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Using Student Knowledge to Enhance Inquiry: A Theoretical and Practical View of Negotiation in a Science Classroom

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Abstract

The purpose of this paper is to discuss the role of negotiation in a science classroom, specifically how teachers can improve their students' ability to construct a scientific claim by focusing on their students' knowledge and how it changes throughout the unit. The paper will attempt to define key aspects of negotiation, the students' role in negotiation, the teacher's role in promoting negotiation, and how negotiation can potentially increase the opportunity for conceptual change in students. Negotiation will be discussed as a notion of assimilation, accommodation, and a relationship of construction and critique.

Key words: Science classroom, negotiation, assimilation, student knowledge.

Science education plays an important role in preparing students for numerous aspects of their future lives: thinking logically and critically, making decisions involving scientific information both personally and as active citizens and, for some, pursuing a career in science (Duschl, Schweingruber & Shouse, 2007; NRC, 2012). Teachers who educate students with these goals in mind, place a special emphasis on teaching the skills of inquiry to students. Learning through inquiry involves the skills needed to ask questions, conduct investigations, generate data, create models, interpret evidence from first-hand investigations, and make evidence-based claims (NRC, 2012). If taught well, the process of inquiry asks students to engage in critical thinking, interpret data, and to consider alternative explanations of evidence (Ford, 2012).

A specific endeavour that asks teachers to explore the dialogic interactions of the process of inquiry is argument-based inquiry. Asking students to construct arguments from evidence has been an extensively supported goal in national-level science education policies in the United States (Duschl et al., 2007; NGSS Lead States, 2013; NRC, 2012). These policies have asked teachers to promote classroom practices that move beyond experiments and investigations, and towards practicing science argumentation. According to the NGSS "Students should engage in the practices of asking questions, planning and carrying out investigations, analyzing and interpreting data, constructing explanations, and engaging in argument from evidence" (NGSS Lead States, 2013 p. 49). Research on how to enact reform-based teaching practices most effectively has suggested that teachers embrace a role that promotes autonomous learning practices, like negotiating evidence with peers, and move away from authoritative, or directive lecture (Hargreaves, 2013).

Asking students to engage in explanations of scientific phenomena through argumentation creates opportunities for students to engage in multiple aspects of scientific inquiry while building their science knowledge. When students participate in scientific argumentation they are provided with a context and a foundation for the process skills of inquiry. In addition, due to the nature of argumentation, students necessarily practice the critical thinking skills that are vital to inquiry, as they need to evaluate evidence and critique alternative explanations (Kuhn & Crowell, 2011; Hand, 2008; Ford, 2012). As students engage in the process of critiquing each other's claims, the act of communicating and justifying explanations plays a central role in their inquiry, underscoring key aspects of the nature of science.

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Teachers who use instructional decision making practices aligned with the theoretical framework of argument-based inquiry have the potential to practice the skills required to think critically and to address the two previously mentioned rationales for the emphasis on quality science teaching being taught in school. First, skills of scientific argumentation align with the commonly held notion that scientific claims are empirical, tentative, and negotiated by the most rigorous standards of peer-review until accepted by the scientific community (Bricker & Bell, 2008). Shaping a student's epistemological and ontological views of scientific knowledge construction may help equip them with the skills required in a profession in the field of science. Second, an understanding of how the scientific community determines what is accepted as scientifically viable would increase the scientific literacy of the population as a whole.

Engaging students in the act of scientific discourse requires teachers to structure their pedagogy from a learning theory that allows students to build their own understanding and knowledge of the world, through experience and reflecting on those experiences.

The interactions described above require teachers to obtain knowledge from their students instead of simply acting as the only source of information in the classroom. Knowledge of student knowledge, especially in the early stages of learning, is a resource that is commonly overlooked in classrooms that utilize more traditional, didactic pedagogy. Using student knowledge to help guide learning will be discussed in this paper in both a theoretical review and in a practical manner as a classroom teacher.

Despite the clear emphasis on student claim construction and classroom negotiation in contemporary science literature, it is surprising there are not many publications investigating what negotiation actually looks like in a classroom, and how a teacher may enhance the experience for their students. Also, published argument-based inquiry literature frequently asks students to make their ideas available to the teacher so he/she can, in turn, provide feedback that asks students to re-evaluate their initial ideas based on observable evidence. The concept of using the knowledge that students provide as a tool to guide instruction, has not been extensively investigated in published science education literature and will be a focal point in this paper. In the following section the teacher knowledge base of knowledge of learners will be discussed.

Knowledge of Learners

The notion that teachers possess different types of knowledge, and that having mastery of these diverse knowledge bases is required for effective teaching, has been studied extensively over that last few decades. A typology of these knowledge bases was put forth by Shulman (1986, p. 8) when he described a framework for Pedagogical Content Knowledge (PCK):

1) Content Knowledge
2) General Pedagogical Knowledge
3) Curriculum Knowledge
4) Knowledge of Learners
5) Knowledge of Educational Contexts
6) Knowledge of Educational Ends
7) Pedagogical Content Knowledge [PCK]

Shulman introduced PCK as teachers' "own special form of professional understanding" (Shulman, 1987, p. 8). Shulman (1987) claimed that the emphases on teachers' subject knowledge and pedagogy were being treated as mutually exclusive domains in research concerned with these domains. The practical consequence of this exclusion was the teacher education programs in which a focus on either subject matter or pedagogy dominated. To address this dichotomy, he introduced PCK as a way of bridging content knowledge and pedagogical knowledge. Shulman (1986) acknowledged that much is known about how teachers manage their classrooms, organize activities, allocate time, structure assignments, ascribe praise and blame, formulate the levels of their questions, plan lessons, and judge general student understanding. What was missing from the research were "questions about the content of the lessons taught, questions asked, and the explanations offered" (Shulman, 1986, p. 7). Shulman's identification of pedagogical content knowledge spawned a shift in emphasis among researchers to studying PCK and its relationship to effective teaching (e.g. Hill, Ball, & Schilling, 2008).

However, the fourth type of teacher knowledge Shulman (1986) identified, knowledge of learners, has not received as much attention as PCK. Little research has been conducted on teachers' knowledge of their own students, yet it may also be critical for effective teaching. Previous research on knowledge of learners has come in the form of creating PCK models that include some or all of Shulman's knowledge bases. For example, Park and Chen (2012) explored the nature of the integration of five components of PCK (Orientations toward Teaching Science, Knowledge of Student Understanding, Knowledge of Instructional Strategies and Representations, Knowledge of Science Curriculum, and Knowledge of Assessment of Science Learning) by tracking the development of each in a small group of expert science teachers. Park and Chen (2012) found that the most common pattern across the teachers' PCK Maps was Knowledge of Student Understanding and Knowledge of Instructional Strategies and Representations. The researchers suggested that the teachers' understanding of student understanding and corresponding teaching strategies were the two variables that were the most influential in moderating classroom instruction (Park & Chen, 2012). Previous research on PCK variables also suggests that teachers' knowledge of student understanding is critical to the development of other PCK variables. Clermont, Krajcik, and Borko (1993) and Loughran, Berry, and Mulhall (2012) indicated that teachers' knowledge of student understanding such as preconceptions, learning difficulties, and reasoning types in a specific domain facilitated the development of their PCK.

As mentioned earlier the role of a teacher in an argument-based inquiry classroom has typically been described as a facilitator of student knowledge, instead of being the only source of knowledge in the classroom. Many teachers who did not experience learning in such a manner may find it difficult to enact their curriculum in such a way. This paper, will attempt to provide a framework (Figure 1) and practical examples that teachers can use to help guide their lessons as they learn how to use the knowledge base of knowledge of learners to help guide their learners to scientifically valid claims that are backed with evidence.

The framework (Figure 1) starts with a stimulus, provided by the teacher, that makes student pre-instruction knowledge of the topic public. If the information is not available to the teacher it will be impossible for the teacher to form an accurate judgment of the students' understanding and to adapt future lessons that fit the students' needs. The exchange must happen in a context that the teacher shares with the student in order for the information to be available. For example, if students feel comfortable explaining their understanding with peers in small groups, but not in front of the entire class the teacher may miss the more private interactions and inaccurately judge the students' understanding of the lesson.

Once the teacher has possession of this knowledge they can provide numerous activities that ask students to accommodate or assimilate their prior knowledge (examples will be provided in a later section). These interactions could include classroom discussion, formal investigations, teacher demonstrations - with follow up discussion, etc. Once the teacher feels comfortable with the students' level of understanding he/she can ask the students to construct claims based on evidence collected during the previously mentioned interactions. The student claims would be suspect to critique by both the teacher and classmates. During this stage of the unit student knowledge would still help guide learning because the teacher would ask students to revise claims if they were not supported with quality evidence. If students are given multiple opportunities to evaluate and critique their own knowledge it is possible that they will form new, more accurate, knowledge as a result of the practice. While the framework is designed in a semi-structured pattern it is important to note that assimilation, accommodation, construction and critique could occur at any stage of learning. For example, a teacher might ask students to make an observation at the beginning of a unit, followed by students assimilating or accommodating their prior knowledge to the stimulus. The students' initial ideas would then be investigated through formal labs, or discussion. Once the teacher feels the students are prepared to construct a claim, based on their observations, discussion between peers and teacher, and a reflection period where the students' initial ideas are challenged and reconstructed, the students will make their claims public where they will be open to the critique of peers. After ideas have been negotiated in the construction/critique phase it is possible the students will create new knowledge. This new knowledge will be evaluated against the students' initial ideas where another opportunity of assimilation or accommodation may take place.

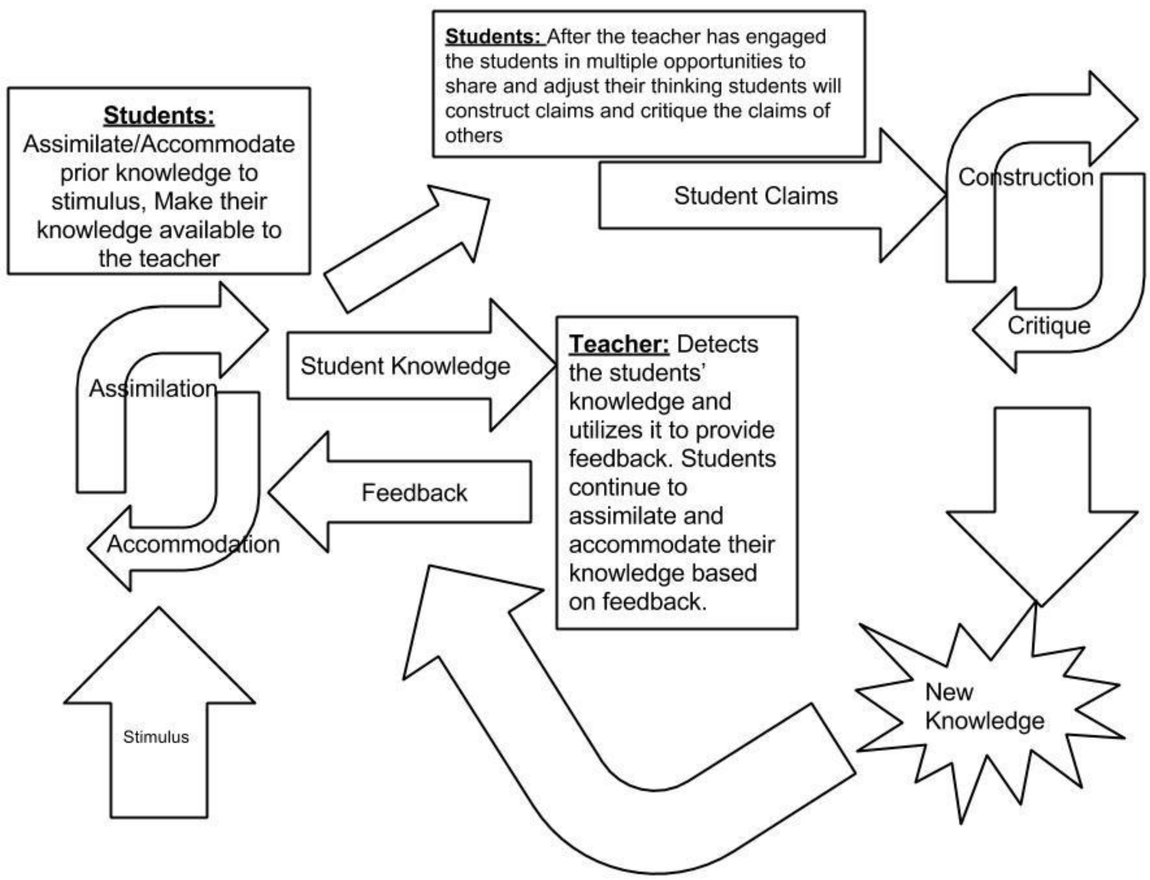

Figure 1 - Theoretical Framework

In the following sections the concepts of assimilation and accommodation and construction and critique will be discussed. These four aspects of quality science teaching are nothing new to the literature, however this paper provides examples of practical application in a classroom, and also emphasizes the use of student knowledge to help teachers guide their teaching.

Assimilation

Existing views in philosophy of science propose two phases of conceptual change; assimilation and accommodation. Conceptual change in a science classroom has been described as promoting changes in a student's conceptual understanding of the subject (Hewson, 1992). Assimilation is a stage of conceptual change and involves students taking existing concepts and immersing them in a new phenomenon (Posner, Strike, Hewson, & Gertzog, 1982). Posner et al. (1982) view conceptual change as the process whereby a learner's existing beliefs change over the course of that person's experience with established concepts. If the learner is adding new knowledge to the framework that is not radical but rather extends or strengthens the framework, then it is considered to be assimilated into the existing framework (Norton-Meier, Hand, Hockenberry, & Wise, 2008). In actual science, research is done against established theories which organize the field of work. Before these theories can become established a series of phases typically occur before the scientific community will accept them. Thomas Kuhn's book *The Structure of Scientific Revolutions* (1970) established stages that ideas must pass in order for them to be accepted. The stages are the Pre-Paradigm, Paradigm, and Normal Science. In the Pre-Paradigm stage there are frequent debates that don't come to agreement and all facts seem equally relevant until one idea takes the lead over others (Kuhn, 1970). This one idea then is evaluated under more strict conditions, scrutinized to its most esoteric flaws. If the idea is found valid after appraisal it becomes a paradigm (Kuhn, 1970). In the next phase the scientific community strives to bring the empirical data established in the paradigm evaluation in concert with theory (Kuhn, 1970). When the scientific community agrees the paradigm becomes the established "normal science." When normal science is challenged by anomalies chaos can ensue and either a new paradigm is established and the old paradigm is removed, or the anomalies are refuted and the rules of normal science remain (Kuhn, 1970).

A learner assimilating new knowledge is a similar process to Kuhn's Pre-Paradigm stage of the journey to normal science. Students come into a science classroom with existing concepts. Even before a human is born they begin perceiving the world through their senses (Murphy & Moon, 2012). These perceptions can lead to false conceptions when the perception is only evaluated by the mind of the child (e.g. objects are pushed to the ground, the Sun moves around the Earth). Kuhn believed that in the Pre-Paradigm period ideas are not viewed as right or wrong, but instead looked at in terms of being understandable, credible, and useful. Scientists negotiate ideas in a related way through a social process (e.g. conferences and peer reviewed journals).

The process of assimilation in a science classroom can take a similar role to Kuhn's Pre-Paradigm period. It does not attempt to force students to surrender their concepts to the teacher's ideas but, rather to help students both form the habit of challenging one idea with another, and develop appropriate strategies for having alternative conceptions compete with one another for acceptance (Hewson, 1992). Experiences provided by the teacher can strengthen a student's belief by taking what they know and assimilating it to a new experience. When a learner encounters a new experience he or she must rely on their current concepts to organize their learning (Posner et al., 1982).

Classroom Activities to Assist Assimilation of Student Knowledge

There are various activities teachers could engage their students in to help assimilate their pre-instruction ideas with the ideas supported by the scientific community. However, before any of these activities can take place, student knowledge must be made available to the teacher. An activity that may be useful in acquiring this knowledge is group concept mapping. A concept map is a diagram that depicts suggested relationships between concepts (Novak & Cañas, 2006). Concept maps provide an opportunity for students to share their prior knowledge, but require the students to advance to negotiation because they are asked to make connections. When students are asked to make concept maps in small or large group settings they must explain why they are making the connection between the concepts. In doing so the teacher builds an atmosphere in the classroom where all ideas must be scrutinized and stand on their merits (Norton-Meir, et al., 2008).

Other organizing strategies like KWL charts can help a teacher identify missing information, but concept maps can help teachers identify missing or inaccurate concepts. KWL Charts are a technique used to access prior knowledge. A general topic is introduced, and students are asked to create a list of what they think they Know about the topic. This information is recorded in the K section of the KWL Chart. Next, the teacher asks students what the students Want to know about the topic. This information is recorded in the form of questions or categorized by topics in the W section of the KWL chart. Finally, after the unit/topic has been completed, individual students or teams complete the L, or Learned section of the KWL chart. The KWL activity is good for summarizing and making comparisons to what the students originally thought, but it is very teacher-directed and does not allow the same opportunities that a concept map does. For example, a teacher beginning a unit on force may have their students fill out a KWL chart where the student identifies they know the term gravity, and the teacher may assume the student understands that gravity is an attracting force that pulls objects closer together. If that same group of students filled out a concept map the term gravity would not be allowed to stand on its own, it would have to connect to another term on the map. If both “push” and “pull” were written on the concept map a negotiation of where to connect the term gravity would need to take place among the students.

The teacher’s role during this assimilation phase would be to ask students to make connections to unattached terms. When a disagreement among students ensues the teacher’s role would not be to step in and be the tiebreaker, providing the answer, but instead ask each student to back their claim with evidence. In either case, the teacher’s role is to evaluate student knowledge, but not correct misconceptions. Instead the teacher must find ways to put the student in situations where their initial ideas are challenged and examined under the scrutiny of evidence-based science (See Table 1). The activities described in this section would require the teacher to have very tentative lesson plans. They would need to adapt future lessons/investigations so the students’ misconceptions could be addressed or the teacher could build upon their initial ideas. When the learner realizes that their belief does not have the plausibility they thought it had the conditions may be possible for them to engage in a more radical form of change; accommodation, which will be discussed in the next section.

Accommodation

Accommodation is a process where students must replace or reorganize their central concepts (Posner et al., 1982). Once prior knowledge conflicts with existing conceptions, then it cannot become credible or useful until the learner becomes dissatisfied with their old conceptions (Hewson, 1992). When the learner realizes that their initial thoughts are not conducive to current conceptions the new conception elevates itself to a higher level than the prior knowledge of the learner. Piaget discussed accommodation as an imbalance of equilibration and the learner will seek to restore balance by mastering the new challenge (McLeod, 2009). The process of accommodation is synonymous with Kuhn’s (1970) description of anomalies challenging normal science. Like the learner holding on to their perceived conceptions and rejecting the new knowledge being told to them, the scientific community initially rejects an anomaly. Both the learner and the scientific community will only begin to accept the new knowledge once they have reason to believe in its plausibility and usefulness. The key factor in inducing the learner’s conception exchange is an understanding of generalizability (Hewson & Hewson, 1984). A teacher will need to give students more than one example of phenomena in order for them to begin to believe in a concept that is foreign to them. If a teacher demonstrates heat conduction to their students by having them rub their hands vigorously and then touch their face, but does not show how the phenomenon applies to nature's laws, the example becomes a random fact left to memorize. But, if the phenomenon is first taught as a general concept and then multiple examples of evidence are given to back up the claim, then the learner's misconceptions may fall short once they realize that they do not hold up to the overwhelming examples that the scientific community has amassed. In Kuhn's *Structure* normal science will not be undone until a new paradigm, can take its place. The mind of a learner who has established a false belief can be equally as stubborn and rigid as normal science dismissing an anomaly.

Classroom Activities to Assist the Accommodation of Student Knowledge.

Posner et al. (1982) claimed that conceptions become initially plausible when one or more of five factors are met:

> 1) One finds the conception consistent with one's current metaphysical beliefs and epistemological commitments 2) One finds the conceptions to be consistent with other theories or knowledge 3) One finds the conception to be consistent with past experience 4) One find or can create images for the conception, which match one's sense of what the world is or could be like. 5) One finds the new conception capable of solving problems of which one is aware (p.218).

An argument could be made that few, if any, of the five factors listed by the authors could be accomplished with traditional lecture. In addition, all five factors all require input from the learner, and ask the teacher to consider the conceptual beginnings of their learners. An approach that may be useful in factors 1-2, could improve the quality of classroom negotiation, and concept accommodation is Jerome Burner's theory of structure. Bruner wrote about organizing topics into simple "big ideas" or concepts before teaching the complexity of a subject. Bruner described structure as: "Grasping the structure of a subject is understanding it in a way that permits many other things to be related to in meaningfully. To learn structure, in short, is to learn how things are related" (Bruner, 1960 p. 7). Bruner (1960) expands by making four general claims about structure: Understanding fundamentals makes a subject more comprehensible (p.23); unless detail is placed into a structured pattern, it is rapidly forgotten (p.24); understanding of fundamental principles are crucial for transfer of knowledge (p.25); and by constantly re-examining material taught in elementary and secondary schools it is easier to narrow the gap between advanced knowledge and elementary knowledge (p.26).

A teacher could use Bruner's model of structure to improve negotiation by first establishing a simple concept that will guide the unit, an anchor that all future learning will be hitched to. Once that big idea is established the teacher can change their questioning from "What do you think is happening?" to "What do you think is happening in relation to the big idea?" The teacher's role in the negotiation process then changes from "gatekeeper of knowledge" who tells students the correct information to facilitator who asks a student if their idea fits the established big idea.

An example of establishing structure to aid in accommodation could be a teacher who first establishes a big idea of "When objects collide energy is transferred between them." The teacher could give examples like toy cars crashing into each other or hands rubbing together. Hopefully the examples would provide enough evidence for the student to support the big idea. Next, the big idea would be investigated further by students by collecting data and analyzing their observations against the structure of the big idea. If the teacher drops a ping pong ball and asks the students why it did not return to the release point answers like "It ran out of energy or the energy was destroyed when it hit the ground" must be evaluated by the classroom. When the teacher asks "What do you think happened? And please back your claim with evidence that is linked to the big idea" the students begin challenging the validity of peer claims, instead of making justifications of pre-conceived notions that their schema developed. Linking initial ideas to a big idea is one way to increase the quality of negotiation, and it can be expanded to other parts of the inquiry experience. When students conduct an investigation and collect data instead of asking the students "What do you think the data is telling us?" a more appropriate question could be "Do the data we collected support our big idea, what evidence do you have to back your claim?". Accommodation is not a spontaneous occurrence, it takes time and repeated examples for the new concept to replace the established ones (Norton-Meir, et Al., 2008). By continually asking students to evaluate findings, in relationship to a big idea, with themselves and peers it is possible that their dissatisfaction with their conceptual beliefs will be lowered to a point that new ideas will overtake them.

Once again, student ideas would drive the instruction during the construction/critique part of the unit. Students would design experiments, self-evaluate their initial claims with observable data, and compare their claims with others. The teacher would not step in and provide the correct answer, initially, but instead ask the students probing questions and questions that challenge their ideas that are specific to the students' initial ideas.

Discussion

In the initial phase of the theoretical model the teacher's goal is to gather student knowledge, and secondly put the learner in as many situations where they must evaluate their ideas by comparing them to data collected from investigations or classroom discussion. The teacher's role is not to collect student knowledge and then correct misconceptions, but instead to help students compare their initial ideas with the evidence provided.

A teacher applying inquiry in such a matter would, in theory, allow students to search for answers to questions and produce an explanation based on their understanding of the problem at the time. It is possible that if the teachers acquire knowledge of their learners, they would then provide feedback and moderate future lessons based on their knowledge of their students' understanding. Teachers who are experts in using this type of teaching in a science classroom should have extensive knowledge of how their students reason through problems, the students' ability to construct a scientifically valid claim, and their overall understanding of the concepts taught (Bruner, 1960). Most science education researchers would agree that a strong knowledge base of student understanding is critical for quality constructivist-based science teaching, but no research could be located that has empirically investigated this type of teacher knowledge. This paper does not aim to quantify teachers' level of knowledge of learners, but rather to provide a framework for future research endeavours.

Once student ideas have been assimilated and/or accommodated to the views of the scientific community the teacher will ask the student to construct a scientific claim and critique the claims of peers. In the following section a theoretical base for construction and critique will be provided followed by a summary of how teachers can use knowledge of their students to implement this type of negotiation in their classroom with fidelity.

Construction and Critique

The relationship of a construction of scientific ideas and critique of those ideas is an interaction that has been subject to much scholarship (e.g. Ford, & Forman, 2006, Lemke, 1990). The term construction may lead one to believe the relationship is promoting constructivist learning theory, but the relationship moves beyond the tenets of said theory. A definition of constructivist learning offered by Jonassen (1991) is: "A function of how the individual creates meaning from his or her own experiences" (p.10). Constructivist do not believe learners transfer knowledge from the external world, rather they build personal interpretations of the world based on individual experiences and interactions (Jonassen, 1991). The belief that learners construct their own knowledge is not being challenged in this essay, instead the construction/critique approach is concerned with the learner's authority to claim that their beliefs supersede the views of the scientific community (Ford, 2008). A learner's claim that is held unaccountable by the critique of agreed upon science is the main criticism of constructivist learning theory (Nola, 1997).

A working definition of the construction and critique relationship in science classrooms used in this paper is: using experience, or schema, to construct a belief of how the natural world works and critiquing that view against the beliefs of agreed upon scientific theory. Or as Ford (2008) claims: "Construction and critique characterize scientific reasoning involved in generating new knowledge claims. Construction without appropriate critique would not result in science" (p.410).

Teacher's Role in Using Student Ideas to Assist Construction and Critique

"Science aims for definite and specific claims, and for evidential support, often in the form of data that are themselves constructed, in the sense of being collected and represented and summarized in some posited pattern" (Ford, 2012, p. 234). In many typical science classrooms the end result of a lab or unit is a write up, which probably aligns with the scientific method. The scientific method is traditionally used for science publication purposes by actual scientists; however, in science classrooms it is a tool that rarely asks students to generalize claims (Hand et. al., 2009). A lab write up also is typically written to the teacher so the language used in the writing resembles a "memorize and recall" style rather than a style that demonstrates a deeper understanding of the vocabulary used.

An alternative approach to traditional assessment is summary writing or writing-to-learn (WTL) activities. "WTL activities are short, impromptu or otherwise informal writing tasks that help students think through key concepts or ideas presented in a course" (Writing Across Curriculum Clearinghouse, 2013, p. 1). As students complete WTL activities their ideas are continuously put on trial and evaluated against data collected during these writing assignments.

WTL activities can occur throughout the unit as students construct claims and critique peer claims. They do not have to be exclusively summative exercises, but can be formative tools of learning where student ideas can be made available to the teacher through activities like journal writing. An example of a WTL activity, post-investigation, might involve the teacher providing students individual reflection time (usually via journal writing) to first explore their personal understanding of the scientific content and data collected from the investigation (construct) and then the views are defended in small and large groups (critique). The role of the teacher is to provide a classroom milieu where there is an attitude of respect for everyone's ideas. When a student provides a false belief the teacher should not instantly correct the student, but instead ask them to back the claim with evidence. That evidence should then be evaluated by a group of peers in the classroom. The teacher's role changes from "gatekeeper of knowledge" to consensus maker. The instructional pressure is not to decree how to construct a scientific claim or argument, but instead is focused on how to critique it (Ford, 2012).

The purpose of the summary-writing is to link all of the unit's activities together (Norton-Meir, et al., 2008). One approach that uses WTL extensively is the Science Writing Heuristic (SWH). In SWH summary-writing activities the audience is typically not the teacher and is preferably younger than the writer (Norton-Meir, et al., 2008). The writing is usually a non-traditional mode of writing (e.g. cartoon, poem, magazine article, blog post). The peer audience is favored because the writer must go through a translation process with the new scientific facts they have learned. This writing is then first critiqued by the authentic audience and then returned to the original author. The critique process that the audience provides is important because they must give feedback based on the author's ability to link theory and practice (observations to the established big idea). This part of the construction/ critique process can be difficult because it requires and audience that is familiar with the big idea and the process of providing feedback that asks for claims to be backed with evidence. If the feedback given asks for more clarification the teacher will ask the student to revise their writing before they submit their final product.

Summary

The purpose of this paper is to provide a framework for Negotiation in the shared spaces where the big idea is broken open, picked apart, and reconstituted. The extent to which this happens is in-part a function of where the student is with the conceptual understanding of the big idea. Table 1 provides information on how this might look in an actual classroom. The table aligns how knowledge of learners could be used in the classroom, notions of assimilation, accommodation, construction, and critique, student activities, and potential teacher questions.

If getting students to engage in scientific negotiation is viewed as a skill that is important for students in science classrooms to learn then the level of student knowledge the teacher possesses should be re-evaluated as a critical component of teacher knowledge. Teachers should not focus solely on science content, or pedagogical knowledge, but in addition focus on getting students to negotiate their way through content by gathering as much knowledge about their student's understanding of the content as possible and then put their students in situations where those ideas are challenged.

Table 1- Practical examples of how student ideas can be used to enhance inquiry.

Use of Student Knowledge	Student Activity	Type of Negotiation	Teacher Role	Teacher Questions
-Establish misconceptions students have. - Help the teacher make decisions about how they will address misconceptions - If students understand basic concepts or can explain the scientific phenomena in the context provided, the teacher can move onto asking students to generalize to a grander scale (example: If they can explain that gravity pulls a baseball down, can they explain how gravity affects the moon and stars).	-Observe -Journal	Assimilation Accommodation	-Set up multiple “Stations” that represent wave movement (e.g. tuning forks, drop a pebble in a cup of water, iPad app that displays sound waves and decibels, youTube video of earthquakes. Put students in groups and have them place a black bucket over their head for 30 seconds – then take the bucket off and have their partner watch their pupils shrink. Have two iPads facetime with each other. - After students observe have them write in their journal, then discuss what they wrote with their small group.	-What did you observe? -What do you think is happening? -Have you seen similar movements in the real world? If so how were they the same or different than what you observed? -What did other people in your group think? -Did they provide specific personal examples for their claims?
	-Concept Map -Develop Big Idea	Assimilation Accommodation	-After students have had time to discuss the observations of the stations the teacher will have the students develop a big idea for the unit.	- Do you think all waves behave the same way? -Can you make connections to the different stations?
-Does the student have knowledge of the structure of proper scientific designs when conducting investigations (can they explain what dependent and independent variable are and what their purpose is?)	-Develop testable question -Create an experiment	Construction /Critique	Ask students to think of a testable question that relates to the big idea. Allow students to construct the procedure, and then critique each other until a consensus is made.	-What are the variables in the experiment? -What needs to be controlled? -How will we collect data? -What materials will we need?

Use of Student Knowledge	Student Activity	Type of Negotiation	Teacher Role	Teacher Questions
-Can the students make connections between data collected and prior knowledge? Can they take their knowledge and align it to the big idea?	-Develop claims based on observations, schema, and data collection	Construction /Critique	-Ask students to write in their science journals -Ask them to compare their thought to other students.	-What does the data tell you about what happened? - Did the results of the experiment make sense in relation to the big idea?
Can students align their prior knowledge, the data collected from investigation, and text they read?	Read information about the scientific concept in textbooks or other sources.	Construction/ Critique	-Ask students to read in textbooks. -Write in their journals -Compare their reflections to others - Attempt to from a sense of triangulation (student ideas, empirical evidence from experiment, and text). - Attempt to track the students thinking and how it changes from the pre-instruction ideas.	-What are the ideas of other scientists? -How do their ideas compare to yours (be specific)? -Have your ideas changed since the start of the unit?
Can students express their knowledge in a creative and non-traditional way so the ideas they support are clearly evident?	WTL summary writing activity	Construction and Critique	Ask students to write using a non-traditional mode of writing to a peer or younger audience.	-How will you communicate your ideas to the audience? -How will you make sure they understand the words you use?

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