line#3) and prompted the teacher to tell Jason that it was still Gareth's' turn.

Time	Speaker	Line #	Talk	Code
04:29:80	Daniel (Teacher)	1 2 3 4 5	Now, Jason was talking about going into a cell or he was trying to kind of explain how it is that we're able to see things. Does anybody wanna elaborate on that? What is going on? What is the process, Alex? What's the microscope is actually doing for?	Teacher recognizes – asks for elaboration from the class
04:43:78	Alex	6	It zooms in	Student2 responds
04:44:78	Daniel (Teacher)	7 8 9 10	It zooms in? Okey. That's absolutely correct, but anybody know how? Gareth?	Teacher recognizes-gives feedback and asks for elaboration
04:55:29	Gareth	11 12	Umm I do believe that there is like umm a ultraviolet break in it.	Student3 responds
05:00:93	Jason	13	No not exactly, it can…	Student4 responds
05:05:42	Daniel (Teacher)	14 15	Hoppp hopp hopp shushh let Gareth finish let Gareth finish	**Teacher's managing the conversation**
05:10:02	Gareth	16 17 18	It's uuumm it's pretty much incoming light in uuuh like cuts the cell par..aahh we could be able to go down into it and see the nucleus and all that.	Student3 responds
05:22:82	Daniel (Teacher)	19 20 21	Okey. So you're thinking that there is some sort of source of energy that is penetrating the cell?	Teacher recognizes- asks for clarification

Based on my field notes, Jason was called "science student" of the class as was known to watch documentaries or TV programs related to science, read science magazines, and go on science related field trips (e.g. bird watching). Teachers expressed that they liked Jason's interest in science. However, teachers mention their challenge when he dominated the conversations by not letting other students express their ideas completely as was seen on the line #13 of the above transcript. At that moment, Jason interrupted Gareth's idea about how microscopes helps us to see by saying "No, not exactly, it can…" and Gareth paid attention to Jason's comment.

<u>Tension Case 2:</u> Division of Labor between Teachers and Students

As mentioned from Well's (1996) study, although teachers should provide dialogic conversations where students' ideas are valued, teachers have the leading role during the conversations. During the second meeting, Daniel mentioned a challenge about how to handle student responses:

> Uumm, so with that I guess… clarifying,… it depends on the students' answer and only you know in my mind, I was thinking I' m doing call that you know ok now raise your if you think, if you agree, raise your hand if you disagree and I assume that's get everybody obviously get everybody involved and kids can have some debate. Why do you think you know if only two, third questions, but I was thinking other case where the student who you know maybe put on the spot if his answers way offend everybody :) nobody agrees with them and depending on the type of student, it can be like you know they're kinda of a blow uumm but then on the flipside, you can have been a really confident like so how many people think that's right, the majority will like you know the majority of the class agree with him like that's gotta feel good. Like you know so used in that context you know would be definitely valuable both in you know keeping the discussion going but also the you know you know highlighting student maybe feel good and you know…
>
> At the same time, you know can be challenge if not done with that thought or just that sensitivity (Daniel, RTM#2, 4/8/2010).

In his statement, Daniel mentioned that asking for clarification was helpful to "keep the discussion going" and asking for votes from the classrooms helped students build confidence in their ideas. However, he also mentioned cases where nobody would agree with the student idea, and in this case, he feared he could offend a student. Therefore, the times when students have off-task or non appealing response or ideas, teachers might have a difficulty connecting those responses or ideas to the lesson.

Thus, this example showed that the leading role of the teachers during conversations needed to be used to reflect *for* the future action of the students in the classroom (Thompson & Thompson, 2008). To be able to do this, teacher needed to think about the type of response (on task vs. off task) they got from the student and anticipate the other students' ideas on that response before putting it on the spot.

Division of Labor as an Advantage During IFA Activity System

The interview data of my study also showed cases where teachers thought that division of labor among students and between students and teachers could be advantage to reach the object of IFA Activity System that uses discourse as a main artifact. In addition, the teachers mentioned both the advantages of division of labor between classroom teachers as well as among teachers, students, and scientific authorities (reached through websites, national research bodies, textbooks). Figure 5-3 shows the IFA Activity System based on the case of the study together with the highlighted subcategories under division of labor that can be advantageous for teachers to effectively implement the discursive moves of IFA cycles.

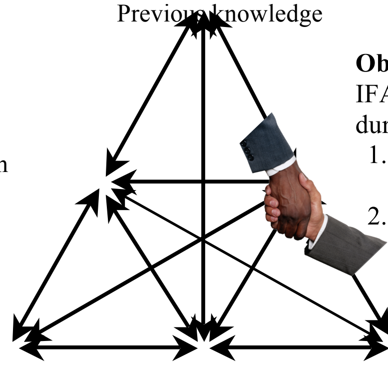

Figure **5-3**: IFA Activity System Representing the Advantages of Division of Labor

I will now explain the cases where the division of labor between classroom teachers and the division of labor between classroom teachers and students during an IFA cycle created advantages.

Advantage Case 1: Division of Labor between Classroom Teachers

As mentioned in the methods of the study, the teachers in my study were coteaching and one teacher in each class had the lead role and the other teacher had the assistant role. While talking about models, Kate (7&8th grade assistant teacher) mentioned that she was an experiential learner and she liked to see real implementation of the model:

> I guess the other thing for me, if like a model like this (*pointing to the guiding model*), I, for me, as a fairly new teacher, because I think it's easy to kind of have this these words, these all fine words, but until… I, I am a very experiential type of learner, I need to see it or experience it but I mean reading you're gonna reading it in a class, an effective loop would be really helpful for me. (Kate, RTM#2, 4/15/2010)

Thus, for Kate, to understand an effective loop (cycle), she needed to "see it or experience it." Then, during the same meeting, Kate said that she "watched Sawyer as an example" and she called the examples in the models as "passive examples" and the examples that she saw during Sawyer's teaching as "active examples." Figure 5-4 shows a scene where Kate (assistant teacher) is watching Sawyer (lead teacher) during an IFA cycle.

Figure **5-4**: Screenshot from the video record of 7&8th grade whole class discussion

As is seen on the screenshot (figure 5-4), Kate observed Sawyer (more experienced lead teacher) to model handling different students' responses. By observing Sawyer who has the model role, Kate saw the real implementation.

Another case when the division of labor between teachers becomes an advantage is when teachers help each other in terms of subject matter. At the first meeting, Charlotte mentioned that she often asked Daniel when she "can't help students when they ask in difficult questions about physics" (Charlotte, RTM#1, 3/5/2010).

<u>Advantage Case 2:</u> Division of Labor among Teachers, Students and Scientific Authorities

Based on the video records of classroom observation and the field notes, teachers used the websites of the scientific authorities (e.g., American Health Association, World Health Organization during Medical School project and NASA, National Geographic during Oceanography project) to handle students' questions (in student initiated cycles). They also constructed IFA cycles around the movies or documentaries from the websites of these scientific authorities to engage students' active participation to IFA cycles.

Below is the scene from 5&6 the classroom during the Oceanography project. Here, Daniel was using a video that a NASA representative was explaining how life on Mars is affecting the lives of deep-sea creatures. The class watched couple minutes of video and right afterward, Daniel started IFA cycles to understand what students learned from the video.

Figure **5-5**: Screenshot while watching the presentation of NASA representative on deep sea life

During the lesson that the screenshot on figure 5-5 was taken, the role of the online presentation by the NASA representative was to help Daniel to encourage students to share their ideas about the life of deep sea animals. Through a current and exciting research from scientific authorities, students could pay more attention to the topic and thus more willing to share their ideas.

<u>Advantage Case 3</u>: Division of Labor among Students

At the first meeting, Daniel defined a case where the division of labor became and advantage during IFA Activity System:

> …it's like you know different kids have different pieces like the snow ball. They're all kind of path along task saying snow ball, building it together because not all of them, none of them know it ALL, but everybody has

> little pieces in that puzzle and, you know they kind of put on their own individual piece as they're building that snow ball and then so then individually they start to see the bigger picture and then digging from there then we can take it you know to the next level (Daniel, RTM#1, 3/5/2010).

According to Daniel, every student response contributed to the "snow ball" and helped the class solve the puzzle. By this sharing of information among students, the understanding reached to a certain level where teachers can "take it to the next level."

Advantage Case 4: Division of Labor between Teachers and Students

During the researcher-teacher meetings, teachers explained two different ways that the division of labor between teachers and students can be advantageous. One was when students challenged the teachers with their questions and motivated them to update their knowledge. Daniel said:

> And then, well I interpreted you know as I interpreted question like personally, it's you know it's like the kids are challenging you in a sense to you know stay on your toes and keep up to date and so I like you as like instantly going to you know doing search, look it up, read through it. You know partly because I wanna feel like know what I'm talking about and teach them and help them learn, but at the same time I am like uhh you know this is cool for me to learn (Daniel, RTM#1, 3/5/2010).

As is seen in the transcript about Daniels' explanation on students' challenging ideas, this interaction between students and Daniel made him feel like he needed to "do more research," "be helpful for students," "keep up to date," and "know what he is talking about."

Another advantage of the division of labor was for teachers to get familiar with students vocabulary. Charlotte described it as:

> And I'm more gonna listen to the vocabulary that they'll use, gonna answer the question. That's gonna shape the vocabulary that I use when I teach.
>
> Umm, vocabulary, the language of science was very important. What do they understand? How well do they understand it?
>
> Daniel is really good at picking it apart. Sometimes kids will say "Oh yeah I know, what, you know, a barometer measures." Then you get it into it more deeply. Then, we're gonna really know it's more complex than they realize. So, then asking questions and having those question cycles, I think helps us really get to the concepts or the language of teaching when the language that they're using to understand the concepts. We couldn't do that if it wasn't this discourse (Charlotte, RTM#3, 5/14/2010).

Thus, Charlotte wanted to know the vocabulary that students are using and then "shapes the vocabulary" of her teaching. Moreover, for Charlotte, it was important to understand the level of student understanding for a specific scientific concept to plan the language of teaching.

Conclusion

In this chapter, I used Cultural-Historical Activity Theory (CHAT) as a framework to explain the IFA Activity System for the case of four teachers who are working at a local charter school. Then, the data from the researcher-teacher meetings and classroom observations were used to analyze division of labor between the participants of the classroom. These analyses showed the case created tension (a) when the division of labor among students included some students having special interest in science and wanting to dominate the IFA cycle, and (b) when the division of labor was between teachers and concerned the difficulty of using off task or unclear students' responses.

The analyses also showed cases where division of labor can be advantageous (a) between teachers – when assistant teacher observed real implementation of IFA from more experienced teachers and when teachers helped each other with subject matter knowledge, (b) among teachers, students and scientific authorities – when scientific authorities were reached through online resources or textbooks to engage students in the cycle, to help responding students' questions and to help teachers update their knowledge, (c) among students- when every individual student's idea combined to understand the scientific idea, (d) between teachers and students – when students' challenging ideas or questions motivated teachers to learn more and when teachers shape their vocabulary by understanding the scientific vocabulary used by the students.

Chapter 6

Conclusions and Further Recommendations

In the book “Everyday Assessment in the Science Classroom” (NSTA, 2003), Sneider, an author of the chapter in the volume, pointed out a paradox concerning classroom assessment based on her science teaching experiences in different states:

> On the one hand, as teachers we are encouraged to treat each student fairly in evaluating his or her work. That means we should ask all students the same questions and evaluate their performances by the same set of rules. That is why teachers give all of their students the same test at the end of a unit, and it’s why school districts and states use standardized tests to measure success districtwide. On the other hand, such tests leave virtually no room for creativity, so we may not be seeing what student can do when motivated by their own curiosity.” (p. 29).

Thus, this study is about a type of assessment that uses different types of questions leading to variety of individual students’ responses and hopefully encourages both teachers and students to learn new more effectively. Standardized assessments that “ask all students the same questions,” “has set of rules” and are implemented only at certain times, limit these assessments to measuring general trends about student achievement. On the other hand, within classrooms, teachers use assessments to achieve more than just to see what students can produce on a test, as they concerned with engaging student understanding to modify instruction.

This study explored Informal Formative Assessments (IFA), which are constructed through discursive moves between teachers and students, do not require any official record keeping, and aim to assist students and teacher’s learning. As stated in the findings of this study, it is through IFA that teachers, during their daily conversations with students, can identify the sources of students’ ideas, evaluate students’ engagement in scientific reasoning, determine the depth and breath of knowledge they plan to teach, help students to communicate the inferences during scientific observations and investigations, and so forth.

The study started with getting to know the culture of the classrooms in the study through recording observations on a video camera and taking field notes. During this period, I had a passive participant role and did not interact with the teachers on the details of the study. The aim was to understand the classroom culture and the teachers own theories about learning and assessment. For every classroom culture, teachers make decisions about what kind of activities they will implement and how they will evaluate students' knowledge and learning processes during these educational activities. According to teacher education researchers (e.g. Argyris & Schon, 1978; Goodman, 1988; Handal & Lauvas, 1987, Sanders & McCutcheon, 1986), teachers' decision-making process is based on their personal practical theories. Handal and Lauvas (1987) define practical theory as:

> a person's private, integrated but ever-changing system of knowledge, experience and values which is relevant to teaching practice at any particular time. This means, first of all, that 'theory' in this sense is a personal construct which is continuously established in the individual through a series of diverse events (such as practical experience, reading, listening, looking at other people's practice) which are mixed together or integrated with the changing perspective provided by the individual's values and ideals.... it is indeed a practical theory, primarily functioning as a basis or background against which action must be seen, and not as a theoretical and logical 'construct' aimed at the scientific purposes of explanation, understanding or prediction (Handal & Lauvas, 1987, p. 9),

Teachers make instructional decisions based on their prior-assumption on how students learn, their teaching experiences (Sato, 2003), and the learning culture of the schools where they work. Therefore, Sato (2003) suggested that teachers' current practices should be examined before engaging teachers to any professional development activity. That is why, in this study, before engaging teachers to discussions about Informal Formative Assessments (IFA) or reflections on their practices, I first examined teachers' current practices of IFA and other kinds of formative and summative assessment artifacts.

Furthermore, for an effective assessment related professional development, Sato (2003) suggested "professional development should provide opportunities to engage in developing a theoretical understanding of the knowledge and skills to be learned" (p.118). Thus, I prepared the summary of related literature for the participating teachers while they are getting prepared for the meetings. Teachers in this study were asked to read two papers based on the academic literature on IFA: One is the summary of models of assessment constructed through teacher-student conversations by me as a researcher (Appendix C) and the other was an article by Furtak & Ruiz-Primo (2005) published in *Science Scope*- a journal for middle school science teachers.

Understanding teachers' current practices and the classroom culture helped preparation of the video-cases of teachers IFA practices for the first researcher-teacher meeting and the questions that guided the interview during the meetings. The two papers helped teachers to develop a theoretical understanding of IFA models and engage in model development activity during the second researcher-teacher meeting. Following the second meeting, I recorded the classroom observations and took field notes during another scientific project. Then, a third researcher-teacher meeting was held to discuss the changes and challenges the teachers are experiencing during the implementation of IFA. The third meeting was also held to revise and finalize the IFA models developed by the teachers of the study. Based on the data from three researcher-teacher meetings and two sets of observations in the 5&6th and 7&8th classrooms, the study revealed the findings that will be reviewed in the following section.

Reviewing the Findings of the Study

IFA are implemented in different ways in the classrooms (connected, non-connected, repeating)

The data from the video records of the first set of observation in 5&6th and 7&8th classrooms with inservice teachers showed different ways of using IFA that fall into three categories. First, there are "connected IFA cycles." Teachers connected student responses or ideas to the following cycle, explanation of the concept, summarizing what has been learned. Teachers connected students' ideas to the following cycles usually by integrating the student responses or ideas to the questions or scenarios teachers used to initiate the following cycle. The second type is "non-connected IFA cycles." Teachers sometimes took students' response, showed that they recognized the students' response, mostly by giving evaluative feedback (e.g., good, great idea). Then, teachers asked another question or make an explanation independent of the students' responses or ideas. The third type is "repeating IFA cycles." Teachers sometimes repeated the same question again and again during IFA cycles. These cycles can either be connected when teachers asked the same question repeatedly to hear different ideas from the classroom and then summed up all of the ideas at the end. These repeating IFA cycles also found to be non-connected when teachers asked the same question again and again and were not satisfied with the students' responses and sought the correct response. During these repeating, non-connected cycles, the teachers recognized student responses by giving an evaluative feedback as correct or incorrect. When the response was correct, the teacher left the cycle. When the response was incorrect, teacher made his correct explanation and left the cycle. Thus students' responses were not connected to the following IFA or following activity of the lesson.

The effectiveness of IFA can be related to the phase of the lessons, the attainment of the aim through student responses, students' identities/disabilities, time limits, and the type of student response

Previous studies on assessment during teacher-student conversations claimed that such cycles are more effective when teachers follow up on student ideas (Wells, 1996) or use students' responses for their subsequent action (Ruiz-Primo & Furtak, 2007). Considering the preference of the teachers in our study, I chose the word "connect" instead of "follow up" or "use." Although teachers in this study agreed with the enrichment of the classroom discussions through connected IFA cycles, they also stated that there were cases where non-connected IFA cycles can be effective. Therefore, I needed to ask the reason why teachers leave the cycle without connecting. This study showed that teachers do not always ignore the students' responses. Sometimes, they left the cycles due to the attainment of the aim through student responses, e.g., when teachers just wanted to know if students had experienced a familiar disease or had knowledge of an organ. Moreover, teachers think about students' identities/disabilities. When "science students" were dominating the whole class discussion, the cycle was sometimes left non-connected as the teachers tried to reach other students who were not participating. Considering their daily, monthly or yearly plans, teachers should be careful about time limits and the time that they spend on "off-task" student' responses. Thus, some of the non-connected cycles may have occured due to teachers' effort to orient the lesson to the focus in their curriculum plans.

Comprehensive and practical models of IFA can be used as a guide for classroom implementation and professional development of teachers

Teachers' comments about previously developed models during researcher-teacher meetings emphasized that these models are "too simple" to show the complexity of the interactions in classrooms. Therefore, this study attempted to develop a comprehensive model (figure 4-7) including teachers' ideas, comments, and critiques. Although this model gave examples of how teachers can handle students' responses and ideas (e.g., teacher recognizes by taking votes from the classroom), these examples were just "passive examples." The teachers of the study called these as "passive examples" since they were not the real conversations. Teachers called the examples including a real discourse between teachers and students as "active examples." The assistant teachers in two classrooms of the study also mentioned their need to see active examples. Thus, the final model (figure 4-7) developed in this study can serve as a draft to observe active examples of IFA in classroom settings. This final model also points to the moves where teachers leave the cycle. As discussed before, this does not entail the ineffectiveness of cycle. However, in either case, the reasons for leaving the cycle during these moves can be discussed during a professional development activity where teachers reflect on each other's practices.

The Introduction of Academic Literature for teachers to develop theoretical understanding can lead to improved video-case reflections

The video cases of IFA shown to the teacher at the first researcher teacher meeting provided some examples of their own IFA practices. In addition, the teachers developed a theoretical understanding through the academic literature, this helped them to understand the concept of IFA and to think about more examples of IFA from their own experience. By seeing previously developed models of IFA, the teachers were both able evaluate and justify their experiences of IFA as well as criticize the models based on their own experiences. Another advantage of teachers' developing a theoretical understanding was that teachers developed an academic discourse and thus helped them explain their experiences in academic language. As teachers mentioned an improvement in their "reflection in action" during their implementation of IFA, they also talked about how they were visualizing the models in their head at the moment of and IFA cycle.

"Science" as a content area creates challenges for teachers during the implementation of IFA in the classrooms

The immediate intervention of the teachers through IFA is crucial during the scientific investigations where students experience the scientific practices such as data collection, measuring, reasoning, and so forth. Hands-on experiences have become an important part of science classrooms; however, research also shows the importance of guiding students' inquiry during these hands-on experiences for students' learning (Settlage & Southerland, 2007). Using IFA during hands on experiences helps teachers to guide students' learning during the activities and tailor the activities when necessary. During the reflective meetings of this study, teachers also mentioned that they use IFA to tailor the scientific investigations if students need more clarifications to continue the activities. Since scientific learning is dependent on the process, the effective implementation of the IFA is necessary to evaluate students' understanding during the process, but science as a content area poses some challenges to the effective implementation.

One characteristic of the scientific knowledge is that many areas of science are available for observation in everyday lives of students. Sometimes, students use this knowledge to respond to teachers' initiated IFA cycles or initiate new IFA cycles. While these ideas enrich the science classroom environment, the variety of students' ideas can be huge, thus making it difficult for the teachers to connect all these ideas at a given moment. Another characteristic of scientific knowledge that creates challenge for teachers during IFA cycles is that "science and scientists are responsive, if not tentative anymore (Duschl, 2008)". In many fields of science, we have established theories that is the basis of science, however, research and discoveries every day at different parts of the world lead to changes in scientific knowledge and become available to us through online resources. The local charter school used for this study is technology powered and every student had a notebook computer connected to the Internet. Students were encouraged to do online searches during their scientific projects. As students were surfing on the Internet, they learned about new scientific knowledge and challenged their teachers who may not have been exposed to the specific knowledge discovered by the student. Spontaneously handling student responses that come through wireless world especially becomes a challenge when teachers need to evaluate the source of the knowledge.

Cultural-Historical Activity Theory (CHAT) can be used to Analyze IFA activity systems

In science teacher education studies, CHAT has been mostly used to describe the activity systems created by communities of practice such as science teacher education in urban settings, university's teacher education programs, practicum experiences, and so forth (e.g., Corbes, 2009; Roth & Tobin, 2004; Tobin & Roth, 2010). However, in applied linguistics, CHAT has also been used to analyze the smaller-scale activity systems embedded in the communities of practice and thus enabling the analysis of discourse as the tool-kit (mediating artifact) of the activity systems (e.g., Wells, 1996). In a previous study with colleagues (accepted for publication, 2011), we used CHAT to analyze the discourse of micro-teaching activity of the preservice secondary school science teachers and their reflections upon these activities. In that study, we first described each component of CHAT for the context of our study by looking at our data and then used the components of the CHAT and the subcategories that we defined by looking at our data to analyze the discourse. This data analysis helped understanding the social dynamics of the pre-service teachers' very first micro-teaching activity and their reflective practices such as the sociocultural practices established through the educational and scientific practices and the division of labor between pre-service teachers and between preservice teachers and students. Nevertheless, the community and the subjects (histories or identities of preservice teachers) component of the CHAT framework was seamless in the discourse data due to the focus on specific activities. In this study, after describing the IFA activity system by looking at my data both from the questionnaires and video records, I focused on the division of labor component of CHAT and analyzed the discourse of the IFA activities to understand the dynamics among the classroom participants and if these dynamics were a constraint or support for the effective implementation of IFA. Division of labor as an observable component of CHAT within the discourse of the practice provided me a language to explain the influence of the distributed roles in science classroom on the effective implementations of IFA practices.

Division of labor among classroom participants can both be a constraint and support on the implementation of IFA depending on how roles are distributed and taken up by the participants

This study used cultural-historical activity theory (CHAT) to analyze constraints and affordances of division of labor among classroom participants within the IFA Activity System defined for the case of this study (figure 5-1). When asked about the challenges to effective implementation of IFA, the teachers mentioned the different roles that students took during classroom conversations. Sometimes, these roles led students to dominate the conversations. When students were viewed to be the "science students" by other students, it was sometimes more difficult for teachers to engage other students who were not as confident in their knowledge or may not have had a special interest in science. Another challenge mentioned by teachers was about the distribution of roles between teachers and students. The teachers in this study had an aim to create equally dynamic and interactive conversations with their students. However, this posed a challenge when some students' responses were not well accepted by the other students or caused teachers to spend more time than they planned to.

Inservice Teachers' learning about models can help teacher interns' learning how to teach in the schools

During this study, Charlotte (lead teacher, 5&6th grade classroom) was working with an intern from a University's teacher certification program. When Charlotte asked about the change she experienced after being familiar with the IFA models, she elaborated further these models helped her to explain the intern about IFA. Charlotte mentioned that the models helped her to explain the importance of using IFA and how to connect students' responses to the lesson. Charlotte's use of these models during the weekly discussions with the intern was also noted in the field notes.

Limitations of the Study

Limitations due to Case Study Design and Ethnographic Perspective

Due to limited number of samples, case studies cannot be generalized to all situations. On case study designs, Yin (1994) states the following:

> The case study has long been stereotyped as a weak sibling among social science methods. Investigators who do case studies are regarded as having deviated from academic disciplines, their investigations as having insufficient precision (that is, quantification), objectivity, and rigor. (p. xiii)

Despite its limitations on objectivity and generalization, case studies lead to new ideas and detailed understanding of nature of the local context. My study does not aim to generalize the findings to all middle school science classrooms, rather it aims to develop better understanding of local conditions, i.e., the formation of IFA cycles via social interactions between students and teachers which has been influenced by their cultures, histories, the established rules of the classroom. For this reason, the IFA models created as a result of this study will not be standard model for every middle school classroom, but it will serve as a model for constructing practical and theoretically sensible models of IFA through teacher reflections. Another threat to objectivity for this study is being a participant observer during some parts of the study to understand more about the social and cultural variables of the context. As mentioned before, the researchers' involvement in the study may have an influence on the teacher's practices (Yin, 1994). However, as my study was framed by sociocultural theories, thus seeing classrooms having their own culture, meeting teachers and talking to them will helped me understand this culture.

Limiting the Meaning of the Construct "Perspective"

This study is limited to the analysis of "what is observable" and does not intend to look at constructs that require the understanding of what is inside the brain of teacher or students. The word "perspective," for example, that I mentioned in my research questions have been commonly used to look at "beliefs and practices" in educational research (e.g., Raymond, 1997, Richardson & Placier, 2001). However, this study will not use any measurement of beliefs. Perspectives will be defined by what teachers' said during their reflections. Furthermore, I did not look at any affective measures that may have influence on the teacher practices, i.e. motivation, interests, and so forth.

Limitations due to the Timeline of the Study

Since the study was aimed to be completed in one-year span, the time to observe the changes in teachers' practices of IFA allowed me to observe only a few cases as an evidence for change. Given this constraint, I draw conclusions about the change in teachers' practices of IFA based on what teachers told during the last researcher-teacher meeting.

Recommendations for Further Research

Recent research on science education focuses on the complexity of scientific knowledge that includes not only conceptual dimension, but also epistemic and social perspectives (Duschl, 2008). As a result, to understand the nature of scientific knowledge, studies have been designed focused on students' experiencing knowledge construction through different strategies such as argumentation (e.g., Erduran & Jiménez-Aleixandre, 2008). These innovations in science classrooms can be further evidence that the formal assessments may not be enough to provide information on what and how students learned. Assessments constructed through everyday classroom discourse seem promising and may provide more insights on student learning aligned with recent research trends as these assessments yielded positive effects on students' scientific knowledge and inquiry skills (Duschl, 1997, 2003; Ruiz-Primo & Furtak, 2007).

However, despite the teachers' central role on managing instruction and assessing students, there is not enough research focused on understanding how teachers select and implement assessment activities aimed at student learning (Tomanek, Talanquer, Novodvorsky, 2008). As Key and Bryan (2001) claimed "only when the voices of researchers are in resonance with the voices of teachers can we begin to create harmonized reform-based instruction that is enduring." And in their article about "co-constructing inquiry based science with teachers," they raised the hope that "teachers' once muted voices will be raised loudly and clearly in the call to reform."

This dissertation study involved the reflections of four teachers on their own practices and relevant academic literature to understand the use of IFA and the challenges to effective implementation. Furthermore, teachers were involved in the development of a practical IFA model, which may serve as a draft to observe classroom practices and to evaluate practice during a professional activity during further studies. Considering the differences in the school and the classroom cultures and thus the varying assessment cultures, case studies to understand assessments constructed during teacher-student interaction are needed. Video-cases have been recently used as an effective strategy to promote teacher reflection (e.g. Abell, Bryan, & Anderson, 1998, Finn, 2002, Roth, 2003, Roth & Chen, 2007, Wang & Hartley, 2003). This study also showed that using papers explaining the academic literature also helps teacher-researcher collaboration because teachers became more familiar with the current literature.

Based on the findings, this study also recommends the use of models as a guide or draft, but not as a script during the professional development activities designed to improve classroom-based assessments. Teaching is a complex activity and the differences in individual students, teachers, and cultures of classrooms and schools can create different cases or different implementations of assessments. Therefore, use of models as scripts, may limit teachers' abilities to reflect on their practice and make effective changes. While teachers in this study were working on developing their models of IFA, they emphasized teachers or interns using this model also need to know this is only an exemplar designed to help understand IFA and evaluate practice. However, this final model (figure 4-7) is not a script to be implemented step by step.

The data of this study was analyzed by using Gee's discourse analysis method. Then, in chapter five, cultural-historical activity theory (CHAT) was used to define the IFA Activity System. This figure (5-1 and 5-3) helped understanding how the subjects, mediating artifacts used during the IFA Activity System, the community, and division of labor between participants of the community, and the rules of the classroom community interact to reach the object of IFA. The CHAT framework was also helpful to explain the tensions and affordances of division of labor based on the data of this study. As a framework designed to understand the tensions within activity systems (Engestrom, 1993, 1999), CHAT can be used to explain the constraints leading to challenges during the implementation of classroom-based assessments.

The findings of this study showed that the roles taken by students in science classrooms may cause tensions (i.e., when some students dominate conversations) or may support the effective implementation (i.e., when different ideas of students help the construction of knowledge in the classroom) during an IFA Activity System. The tensions happen due to students who have taken or have been given an identity as "science student." Thus, for further research, I suggest analysis of students' identities during IFA cycles and consideration of solutions for teachers on how to deal with different identities of students.

All in all, this study was an attempt to focus on improving teachers' perspectives on understanding the nature of Informal Formative Assessments (IFA). The teachers come to see IFA as a process of ongoing assessment and readjustment (metaphorically, a video of everyday life), rather than a measure of achievement at a given time (still shot photograph). By video-filming students' and their own learning processes, teachers can focus on different dimensions of science learning by assessing students' reasoning, scientific practices and so forth. Teachers can also make modifications for their following lessons by understanding the depth and breadth of students' understanding of the scientific concepts. Through IFA, these modifications can be done based on data available to the teachers during everyday conversations. The study involved teachers developing a comprehensive and practical model of IFA for effective classroom implementation and for use as a mediating artifact for observations of classroom practices and teachers' reflective practices. Research on assessments constructed through conversations in classrooms (e.g., Duschl, 1998) identified challenges that constrain the effective implementation of similar assessments. This study also explained two more challenges due to the limitless sources of scientific knowledge and distribution of roles among classroom participants, which can be analyzed in more detail in further research.

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Appendix A

History and Current Practices of Teaching Questionnaire

Educational Background

1. What is the highest academic degree do you hold?

2. Did you have a major, minor or special emphasis in any science related subjects (e.g., biology, chemistry, earth science, and engineering) as part of your ***undergraduate*** coursework?

3. Did you have a major, minor or special emphasis in any science related subjects (e.g., biology, chemistry, earth science, and engineering) as part of your ***graduate*** coursework?

4. As part of either your undergraduate or graduate coursework how many advanced science courses (e.g., astronomy, biochemistry, molecular genetics)?

5. As part of either your undergraduate or graduate coursework how many science education courses did you take

Teaching Experience

1. How many years have you worked as a teacher?
2. How many years have you taught science?
3. Did you enter teaching through an alternative certification program?

Current Teaching Practices

1. How many students are in your group?
2. About how much time do you spend with this class on science instruction in a typical week?
3. What are the assessment techniques you are using?
4. What are the technological sources you are using the class?

Appendix B

Interview Protocol for Researcher-Teacher Meetings

Meeting #1: Reflection on Video-Case Samples

Step 1: Researchers' brief introduction to the concept of IFA

While you often try to understand students' learning through quizzes, projects, essays and other measures, you are also assessing their understanding when you are eliciting student knowledge (mostly by questioning) during your lectures and discussions with your students. These are referred to "Informal Formative Assessments" in educational research literature. These are the assessments that are

- Embedded into daily conversations between teachers and students
- Do not require any official or written record keeping
- Has the purpose of improving student learning and teachers' frequent recognition of student understanding

Step 2: Teachers' perspectives on the concept of IFA

At this step, the researcher will ask the following questions to the teachers to understand their initial perspectives on IFA.

1. In what ways do you think these IFA activities can help students?
2. In what ways do you think these IFA activities can help teachers?

Step 3: Watching four different video cases of IFA practice

Step 4: Teachers' reflections on their own practices of IFA through the following guiding questions:

1. We watched four scenes from your teaching practices. Can you tell me the aim of each activity in these video cases? Do you see any commonality in the video cases we watched?

a. If yes, what are the commonalities? (Expected- checking student understanding, assessing students, and etc.…)
b. If you think they are different, in what ways?

2. How will you evaluate each video case that we watched?
    a. What are the things that you liked about your IFA practice?
    b. Do you have any comments to yourselves or to each other?
    c. What are, if any, your critiques about your practices?
3. From your point of view, what makes an IFA activity effective? How should a teacher start this activity? What are the possible ways that students' responds to teacher's initiation? How should teachers guide and evaluate students' responses? Can you please draw a diagram of an effective IFA practice? (This question will be provided on a piece of paper)

Meeting#2: Developing a Practical Model of IFA with Teachers

Before this meeting, teachers will be given a paper that summarizes theoretical IFA models. These models will be discussed at the meeting trough the following questions:

Step 1: Discussion on theoretical models of IFA

1. What do you think about researchers' IFA models?
2. Do you have any comments and critiques on these models?
3. Can these models help teachers to improve their assessment practices?
    a. If yes, in what ways?
    b. If no, why they can't?

Step 2: Using teachers' draft IFA diagrams to improve an IFA model

1. Teachers will be given IFA diagrams that they created during the first meeting. Now that you have seen the models developed by researchers is there anything that you want to change or add in your IFA diagrams?
    a. If yes, what are they?

Meeting#3: Revisiting Teacher's Perspectives on IFA and Challenges of Using IFA

<u>Step1</u>: Teachers' perspectives on the concept of IFA after their reflections on video case

1. In what ways do you think these IFA activities can help students?
2. In what ways do you think these IFA's can help teachers?
3. How do you evaluate your use of IFA?

<u>Step 2</u>: Researchers' revisiting IFA models

1. Do you want to make any changes on your IFA model?
    a. If yes, what are they? Can you show it on the model?

<u>Step 3</u>: Teachers' challenges of using IFA

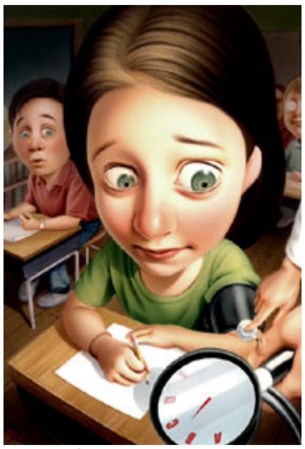
1. What are and can be the challenges for teachers to effective implementation of IFA?
    a. Is there any kind of student response that will lead a teacher to leave an IFA sequence?
    b. Can there be any external challenges (outside of the classroom) for teachers to implement IFA effectively?

Appendix C

What are Informal Formative Assessments?

INFORMAL FORMATIVE ASSESSMENTS

Tracing Students' Reasoning on Scientific Ideas



C opyright ©
http://tccl.rit.albany.edu/knilt/index.php/File:Assessment.jpg

Assessing student learning has been a part of the educational process since Socratic times. Until the 20th century, in many countries, tests were designed in small group settings and people were asked to perform a task (Suen & French, 2003). However, the methods of assessing students' improvement have been changed drastically. Objective selection and replacement required high stakes situations (e.g., job applications, college entrance) leading to the standardization of test scores. Multiple-choice tests became common measurement devices after the discovery of the optic scanner. Although these tests had the limited purpose outside of the classroom, the changes influenced classrooms and led teachers to "teach to the test." What happens when standardized tests are the focus of the classroom is that we overlook some important aspects of students' learning by:

- measuring predominantly low level mental processes;
- failing to capture scientific practices, such as reasoning and argumentation; and
- missing the opportunity to provide feedback to improve instruction.

Due to these drawbacks of the multiple-choice tests, educational researchers recommend the use of formative assessment techniques, such as journals and e-portfolios (Black & William, 1998; Dori, 2003; Yung, 2001). However, most formative assessments are not capable of assessing the dynamic social construction of scientific knowledge and students' skills to reason, argue, and evaluate the scientific knowledge. Furthermore, according to a study in New Zealand (1994), "teachers gather a large amount of diverse information on student learning during informal interactions with them" (as cited in Bell and Cowie, 2001). Therefore, a careful analysis of assessment activities in the classroom discourse of teacher-student interactions can be more informative. In this paper, I will mention ideas from researchers to assess student reasoning of ideas during classroom talk.

Questioning Cycles in Science Classroom

I
- stands for Initiation
- normally through a question from the teacher
- ***(What have you learned about heart today?)***

R
- stands for Response
- from the student
- ***(it helps blood circulation)***

E
- stands for Evaluation
- by the teacher
- ***(very good)***

Questioning cycles formed the basis of models of assessment embedded into classroom talk. An early model on questioning cycles – the IRE model - was developed in the field of applied linguistics (Sanclair and Coulthard, 1975; Mehan, 1979). In this model, the teacher initiates the cycle, usually with a question. A student responds. Then, the students' responses are evaluated by the teacher Later, Scott and Mortimer suggested elaborating the cycle with F for feedback, rather than ending with Evaluate (e.g., very good, this is an important function of the heart. Blood circulation brings lungs oxygen, food particles to the cells, and etc.). For them, using feedback after evaluation can lead to a more interactive classroom talk.

- **I**
  - stands for Initiation
  - normally through a question by the teacher
- **R**
  - stands for Response
  - by the student
- **F**
  - stands for Feedback
  - by the teacher
- **R**
  - stands for further Response
  - by the student
- **F**
  - stands for further Feedback
  - by the teacher
- **... Cont.**

Later, Scott and Mortimer (2005) developed another pattern I-R-F-R-F,… that can foster interactive and dialogic instruction. During I-R-F-R-F,… pattern, teacher feedback is followed by another response from the same or a different student. As shown in the transcript below, the teacher initiates the IRFRF.. sequence by asking students to give her an example and this IRFRF… sequence continues until the teachers gets the response s/he expected. IRFRF… pattern may help understanding of students' reasoning about their responses. As in the transcript below, giving example "powder" may not be enough to understand why students think that powder can be an exception. Thus, this dialogic interaction between teachers and students are more aligned with the recent aims of teaching science as thinking and talking about scientific ideas, phenomena and so forth.

Teacher:	Well, if you say 'no', put your hand up and tell me, give me an example, which would prove an exception to that…(*the idea that solids are hard*) (Inititation)
Suzanne:	Powder's a solid, but you can crash it. (Response)
Teacher:	Powder's? (Feedback)
Suzanne:	a solid but you can still crush it. (Response – repeating the same response)
Teacher:	Powder's are not particularly hard, yes, if you are talking about hard to the touch. Paul? (*who has his hand up*) (Feedback – elaborating on student' response)
Paul:	It's…cos…it's (the powder) got a gas in between, so it's hard. (Response – reasoning on the idea by another student)
Teacher:	So, do you think that all solids are hard? (Feedback – asking for assurance of the idea)
Paul:	Yeah. (Response)

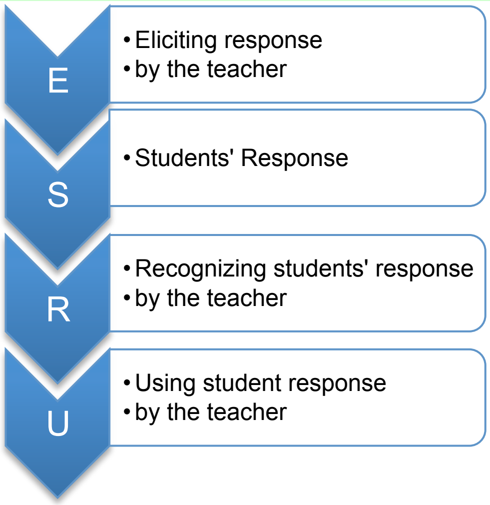
Using Questioning to Assess Students' Reasoning in Science Classroom

Assessment Conversations

- **Stage 1**
  - Receiving Information
  - by the teacher
- **Stage 2**
  - Recognizing Information
  - by the teacher
- **Stage 3**
  - Using Information
  - by the teacher

Duschl and Gitomer (1997, 2003) studied "Assessment Conversations." These assessment conversations have three parts: the teacher *(1) receives, (2) recognizes,* and *(3) uses* information provided by the students. To receive information, teacher arranges small group activities and tasks during which students can display their understanding. The recognition of student responses involves the teacher's careful analysis of student understandings by considering the conceptual goals of lesson and also working with students for the synthesis of the ideas. Finally, the teacher uses what has been learned in order "to evaluate previous efforts, meanings, and understandings, and performances" and to improve students' understanding, meaning making, and performances. According to the results of Studies by Duschl and Gitomer, assessment conversations are very helpful for practicing inquiry in science classrooms.

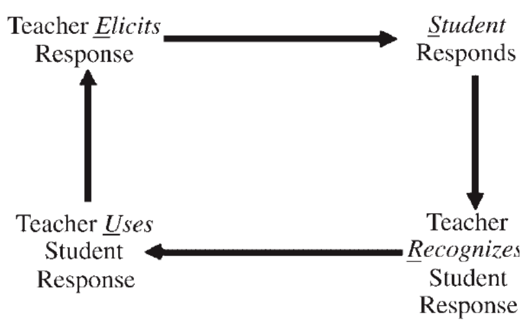
ESRU Cycle



After Duschl and Gitomer, Ruiz Primo and Furtak (2007) used the term “Informal Formative Assessments (IFA)” for the cycles used to assess students’ scientific thinking and reasoning. Informal Formative Assessments are defined as (Bell and Cowie, 2001):

- Embedded in the discursive moves between teachers and students during everyday instruction.
- Do not require any official or written record keeping.
- Have the purpose of improving students’ learning and the teacher’s frequent recognition of student understanding.

Thus, during IFA cycles, teachers can understand how students are reasoning about scientific ideas on the spot and can guide students’ improvement of ideas and skills required for scientific learning.



In their study, Ruiz-Primo and Furtak introduced ESRU cycle to three middle school science teachers at the beginning of the study. During these cycles, the teacher *elicits*, students *respond*, and the teacher *recognizes* and *uses* the information related to scientific content. Their study showed that IFA can provide more frequent feedback to the teacher to monitor classroom activities, and the effective use of these cycles (more complete cycles) resulted in better scores in formal written assessments.

Ruiz-Primo and Furtak provide some suggestions on how teachers can elicit, recognize and use students’ responses during IFA:

How teachers elicit response?

The teacher asks students to:

- provide potential or actual definitions
- apply, relate, compare, contrast concepts
- compare/contrasts others’ definitions or ideas
- check their comprehension, compare/contrast observations, data, or procedures
- use and apply known procedures
- make predictions/provide hypothesis
- interpret information, data, patterns
- provide evidence and examples, and relate evidence and explanations

How teachers recognize response?

The teacher

- clarifies/elaborates based on student responses
- takes votes to acknowledge different students’ ideas
- repeats/paraphrases students’ words
- revoices students’ words (incorporates students contributions into the class conversation
- summarizes what student said
- acknowledge student contribution, and captures/displays students’ responses/explanations

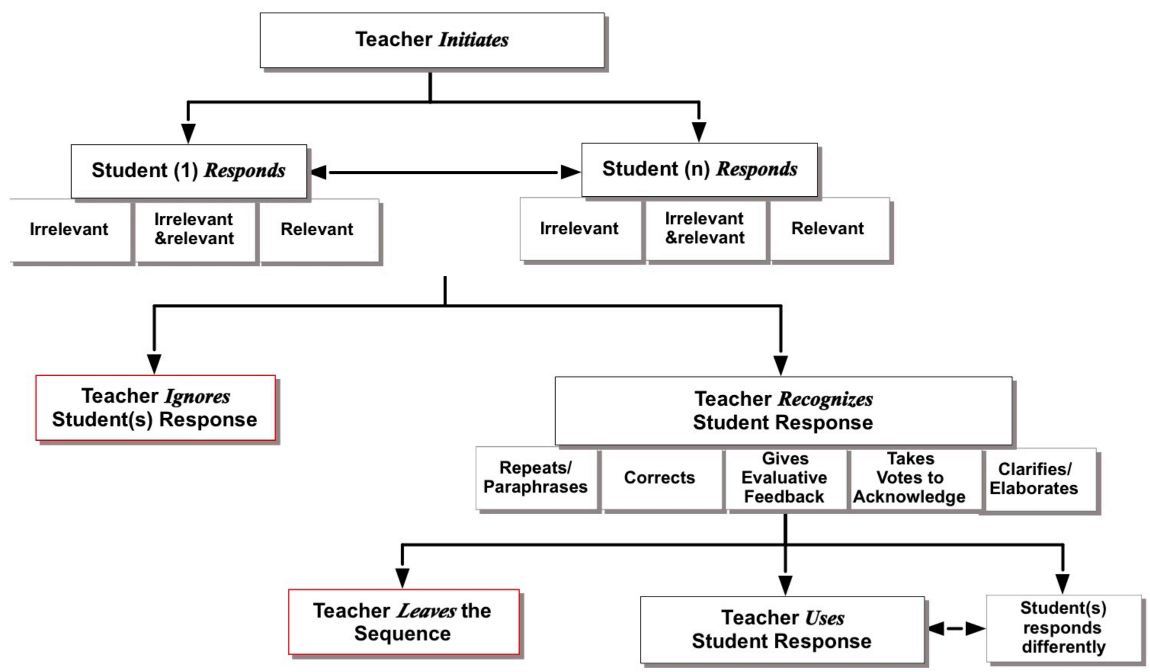
How teachers use response?

The teacher

- promotes students’ thinking by asking them to elaborate their responses (why, how)
- compares/contrast students’ responses to acknowledges and discuss alternative explanations conceptions, promotes debating and discussion among students’ ideas/ conceptions
- help students to achieve consensus, helps relate evidence to explanations
- provides descriptive or helpful feedback

Developing a Practical Model of Informal Formative Assessments

For my research, I have the aim to develop a practical model of Informal Formative Assessments (IFA) by considering teachers' opinions and expertise in classrooms. Therefore, I would like your help to construct a model of IFA, which will be practical for classroom use. To guide our discussions on developing a model, I created the following model based on the literature you have just read. Different from others, this model attempts to describe the types of students' responses (i.e., irrelevant, irrelevant & relevant, relevant) and the ways teachers recognize students' responses (repeats/paraphrases, corrects, gives evaluative feedback, takes vote to acknowledge, clarifies/elaborates).



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Appendix D

Transcription Convention for Discourse Analysis

<u>word</u>	Underline indicates speaker emphasis
WORD	Upper case indicates shouting
!	Animated and emphatic tone
?	Rising intonation, not necessarily a question
.	Full stop, stopping fall in tone, not necessarily end of the sentence
,	Comma indicates a gap between utterances which is too short to time, more likely a very short pause
#	Inability to hear the words
#word(s)#	Uncertain hearing the words
(words or actions)	Transcribers description of words or actions
"word(s)"	Speakers' imitations of others or speakers' using quotes
01:06:21	Timestamp (start and end time)
02:15:84	
P: 00:02:00	Duration of the pause

Adapted from the following resources:

Hutchby, I. and Wooffitt, R. (1998) Conversation analysis: principles, practices and applications. Polity Press.

Du Bois, John W. , Schuetze-Coburn, Stephan, Cumming, Susanna, and Paolino, Danae. (1993). Outline of discourse transcription. J. A. Edwards and M. D. Lampert (Eds.) In Talking data: Transcription and coding in discourse research, eds. 45-89. Hillsdale, Erlbaum, NJ.

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