

Radical versus Social Constructivism: Dilemma, Dialogue, and Defense

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Abstract

This paper aims to discuss epistemological and philosophical foundation of meaningful learning and teaching mathematics and science from the perspective of radical and social constructivism. I have reflected on my experiences of radical and social constructivism through dilemma, dialogue, and defense of my personal epistemology of learning. I went through articles of different authors which immensely put me into a dilemma as I tried to make connections to my experiences of learning and teaching mathematics and science. While doing this, I found myself in a great crevice of philosophical tensions between radical and social constructivism that lead into further dialogue between two selves, one as radical and other as social constructivist, and defended each epistemological/philosophical identities in terms of learning and teaching mathematics and science.

A Bricolage of Epistemology

Are there as many theories of teaching as there are theories of learning? Is constructivism a theory of teaching or learning? Why constructivism is radical or social? Does it matter if it is radical or social? To me, each method or approach of teaching has a backdrop to a theory of learning. Different styles of teaching demand understanding of different styles of learning by students. Therefore, “How students learn mathematics and science?” is an area of wide discussion, study, and theorizing. Many philosophers and Psychologists (e.g., Maxine Greene, Jean-Paul Satre, Karl Marx, Henry Giroux, Paulo Freire, B.F. Skinner, Evan Pavlov, John Dewey, Lev Vygotsky, J. Bruner, Richard Rorty, Pestalozzi, Vico, Satre, P. Ernest, von Glasersfeld, L. Steffe, etc.) contributed in the theory, epistemology, and philosophy of learning, and subsequently, they impacted in teaching mathematics and science differently at different moments. Focus of this paper is social and radical constructivism in relation to how do these epistemological and philosophical perspectives and methods influence teaching and learning of mathematics.

Paul Ernest (1995) discusses key paradigms of education with various forms of constructivism. He uses different metaphors of mind to describe various forms of constructivism. He mentions that metaphor of mind in *traditional empiricism* is like an empty bucket, a tabula rasa, or a passively reflecting mirror. This means mind at the beginning of learning is empty, and learning meant to transfer knowledge from teacher’s mind (as a reservoir) to learner’s mind (as an empty bucket) like transfer of a commodity from one vessel to another. The mind within this context reflects objective reality in the world. The metaphor of the world is like *absolute space* with all the natural bodies in it to be discovered by a mind. This is Newtonian absolute space where the things appear to us as they are in the nature. The space out there and objects in it are the reality. This paradigm considers mind and body as separate entities and knowledge and knower are detached. Scientific realism is close to this paradigm within which mind is considered as

a physical object and hence process of learning is a mechanical phenomena going in the mind.

Next paradigm is *information processing* in which the metaphor of mind is like an *active processor* in a computer. This metaphor considers that mind is like a processing machine that passively receives data, processes them objectively, and produces outputs (Ernest, 1995). There is no role of subjective judgment even in the individual mind when acting like a processor. The mind processes, recalls, remembers, compares, classifies, retains, and reproduces facts. The teacher's mind inputs information to student's mind, and student's mind like a machine processes this information to gain desired output. The metaphor of the world is like an absolute space with all the natural bodies in it to be discovered by a mind. The world out there has true knowledge that we have to discover. Johnson (2001) lists three tenets of information in the eyes of the beholder "information does not exist physically, information is conveyed signals, and systems process information indirectly by acting on signals" (<http://www.ima.umn.edu/>). This clearly shows that the metaphor of mind is an active processor of the information or signals that it receives through sense organs. The metaphor of the world is still objective Newtonian absolute space where the mind acts as a processor.

The third paradigm is trivial constructivism in which the metaphor of mind is like an ideal of soft computer. This metaphor of mind assumes that mind is not like a passive computer processor, but it is a processor which constructs its own processing data (Ernest, 1995). This seems more invigorative than the information processing metaphor in the sense that mind is not just a passive receiver and processor of information (or data), but also an active creator of its data. The metaphor of the world is like absolute space with all the natural bodies in it to be discovered by a mind. This is Newtonian absolute space where the things appear to us as they are in the nature. Here, the thought-provoking thing is that the mind has been considered as an active creator of data that it processes, but still the world is considered as objective and absolute. The mind constructs knowledge from the objective reality present in the Newtonian absolute world out there.

Sociocultural cognition is another paradigm in which the metaphor of the mind is like a strategist or game player (Ernest, 1995). Here, I think, a game player means an active processor, but it is making choices among the available alternatives. The mind as strategist manipulates data, and then, it makes best of the choices available in the data that it creates either within the self or the community (with others). The mind as strategist has a goal, adopts appropriate strategy to optimize efficiency, and produces desired results. The metaphor of the world is like a society in Newtonian absolute space with all the natural or artificial bodies in it to be discovered by a mind. The society in Newtonian absolute space means, to me, that a reality either created by individual or collective minds is subject to an objective verification. The society in terms of knowledge, practices, and history is viewed from the frame of an absolute truth. Social participation, interaction, and networking is viewed from absolute objective reality in the world.

Next paradigm is radical constructivism which assumes that mind is like an organism undergoing evolutionary process. The metaphor of the evolutionary mind, to me, is the cognitive construction continues adaptation to the better and clearer concepts or mental percepts through reorganization of the experiential world (Ernest, 1995). The mind is like an organism that undergoes continuous evolution like Darwin's theory of natural selection. Here, the selection process is governed by the adaptation of mind to the

experiential world. The metaphor of the world is the subject's experiential world. The Newtonian absolute space is rejected and is replaced by the subjective world of an individual. There might be objective reality, but there is no way to know it meticulously. Whatever we claim as reality, that we know about the world, are all subjective experiential world(s). The construction of meaning is an individual process though there might be mediation of some social activities in such process.

Social constructivism is another paradigm in which the metaphor of mind is like a connected network of self and other. The mind is seen not only in individual context, but it is expanded to be a part of broader social context, and construction of meaning is considered as social phenomena. The role of an individual mind in the construction of meaning is valued in a broader context in relation to others. The mind constitutes social entity which creates meaning through conversation, dialogue, interaction, and social exchanges of ideas (Ernest, 1995). The individual mind becomes collective mind through social phenomena such as relationships, participations, negotiations, and sharing. The metaphor of the world is associated with socially constructed world. It does not assume that there is an isolated individual reality far from socially constructed world. The metaphor of the world is like a social and connected experiential world. It also denies the existence of absolute reality. Personal experiences of individuals become social and collective experiences when they are shared, interacted, and retained as knowledge. Therefore, the world is constructed out of shared experiences either from the society and culture and/or from the physical world.

The next paradigm of learning is social constructionism in which the metaphor of mind is like that of dialogue or drama with individuals represented as actors with parts played in the drama (Ernest, 1995). The mind in this paradigm is seen as an actor in a socially constituted dialogue or drama. I think the mind is considered as an active role player in the religious, social, cultural, economic, and political arena through interconnected actions and reactions at different levels (as leaders, followers, or bystanders). The metaphor of the world is associated with social reality. The social reality dominates individual perspectives in many decisions and actions in social phenomena.

Are there other metaphors of mind and the world? I think we can construct such metaphors to portray our personal epistemology and philosophy of what constitutes learning, teaching, and existing in the world. To me, these metaphors are not static, rather exceptionally dynamic. An individual can move from one metaphor to another quickly or may take longer time (even ages) depending upon his or her perceptions, beliefs, values, and practices, and through scholarly discussion with colleagues or other community members. The dynamic interplay of these metaphors helps us to understand the multiplicities of epistemological and philosophical bases and interpretations of mind and body, being and existing, performing and acting, and relating and connecting things in natural and social arena. I think the metaphor of mind and the world is helpful to understand the ontological, epistemological, methodological, and axiological standpoints of an individual or a group. The mind-body Cartesian dualism sees mind and body as a separate entity where as physicalism or materialism sees both mind and body as same in terms of matter. All About Philosophy (www.allaboutphilosophy.com), states that "materialism holds that everything in the universe is made from physical materials including human mind or brain and that spiritual attributes do not exist in the universe" (n.p.). The website also mentions about different forms of mind such as material only

mind and spiritual mind. To me the metaphor of mind and the metaphor of the world is associated to personal beliefs and practices based upon whether we consider material only mind or spiritual mind. Then these metaphors are also associated to constructed (personal and social) world and the absolute physical world that we sense through sense organs. I think the debate still continues about “Which mind (material or spiritual or materiospiritual) and which world (constructed or absolute physical or constructed relative) we believe in and make sense of?”

All of these theories of knowledge can be divided into two types: constructivist epistemology and non-constructivist epistemology. The differences in these categories, to me, are in the ways they explain the nature of knowledge (subjective or objective), the way we reach the knowledge (methods or approaches to construct knowledge), and meaning of knowledge (what constitutes knowledge to us). Constructivist epistemology assumes that knowledge is actively constructed by the cognizing subject. This theory of knowledge considers that knowledge and knower are inter-connected. Therefore, knowledge about the world is subjective. This epistemology does not speak about ontological reality (Noddings, 1990). Knowledge is built up on experiences of the knower. When a subject comes to know something, means that he or she builds up a mental construction of thing that he or she knows. Over time, this mental construction continues changing in the due process of adapting with the knowledge he or she has, and the new knowledge he or she gains through experience. Therefore, constructivist epistemology considers that knowledge is self-adaptive (von Glasersfeld, 1995) and self-adjustable based upon new experiences. Constructivist epistemology rejects objectivity of knowledge though there may be objective reality beyond the world of our experience, but we do not have yet any tool to know it. Since knowing is always a personal or subjective experience, what a person knows of an object or an event might be totally different from what another person knows about the same object or event at the same time and in the same context.

Non-constructivist epistemology assumes that knowledge is objective. It is absolute and can be verified objectively. The knowledge of/about the world is independent of the knower. Knowledge is eternal. Whether there is the presence of knower or not, knowledge exists for ever. Therefore, for non-constructivist epistemology, knowledge is priori (Restall, 2009) and it can be achieved through scientific methods. This epistemology assumes that scientific methods and reasoning can lead us to the ultimate truth about an object or the world. The natural world is out there for us to discover its miracles. The theory and method of non-constructivist epistemology considers positivism and post-positivism as epistemology to understand knowledge and reality of both physical and social world. This epistemology assumes that scientific knowledge/model of the world can truly represent the reality about the world. Though 100% precision is difficult to achieve, but they claim best understanding of the reality through scientific methods in which degree of precision can be increased (theoretically) close to 100%. They reject the subjectivity in knowledge. They claim any knowledge is unique no matter how we come to know it. They still value Descartes’s mind-body duality. They consider that what one knows about an object or the world is different from him or her. The knower and known are separate, and they exist separately (ontologically).

I would like to connect my line of thinking with Noddings’s (1990) question in relation to the nature of constructivist epistemology. Noddings says, “even if

foundational epistemology is rejected (and this is what constructivists should do), some epistemological questions remain, and, of course, constructivists have not rejected epistemology” (p. 11). She further asks, “What sort of assumption (epistemological, psychological, or both) is being made when one says, ‘all knowledge is constructed’?” (p. 11). Constructivists believe that knowledge is constructed personally and socially based upon experiences. Then, Noddings further asks “What has the assumption to do with judging the status of general knowledge claim? How do we judge when one knows and when s/he does not?” (Noddings, 1990, p.11). To me, these epistemological questions are significant indicators of judging and distinguishing constructivist and non-constructivist epistemologies.

Stepping on Radical Constructivism

The epistemology and theory of radical constructivism has a backdrop on Piaget’s constructivist theory of knowing. Von Glasersfeld (1995) clarified how he interpreted Piaget’s constructivism and came up with landmark epistemology of radical constructivism. He points to the learning theory that emerges from Piaget’s work. He summarizes Piaget’s learning theory:

...that cognitive change and learning in a specific direction take place when a scheme, instead of producing the expected result, leads to perturbation, and perturbation, in turn, to an accommodation that maintains or re-establishes equilibrium. (Von Glasersfeld, 1995, p. 68)

I think the condition of perturbation is similar to von Glasersfeld’s idea of subjective experiential constraint. These perturbations or constraints are associated with Vygotsky’s zone of proximal development. Because of these zones, an individual feels that his or her existing experience contradicts with new experiences and develops a state of readiness for learning (by resolving the tensions between existing scheme and new scheme). To me, this readiness is associated with Steffe’s idea of epistemic students. “Epistemic students are dynamic organizations of schemes of action and operation in the researcher’s or teacher’s or student’s mental life (Steffe, n.d., p. 17). Steffe further clarifies that the schemes of actions and operation include accommodations in the schemes. In short, constructivist epistemology deals with what knowledge is, and from where it comes (Von Glasersfeld, 1991). Von Glasersfeld further claims that “the constructivist theory does not fit into the conceptual patterns of traditional epistemology, precisely because it posits a different relation between knowledge and that ‘real’ outside world” (p.170).

Von Glasersfeld (1989a) states that “knowledge is not passively received, but actively built up by the cognizing subject” (p. 182). Ernest (1995) claims that constructivism well acknowledges that knowing is active; it is an individual mental or physical process that goes on while knowing; and it is a personal phenomena. Largely knowing is based on previously constructed experiential knowledge. Ernest (1995) further points to politics and states that it has to do with giving respect to those positions with which we disagree. Ernest (1995) claims that radical constructivism values multifaceted pedagogy with its heart being sensitive to individual construction. A constructivist teacher does not assume his authoritative role in class. Rather he or she brings democratic ideals in the class providing enough opportunities to the students to learn from their participation in various activities. These activities relate to creating new

experiences or re-adjusting prior experiences while constructing knowledge by students. The teacher considers that his or her role in the class is like a facilitator or a guide to the students. He or she considers the students' active role in learning, and creates such environment in which students feel free to learn in their pace. The teacher acknowledges the role of students as co-authors or co-researchers in the class. Learning does not mean to just assimilating with new information, but also involves constructing meaning. Then focus is on thinking and meanings attributed to experience by the learner (Hein, 1991). Hein further mentions that learning is an active process, involves construction of meaning, and it is a mental process. Other characteristics of constructivist learning are-learning involves language; learning is a social activity; learning is contextual; and learning takes time (Hein, 1991). Ernest (1995) states that "all knowledge being constructed by the individual (learner) on the basis of his or her cognitive processes in dialogue with his or her experiential world" (p.14). This clearly means that learning is a self-cognizing process from one's experiences. The process of cognizing is progressive since it always goes from simple to complex in an ordinary situation, whereas in some cases, it may flow in any direction depending upon the maturity of the learner, self-directed goal of learning, and complexity in the learning environment. I would like to emphasize on what Noddings (1990) states:

The great strength of constructivism is that it leads us to think critically and imaginatively about the teaching-learning process. Believing the premise of constructivism, we no longer look for simple solutions, and we have a powerful set of criteria by which to judge our possible choices of teaching method. (p.18)

Noddings' statement about constructivist approach takes us to think beyond the actual teaching and learning process, and to consider creative, critical, and imaginative thinking as over arching theme of constructivist pedagogy that Ernest (1995) emphasizes. To me, these qualities of constructivist teaching and learning are the things that I can imagine about any ideal method of teaching-learning that focuses on students' productive construction rather than teacher's imposition. In traditional criterion of objective truth (or Truth), objectivity is a key to maintain the validity and reliability of the methods and tools. Absolute truth can be represented by mathematical or scientific models. In constructivist theory an absolute truth is not possible, and it is not possible to examine whether what we know is absolute objective truth. This theory assumes that viability is one of the key alternatives to the standard or classical criterion of an objective truth. Any representation of knowledge or mental construction of what we know about the world can be a just a viable tool to understand the world as far as it best represents what it is supposed to represent.

With reference to Von Glasersfeld's second principle, the knowledge is self-adaptive, and it serves the organization of experiential world. It continues self-adjustment with new facts (?) or information about the context. The knowledge can be modified with new information. Therefore, an equation may not represent a true picture at a time (ontologically). For radical constructivist epistemology, the knowledge (e.g., a growth equation) is associated with the knower through symbols used and meaning associated with those symbols. But the equation is a construction that is most viable at the moment is created to represent the population growth at a place, and it is always at a differential status due to continuous changes in the population that may not be well reflected by the

equation. In radical constructivism, people who are in favor of this epistemology neither discard nor accept the existence of such ideal equation that can truly represent the context (e.g, population growth/change in a place). They can only claim that there is no way to know such ideal equation from experiential world even if it exists. They admit the limitations of human experiences to know the ultimate reality, and instead they introduce the idea of viability. For them, any mathematical equation or model becomes a viable representation to a phenomenon (e.g., the population growth in a place), but not an absolute representation. Viability is not a measuring rod to look at practical truth or reality as close enough to ideal truth or reality, but to me, it is a way to judge the usefulness and rationality of knowledge by “fitting within or sliding between its constraints” (Hardy & Taylor, 1997, p. 137).

Ernst von Glasersfeld’s theory of radical constructivism considers two viabilities as legitimate ways to establish knowledge. He states that:

Piaget’s theory of cognition involves two kinds of ‘viability’ and, therefore, two kinds of instrumentalism. One is at the *sensory motor level* in which viable action schemes are instrumental in helping organisms to achieve goals through sensory equilibrium and survival in their interaction with the world they experience. The next is at the level of *reflective abstraction*. (von Glasersfeld,1995, p. 68)

His second principle of radical constructivism assumes these viabilities at sensory and abstract level to modify and accommodate with new or existing mental schema or constructs. While doing this, we try to overcome the conceptual (or schematic) obstacle or constraint that comes to cognitive experience. Trying to overcome these cognitive experiential constraints leads us to learning. Then, reflective and reflexive thinking as a cognitive process (of thought experiments) becomes a major part in construction of new knowledge. “Insofar as their results can be applied and lead to viable outcomes in practice, thought experiments constitute what is perhaps the most powerful learning procedure in the cognitive domain” (von Glasersfeld, 1995, p. 69). I think viability is associated with establishing the usefulness of methods and findings of such procedures as alternative to traditional criteria of objective truth (or Truth).

Ernest (1995) further indicates that “one’s representations of the world and other human beings are personal and idiosyncratic” (p.14). For him, “such a view makes it hard to establish a social basis for interpersonal communication, for shared feelings and concerns, let alone for shared values” (Ernest, 1995, p.14). I think radical constructivism does not explicitly take account of social interaction. There is no explicit discussion about the role of social interaction in construction of meaning and self-adaptation of mental schemas while shaping learning from the experiential world. This does not mean that it does not take account of social interaction at all. I think there can be various ways to look at the issue. One is the role of language through semiotics in learning that I indicated earlier. The semiotics through which a child makes meaning of any object or event is a social process. There is interaction of child with an object, or text, or any artifact through semiotics. Semiotics clearly takes meaning from social interaction in a direct way (face to face communication) or in an indirect way (communication through artifacts). This is what my interpretation is about implicit account of radical constructivism toward social interaction. Social interaction is a necessary condition for learning and making sense of what one learns, but to me, it is not sufficient condition for learning. Social aspect is an

accessory part of learning as all social interactions do not result into learning. It is always personal or individual matter that takes place differently even within same context. Then, it is clearly a secondary aspect in learning. True learning takes place in one's brain or mind. Therefore, to some extent, learning is an individual responsibility, and teacher is simply a facilitator to help in carrying out that responsibility. There is no direct control of a teacher in one's learning, though there can be influence of the teacher in a way students learn or do not learn as intended.

If radical constructivism fully acknowledged, adapted, and incorporated the role of social interactions of learners in the process of constructing knowledge, I think, there would not be any room for the emergence of social constructivism. However, this does not mean that radical constructivists totally ignore the role of social interaction. Piaget's idea of perturbation, von Glasersfeld's idea of constraints, and Vygotsky's idea of zone of proximal development are some how associated to social interaction. Feeling or experiencing a constraint maybe due to personal experience toward an object or phenomena or it may arise due to social interaction. Ernst von Glasersfeld admits that social interaction plays a key role in construction of individual knowledge, but as a radical constructivist, he argues that the understanding and making meaning of an object or phenomena is purely an individual process, though there might be some compromises in the meaning or sense of the object or the phenomena even when individual differences still may exist.

Re-conceptualizing Radical Constructivism

Why radical constructivism is considered as radical? When I was writing this reflective journal, I was constantly thinking of why it is radical. I was in a great dilemma in many issues. I tried to draw out ideas from examples, but any example (e.g., population growth model) did not satisfy me. Also, I was confused about construction of knowledge and evolution of mind. Both construction and evolution are vague terms to me. As I was developing the journal and finalizing it, more I felt like I was just beginning. Every revision began a new beginning. Every attempt to read the papers became a new reading because every time I found new ideas that led me to thinking differently. Then I was not constantly moving toward a direction, but carrying ideas from this or that direction, and trying to synthesize my understanding of radical constructivism. I think I am too immature in this field in the sense that I am not yet able to ground my own concrete perspective of "*What is radical constructivism? Why is it radical? How is it theory of epistemology or post epistemological? What is its significance in theory of teaching and learning? Is it theory of teaching or learning, or research method?*" I am perplexed. I am at the moment in the whirlpool of thinking, reflecting, and abstracting 'radical constructivism' from the root, though I am yet not being able to find its root, and I think it will be a long journey to find a root and to the top.

Metaphorically, the reading and journal writing on radical constructivism was a journey to me. It was an adventurous, intellectually thinking, and abstracting journey. The day I began this journey should be a late evening. My daughter showed her painting to me. I asked her what the picture meant to her. She just smiled at me. She did not speak. She went to get the remote control and switched on the TV, and soon deeply engaged in watching the *Disney Chanel*. I watched her painting. A mixture of colors produced new colors. A mixture of lines produced new lines. A mixture of lines and colors created a mixture of images. A mixture of images created a different impression. A mixture of

impressions created a different thinking in me. A mixture of thinking created a silence within me. I was quiet and thoughtful for a while though there was a noise from the TV program, and there was a noise from the kitchen where Basanti (my wife) was busy in preparing the evening meal. I just remained silent for a while and imagined vivid images in the collage. I thought about Anjila's thinking when she was drawing. I thought about her thinking when she was selecting colors. I thought about her thinking when she was painting. I thought about her thinking when she stopped painting. I thought about her thinking when she was giving her painting to me. I thought about her thinking when I asked her to interpret the painting. I thought about her thinking when she was away from the painting while watching the TV program. I was thinking of her painting. I was thinking of her thinking. I was thinking. The thinking in the complexity of human interest (why she painted the collage the way she painted), the complexity of drawing (why she drew lines the way she drew), the complexity of collage (why she formed the collage of painting the way she did it), the complexity of interpretation (why we see different things in the way we see in a collage), and the complexity of thinking (why we think of things the way we think) all drew me into reflection toward the collage.

Can I know what the artist was thinking when she was painting? Can I know what could be the different interpretation of her painting? Is there any way to know the answer of these questions in absolute form? What would be the answer if I ask these questions to empiricists, information processing theorists, trivial constructivists, sociocultural theorists, radical constructivists, social constructivists, and social constructionists? If I have to answer these questions from my perspective, what will be my answer? The journey began with these questions.

While I am in this path (Radical Constructivism), I want to pretend myself as a radical constructivist, and I try to answer the questions as a radical constructivist. Then I believe that the metaphor of mind is like "organic evolution". The mind is "thinking, reflecting, abstracting, assimilating, adapting, and reorganizing" every moment in relation to personal, social, and physical environment creating subjective experiential world. To me, this experiential world is what we have access at the moment we experience, but this is not replicable. Every experience in the experiential world is unique like every object in the physical world is unique. Every experience has its own position in a space consisting of temporal, spatial, and corporeal coordinates (a few to list). Therefore, to me, every experience of every experiencing body is unique. The metaphor of the world is subjective and experiential world of meanings, senses, essences of things or phenomenon we experience. I simply do not reject the ontological reality. Because I do not have any tool to know the reality that may exist out-there, but I do not know how to know it. My sense organs have limitations of knowing from the environment. As a radical constructivist, I can claim that knowledge about what the artist was thinking when she was painting and what could be the different interpretation of her painting is associated with constructivist epistemology. This epistemology does not claim that there is a way to know the absolute reality, but it considers viability as a way to confirm or disconfirm the knowledge. This journey took me to the world of thinking and abstracting of knowledge within constructivist epistemology.

This journey is not linear. The idea of radical constructivism is associated with complexity of understanding construction of knowledge by cognizing subject, and evolution of cognitive constructions in the experiential world. The construction of

knowledge is associated with gaining information through sense organs, and making sense of the information through converging or diverging toward experiences. I think we have limited sense organs, and these sense organs have limitations within themselves. We cannot experience temperature more than certain limitation (lets say 500 Degree Celsius), and we cannot experience temperature less than certain limitation (lets say absolute zero). We cannot experience sound less than 20 and more than 20,000 Hertz. We cannot experience light beyond $(4-7.5) \times 10^{14}$ Hertz. We have a limitation of sense of smell. Though we all may have the same kind of sense organs, we may have differences in their ability. My red color may be different from your red color though it is color of the same flower. We cannot claim that there is nothing beyond sense organs, but I admit that there is no way to experience them through my existing sense organs, and construct knowledge about those things or properties of things absolutely. When I use scientific instrument to measure quantities that are not perceived by sense organs are brought into the scope of my sense organs. Again, I depend upon my sense organs to make interpretation of those values beyond the capacity of my subjective experience. This way, to me, constructivist epistemology is not associated with confirmation of absolute reality, but it is a way to seek viable means to understand the reality from within experiential world. Then to me knowledge and knower are connected together. There is no knowledge out of one's experiential world. For example, if I meet a friend from China, we cant talk in English that makes sense to both of us (through audible speech or written script), but I speak Nepali and he or she speaks in Chinese language, then experiential world can not comprehend the sound and scripts in a meaningful way. Then, for us what we speak to each other in a language that we do not understand is meaningless. There is no knowledge construction in the communication process in the language that one of us does not know though there might be sound and scripts we use in the process. Also, in the case of using English as a common language, there is personal level of interpretation of what we say to each other. There is a vast difference in the syntactic and semantic interpretation of the same word and the same sentence between two persons.

Then the journey of radical constructivism in relation to its pedagogical implication made me thoughtful about possible ways to bring the idea of knowledge construction in teaching and learning. From a constructivist perspective, every child constructs knowledge by himself or herself during pedagogical processes or activities. Children and their activities are at the center of teaching and learning. No matter what teaching method is applied, no matter what materials are used, and no matter what assessment practices are in use, learning in constructivism meant to construct knowledge by children. I think there might be some priorities for constructivist teaching, but to me, the fundamental theme or core of teaching-learning is associated with what do children construct as knowledge, when do children construct that knowledge, how do children construct the knowledge, and why do children construct the knowledge. At the next level, the concepts and ideas as knowledge become self-adaptive in the cognitive experiential world. When I come to the question about “what Anjila was thinking when she was painting, and what interpretations can I draw from her experiences” in relation to constructivist pedagogy. I think constructivist pedagogy is associated with subjective construction of meaning, and valuing subjective interpretation of knowledge about the world. Then, except defining role of teacher as a facilitator or a guide, and role of students as active participants and constructors of knowledge, to me, there is not much

clarity in constructivist pedagogy. Because, there is no way to measure or see whether a child has constructed knowledge or not. Any test or exams does not really reflect the knowledge of a child. The knowledge from experiential world is too complex. There is no linguistic tool (any semiotics) to convey one's experiences to other in the exact sense. The language we use to express thoughts, feelings, and experiences are limited in terms of depth of expressions, meanings, and structure of information. Though we think, reason, and interpret meanings through language, but to me, there is much more in experiences in terms knowledge that is beyond the capacity of linguistic tool. Therefore, pedagogy is implemented through actions and operations of language, and hence, there is a limitation in it in terms of helping children in construction of knowledge.

In constructivist epistemology, we do not seek to justify methods and tools based on criteria of objective validity and reliability, but we seek to judge them based on the criteria of viability. I came to know that there is no absolute measure of one's experiential knowledge. Then what scientist call absolute is already a relative in terms of formation of unit of measurement, comparing units, and making decisions based upon alternative results. In constructivism, there is no tool or method to know the absolute reality of the world through experientially constructed knowledge. We can experience the reality, but we do not have access to measure it. As a constructivist teacher, student, or researcher, I can describe my experiences or other's experiences through language though there is a limitation of language to bring actual experience into text. The best way of expressing experiential and subjective knowledge can be through reflections. There maybe a way to explain and interpret what Anjila was thinking when she was painting and the different meanings of her painting. I think this is what viability means in constructivism. Viability refers to the deepness, richness, and verisimilitude in the expressions of experiences and meanings. Viability has been discussed in literatures of radical constructivism as a way to establish the knowledge in and through the experiential world. The focus of viability can refer to perceptual viability and viability of abstraction in method and process.

Next step in this journey is associated with the idea of social interaction in radical constructivism. To me, radical constructivism does not deny the importance and role of social interactions in the construction of meanings. The implication of language in the construction of meanings of an object or phenomena is somehow associated with social interaction. The evolutionary mind is associated with social interaction, assimilation, or adaptation in the cognitive experiential world. The evolution of mind, to me, is either accommodation of existing cognitive concept to the new concept within self or other. Social interaction can accelerate the evolution. Again, I believe that radical constructivism assumes construction of knowledge as an individual process. If it is social, then I think there would be uniformity in the experiences. For example, when we talk about the concept of fraction in a class, we use the same material, the same language, the same concept, and the same time to discuss a fraction $\frac{1}{2}$. But students grasp it in a different way. They may discuss the fraction $\frac{1}{2}$ in the group, but finally they construct their own image of a fraction that can be different from each other's. More complex it is more variety we can find within the same group, the same time, and the same context. Social interaction, to me, can be a way to confirm or disconfirm one's idea with others. This confirmation or disconfirmation does not wipe out one's conceptions and misconceptions about fraction. The conceptions and misconceptions remain in one's mind until it gets into the next level of confrontation and re-construction through

adaptation to new experiences. For one student, the idea of fraction a/b can be a ratio of two whole numbers a and b . For another student, this fraction can be unitization of a in terms of b (How many units of b is a ?). For another student, the concept of the fraction a/b can be a product to two numbers a and multiplicative inverse of b . A constructivist teacher keeps all these options open to students for meaning and interpretation. Just group discussion, interaction, and exchange of ideas do not mean that mental construction of knowledge is social, but to me, it is always individual (as a radical constructivist). Social interaction facilitates such construction of knowledge by individual mind. There is no social mind that can construct ideas itself and goes through an evolutionary process. Collective of all individual minds in a society could be termed as social mind, but for radical constructivist, this is not a unit as a single mind within the control of single cognizing body. This is simply a constructed mind, constituted mind, and mind at large. We construct such social mind through collective thinking, abstracting, and reasoning in the social arena. This mind is everywhere in the society, and also nowhere because it does not rest on a body.

A child learns that the fire is hot by his or her own personal experiences when he or she touches a burning candle. Just interaction between the child and adults, saying that fire is hot and electricity gives a sock, does not construct knowledge in the child's mind. Gaining information through hearsay communication is not construction of sense and not learning at all because it does not produce any experience about the phenomena. It may give information to the child, but that information, to me, is not knowledge in the true sense because the child does not know whether the fire is hot or not by himself or herself. Once he or she experiences that fire is hot and electricity gives a sock, then it is not necessary for him or her to confirm that fire is hot and electricity gives a sock to others too. In a social interaction, majority of people may tell him that the fire is cold, he or she does not believe it, and does not accept it as true. Therefore, social interaction can be misleading in relation to construction of knowledge. I did not find any discussion about this kind of misleading in the literature of radical constructivism. While focusing excessively in the individual construction, critiques blame that radical constructivism may lead to solipsism. To me radical constructivism does not deny the existence of other mind and other ideas. Construction of knowledge from self-experiences does not mean that it is to reject other's ideas. A radical constructivist respects the presence of different ideas in relation an object or phenomenon. When I interpret Anjila's painting collage, I can't claim that only my interpretation is true and it is final. I accept that my interpretation maybe different from other's interpretation. Also I accept that A's interpretation maybe the same or different from B's interpretation about her art. Different person may have different interpretations about the same art, and all these interpretations are viable interpretations so far they somehow represent the collage and the way it make sense to me as a radical constructivist (for the time being).

Radical constructivism has a root in the self-construction of sense, meaning, or ideas about objects of phenomena around us. This process of construction of knowledge by an individual is deeply associated to metaphorical thinking. When we think of objects or phenomena, we make sense of them in cognitive concepts, percepts, or constructs in mind. While constructing these cognitive constructs of experiences about things or phenomena, we go through the process of reflection and abstraction. Reflection and abstraction, to me, are a kind of thinking metaphorically because we reflect upon

experiences in terms of metaphors; and we reach the depth of abstraction through the use of metaphors. These metaphors become means of conceptualizing the ideas through some sort of representations in the mind. When Lakoff and Johnson (1980) portray the notion of the metaphor as thinking one as another, reasoning one idea as another, conceptualizing one object in terms of another, understanding a relation in terms of another, and making a connection of one idea with another through a bridge that connects simple to complex, concrete to abstract, and finite to transfinite. To me all these processes described by Lakoff and Johnson (1980) are connected to construction of knowledge by cognizing subject, and evolution of mind through continuous adaptation to new experiences. I think these metaphors have great significance in mathematics, science, and other areas of study in terms of epistemological, methodological, and pedagogical assumptions of what we do, how we do, when we do, why we do in the classroom from the view point of radical constructivism.

In conclusion, this journey was like climbing up a mountain with many ice-rifts, glaciers, and steep ways with a few climbing gears. On the way up to the mountain, I was in frustration due to my internal conflict of ideas. I tried to portray as a radical constructivist when I had a very few tool to defend my claim to be a radical constructivist. I tried to understand epistemology, methodology, pedagogy, and axiology of radical constructivism from readings of various papers and online sources. I am still lost. I am still perplexed. I am thinking of which way to climb up and which way to climb down, so that I will reach the maximum height possible with minimum harm to myself and intellectual community. My misconceptions and misunderstanding will harm the intellectual community and myself if the journey does not go a right way. However, I think this is a good beginning, somehow it is a journey through which I am trying to make sense of what does it mean to be a radical constructivist.

Stepping on Social Constructivism

Let me begin from “How knowledge is constructed”. It may be a good idea to begin this discussion from science and objects of science. What is science and what constitutes objects of science? Science as a process of systematic study of nature and natural phenomena maybe a positivistic view. Whereas science as systematic study of human constructs for interpretation of natural phenomena maybe inclined toward constructivist view. Domain of science within positivist and constructivist epistemology maybe different. The positivist epistemology considers science as empirical studies of natural and social phenomena as its domain. The constructivist epistemology considers science as interpretation of nature through constructs of the scientific community. Then from this point of view scientific knowledge arises from negotiation of personal and social constructs and meaning of the natural phenomena. From the social constructivist perspective of Driver et al. (1994), scientific knowledge originates from personal constructs of individual scientists or researchers in a raw form. The raw knowledge is brought to the scientific community for further processing. Processing means bringing that raw knowledge into discussions among the members of the community through publications, oral presentations, group discussions, and sharing among each other. This may broaden the original knowledge with inputs or comments or critiques from the scientific community. The shared knowledge becomes a socially accepted and socially constructed knowledge that can be considered as ‘taken for granted’ knowledge within

the community. This process not only brings the personal to the social, but social to the personal for further thinking and construction of new knowledge. While doing this, the knowledge system creates common symbolic or semiotic entities in terms of functions, units, and entities such as force, mass, electric current, gravity, electron-proton-neutron, supernova, black-hole, gene, chemical disequilibrium, etc.

So far a relativist view is concerned, I think it is a view that considers nothing as absolute truth. Everything has a certain degree of truthfulness depending upon the context. Therefore, a relativist view is related to the existence of one truth with respect to other truth. This other truth may still be based upon another truth. This ultimately forms a cycle in which we look at one with respect to other and vice versa. Again, relativist view is confined within the empiricist perspective of looking at the nature. The existence of gravity is relative to the existence of mass. The existence of force is relative to the existence of some other physical entities (e.g., mass and acceleration). In the same way, existence of one reality can be realized with respect to other realities constituted socially or culturally. To me, a relativist view is about looking at something with respect to other, like judging a method of teaching as effective or not with respect to alternatives available. If there are no alternatives to compare with, then we cannot say whether a particular method of instruction is being effective or not. According to Driver et al. (1994), there is no way of knowing whether such knowledge is a true reflection of the world, and the notion of scientific progress is problematic (when it is viewed from relativist view). I think every knowledge system that we have till now is not beyond such problematic situation. Only thing that is noteworthy is 'to what extent these problems have been resolved' through studies and further knowledge in order to get more viable interpretation. Constructivists claim that there might be such absolute reality in nature, but construction of knowledge is limited to thinking, understanding, analyzing, synthesizing, and creating meanings through cognitive and motor actions. Even a scientific knowledge through empirical studies is a cognitive construction of mind, and there is no way to know whether they truly represent the truth in nature.

Driver et al. (1994) claim that the metaphor of learning as enculturation is more beneficial than the metaphor of learning as discovery. From a social constructivist perspective, the notion of learning is associated with collective building of knowledge through negotiation, agreements, and common practices. Learning as enculturation points to the nature of learning in a group through dialogic or dialectical thinking, and making a common meaning of things or phenomena. While doing this, every person plays the role of a learner or a learned depending upon the context and complication of things that he or she deals with. A more experienced person guides a less experienced one in the process of learning. Therefore, learning is not just a personal or individual interpretation of things, but it is a collective interpretation of things through which the less experienced members get exposure to the community of practitioner from where he or she learns the culture of knowing, doing, thinking, and reasoning. According to Driver et al. (1994) knowledge is constructed through social conversations, and activities about shared problems through which meaning is interpreted by involving persons-in-conversation with the help of skilled members. The process of appropriation of cultural tools through involvement in the social activities also helps individuals to gain control over the tools.

The metaphor of learning as discovery assumes that learning is as an individual process through which individual makes meaning of things or phenomena, and constructs

ideas out of them. Driver et al. (1994) state that “if learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical enquiry” (p. 5). In this statement, the authors emphasize access to physical experiences, concepts, and models of conventional science. They further claim that there is more benefit of metaphor of learning as enculturation than the metaphor of learning as discovery. Certainly there are benefits of social interactions. There are benefits of Socratic dialogues. Certainly there are benefits of dialectical interactions over the metaphor of learning as discovery. Learning as discovery connotes that there are certain absolute things out there that we need to find out. Learning as discovery, to me, is more positivistic and post positivistic view of learning. I am not being able to understand why individual construction of knowledge is similar to discovery learning. I don't think the social construction exists at isolation without individual construction or vice versa. Many individuals' construction of common or differing ideas may contribute in the social construction of knowledge. Construction of ideas, to me, actually may originate from an individual or a group. I could not understand why Driver et al. (1994) label it as similar to discovery learning. Existence of sea depends upon the existence of each drop of water in the sea. The existence of each drop of water depends upon the existence of each molecule of water in it. When we look at the issue from a holistic view, then knowledge construction at an individual level plays a vital role in the entire knowledge system. It has a significant impact on the knowledge construction even through the social process. The social process, to me, is a validation process of that knowledge constructed at an individual level that comes after individual's long effort on it.

A dominant philosopher or a renowned scientist can dominate entire scientific community through his her personal construction of ideas or knowledge. His or her logics, reasoning, and construction of knowledge after appropriation by the community maybe regarded as a social knowledge. Every mathematician, every scientist in history, and even today one is constructing knowledge at the individual level at first, and then they bring their knowledge to the social for critiques. In many cases, they do not change their stance over the issues even when there are arguments for or against their knowledge. Enculturation is a populist term, but it is not a fully constructivist term to me. Enculturation, in many cases, kills individual creativity, and it simply helps individuals to follow the tradition as an unquestionable system. I agree that there should be a balance in construction and enculturation. Enculturation only does not help society and individual to make a radical change or progress. Enculturation to me is similar to Darwin's theory of evolution in which change is a gradual process. If we accept and continue following the same traditions, or same practices of knowledge, we will not be able make progress further or even if it is made then it will be a slow process. Knowledge construction becomes evolution but not a revolution. It is difficult for me to agree fully with Driver et al. (1994) that the metaphor of knowledge as enculturation has more advantages than knowledge as individual construction (but not discovery).

So far the interventionist role of the teacher is concerned, we should make it clear why a teacher need to play such a role. Why intervention in science/math learning is crucial? I think intervention is necessary when students cannot learn on their own, when they are misguided by other learning sources, and when there is no time to wait until they figure out the problems and their solutions. Also, students have to learn certain rules, practices, and symbols as a common way to develop an understanding of things or

phenomena. In many cases, intervention may be necessary to bring uniformity or a structure of such practices so that what one is doing will make sense to others too. Then teacher is the one who at first intervenes in their learning in the classroom acting as a facilitator. The role of a teacher as an interventionist is essential for enabling students to construct 'cultural tools'. These different cultural tools may be associated with certain ways of doing things (such as using formula), writing symbols, defining things or phenomena, making assumptions, and using tools and techniques to solve problems. Also, teacher's intervention is necessary in order to make sure that students are spending time in productive learning, not just wasting resources in the name of group projects. In this context, I remember reading a novel "Lord of the Flies" by William Golding. If children (and even adults in many cases) are left to learn by themselves in a group or groups, then the situation may turn into one as Golding beautifully captures in his novel. The group of boys (in the novel) tries to govern themselves, but there is a conflict among themselves regarding who will be a leader, and that leads to unfortunate disaster. Therefore, teacher's role as interventionist is essential in science and mathematics learning at least to make sure they are in the right direction, and bring them in the right direction when necessary.

Driver et al. (1994) discuss about conceptual profile as a model of learning. Students can have different experiences of the same objects or phenomena in different contexts, and consequently they may have differing 'conceptual profiles' developed in their mind (in thinking). For Driver et al. (1994) there can be existences of such conceptual profiles in the minds of students, and they can use these profiles wherever they can fit them depending upon contexts. I think, such differing conceptual profiles even when they contradict each other may exist as separate entities, and students can utilize appropriate profile depending upon the situations they come to deal with. These conceptual profiles may have different views of the same object or phenomena, and they exhibit them wherever they feel comfortable. They may develop these conceptual profiles with respect to different theoretical, ontological, and epistemological considerations. These conceptual profiles may represent layers of reasoning, understanding, and making sense of things or phenomena in different social and cultural contexts. Developing a new conceptual profile as a result of amalgamation of existing profiles or an independent profile may not supersede or replace the existing profile. That means, the conceptual profile may exist in one's mind as quantum of thinking or reasoning from a different perspective. To me, this makes one to hold multiple perspectives about any problem or issues can use them based upon context.

Driver et al. (1994) do not give detail accounts of such conceptual profiles, but they point out that the existence of such conceptual profile may be problematic about the notion of 'conceptual change' because students do not necessarily abandon their commonsense ideas as a result of science instruction, and they will have such ideas available to them for communication within appropriate social contexts (Solomon, 1983 as cited in Driver et al., 1994). "Human beings take part in multiple parallel communities of discourse, each with its specific practices and purposes" (Driver et al., 1994, p. 6). This process also helps to create such differing 'conceptual profiles' in students' mind. When learning science is viewed from the perspective of 'conceptual change', then existence of such 'conceptual profile' is a problem because, to me, these conceptual profiles may be an obstacle in conceptual change. The existence of differing conceptual

profiles may not lead to conceptual change, but it may generate a new conceptual profile. I think, when students already have such differing conceptual profiles through experiences in different community of practices, then 'conceptual change' may not happen in a real sense because students may not exhibit such change in a different context. The perspective of conceptual change is problematic in the sense that students may not discard the existing conceptual understanding when they come to experience new concepts.

Social constructivist view of learning may have some suggestions in relation to making teaching-learning student friendly by beginning any science/math discussion from their experiences to the new (un-experienced) world of knowledge. The prime focus of constructivist learning/teaching is engaging students in productive thinking, analyzing, and synthesizing of ideas through individual and the social construction of knowledge. Then, there is certainly no simple rule for pedagogical practices or pedagogical choices in order to foster constructivist learning. Constructivist learning focuses on construction of knowledge by students themselves through their active participation in learning. Some constructivist educators prescribe different stages of constructivist lessons, but I think constructivist view of learning actually does not prescribe any order or sequence of activities for learning. Constructivist learning assumes that a learner actively constructs knowledge instead of passively receiving it from the teacher or his/her peers. I agree with Andrew Gray (1997) when he states that "constructivist classrooms are structured in such a way that learners are immersed in experiences within which they may engage in meaning-making inquiry, action, imagination, interaction, hypothesizing, and personal reflection" (n.p.). Also, constructivist learning focuses on autonomy and ownership of learning by the learners in relation to what to learn, why to learn, when to learn, and how to learn. Then, obviously there may not be simple rules for learners to orient them in a most efficient learning. The way one learns certain idea may be different from other persons. Some students are more visual, and others are analytic. The teacher's role is simply to act as a facilitator. The teacher in a social constructivist classroom needs to understand the classroom dynamics, and he or she should help students in using their prior experiences to build up new experiences, and recognize their physical and interpersonal environments in order to construct meaning from contexts. The teacher does not dictate students, but he or she encourages their learning from actions. He creates an environment in class in which they learn from collaborative actions, dialogical and dialectical interactions, and reflective thinking. Next, essential role of a teacher in a social constructivist learning is to engage students in planning activities, conducting activities, and self-evaluation of what they learnt and what they could not learn. I think this role of the teacher is extremely important in a social constructivist learning in order to develop a sense of ownership of classroom activities and learning from those activities.

Open discourse is the discourse on a topic or idea from different paradigms being open to all perspectives. Open discourse is a democratic practice of telling/sharing and critiquing one's views and ideas from multiple angles to broaden the ideas. In a classroom context, open discourse can be discussing any knowledge from different cultural and social perspectives. There can be different systems of counting numbers across the cultures. When students share counting systems in their family cultures, then such discourse is open discourse. In such discourse, students simply take part in discourse by sharing what they know and how do they know things. Critical discourse is a practice

of sharing ideas and knowledge through appreciation and critiques to other's views, opinions, and knowledge. A critical discourse requires higher order thinking than open discourse. In a classroom context, critical discourse invites critical comments from the teacher and peers about one's ideas or knowledge whereas in open discourse, any idea is welcomed in the class without any critique.

Dawson and Taylor (1990) use personal relevance and student negotiation as referents of critical constructivism in relation to open discourse in the class. Students in a teaching experiment try to understand the issue of organ transplant from the context of the outside world in relation to their life. The authors bring the science issue from the out-of-the-class context to in-the-class context through personal relevancy of such issues. They even shared their experiences of the issues from their family cases. Bringing personal opinions on the subject matter into class and making them public through sharing and negotiating meanings was an excellent example of how the authors encouraged open discourse in the class. Also implementing critical discourse in the class through deconstruction of myths of repressive science made students aware of scientism and pedagogical practices influenced by cold reasons and hard control (Taylor, 1996 as cited in Dawson and Taylor, 1998, p. 16). The authors bring out four key factors in relation to the problems in their social constructivist class especially that contributed to students' resisting invitation to engage profitably in open and critical discourse. In many cases, students show disruptive behavior in the class not because of subject matter or pedagogical approach, but because of impressions that the students have about the teacher. The authors mention that "two of the students began to whisper and comment during whole-class discussions" (p.10). This clearly indicates that the students might have some prior misconception about the teacher and her teaching. Though the authors claim that these two students seemed to be uncomfortable about their changed status in the classroom, but they do not explicitly clarify this changed status from critical social constructivist perspective. The second factor to me was the subject matter. Maybe, these two students did not like the subject matter "Bioethics" in their science class or they did not think this subject as equally significant as other science classes. I think when their perceived importance of the subject is less compared to other core sciences (physics, chemistry, biology, etc.), then students might show reluctance in active participation in learning. This clearly indicates that these students might not have enjoyed the open and critical discourse in the class, rather they might have expected teacher to play an active role as transmitter of knowledge. The fourth factor was students' personal character. In many cases, how students respond to the class or teacher depends upon their individual characters. The students who were showing disruptive behavior in the class seemed to have a negative attitude to the teacher and/or other peers in the class. "Although some of these students were keen to voice their opinions, they were seemed unwilling to listen attentively to, or respect the views of, their peers" (p. 15). This clearly indicates that these students' did not value other's ideas, and they did not have willingness to change their established mind-set.

One of the most important things that I learnt about teaching from a social constructivist perspective from Confrey's (1990) paper is 'reflective practice'. Confrey emphasizes reflective practice as a means of construction of mathematical and scientific ideas. For high-quality reflection, Confrey (1990) proposes three categories of questions to be answered by students while reflecting on their construction of mathematical ideas.

These three categories are- the problematic, courses of actions, and reflections. Students may reflect on their problematic contexts where they are blocked off. They can state the problematic situations they face while solving a problem. For this, they interpret the problem in terms of 'what they were doing, what did the problem say, why there was a problem, what was the actual problem, etc.' in order to develop an understanding the nature of the problem. Confrey (1990) labels this stage as level one. When students reflect upon the course of action, they come up with cognitive strategies they employed while solving the problem. Then the students can reflect upon 'what they were doing' in order to solve the problem. They also describe the choice of methods and different course of actions they follow until the problem is solved. Finally, they may reflect back on 'why they chose certain strategies, and why not others...and how their choices worked or did not work' in order to defend their choice of methods or course of actions. While doing this, students not only reflect upon the mechanical process of problem solving, but they also reflect upon their interaction with the teacher and other peers in the class. From a social constructivist perspective, reflective practice is not a monologic process in which students simply write their stories of how they faced problematic, decided courses of actions, and looked back, but it is also a dialogical and dialectical process in which students not only enter into open discourse, but they also participate in critical discourse.

Another important thing that I learnt from Confrey's (1990) paper is retracing and reviewing solution path and negotiation of a tentative solution path. This reminds me of a mathematics lesson I taught in high school in Nepal. Confrey states that "when the problem was solved, the instructor would revisit the problem with the student that would provide an opportunity for reflection, provide an overview of the problem, provide occasions for the teacher to advocate for his/her view of mathematics teaching and learning, and provide the student with a sense of accomplishment (Confrey, 1990). I think this process of retracing and reviewing is an important aspect in social constructivist learning in order to keep track of student's progress and his/her method of problem solving. Once, a student complained about her grade on the exam paper. In one of the problems, she solved it in the exam paper with the approach that was partially wrong in the last steps. I deducted some points for not solving the problem with appropriate steps. She brought her classroom practice-book to show me that she followed the same method in the class in which I did not make any comment. Actually, I did not retrace her approach and did not review her solution thinking that she might have followed right approach as others did in class. She thought that her approach was right together with others' approach in the class. We did not get a chance to make negotiation of her solution path. This led us to the conflict in the exam paper score. She was not wrong from her perspective and I was not wrong from my perspective to deduct a few points for her wrong approach, but the lack of negotiation of the solution path kept us in misunderstanding of each other that was revealed only during the exam. Retracing and reviewing not only help us be informed about how students are doing, but this process helps us in building a model of how the students are thinking about the problems and how they interpret them, how they follow the course of actions, and how they reflect upon their actions and operations of problem solving.

Re-conceptualizing “Social Constructivism”

When I think of my teaching from the beginning of my career as a teacher, it was more guided by instructionist approach focusing teacher lead lectures and activities in math and science classes. Though I tried to make discussion student centered, the choice of subject matter and the way they were introduced among the students, even when they were doing group works, were guided by the teacher. There was a little or no questioning by the students except in the procedural steps of problem solving. With the advancement of training and education, gradually I realized the power of student centered teaching, and normally group discussions in class. When I was teaching in university level courses, I tried to organize group works and student lead discussions around the subject matters as prescribed by the curriculum. Though I could make some adjustments in the curriculum matter, but most of the group discussions and projects were around the already set curricular arena. In the latest teaching episodes in my career, I used to engage students in group activities and individual presentations encouraging critical analysis of the topics we discussed in the class. Though I was not much aware of social constructivism, I was trying to engage students in the classroom discussions considering them as co-constructors knowledge and collaborators in the teaching and learning. When we tried to create an environment of sharing ideas and making comments and critiques of the established system of knowledge, we agreed to disagree whenever we had differences in opinions and ideas by respecting those differences. This way we built a foundation of socially collaborative, culturally responsive, and pedagogically creative classroom environment. To me, those efforts were made in order to create constructivist learning environment without being conscious of social or radical or critical constructivism.

The students were engaged in collaborative learning activities through think-pair-share and simple jigsaw together with simple group works and presentations to the class. While doing collaborative activities, they were culturally responsive in the sense that they considered themselves as responsive members of community of learners and community of teachers. They always tried to balance their role as teachers and students. We considered a mixed ability and gender group while forming discussion groups. These students, who were school teachers, always brought issues and challenging problems in the class in relation to problem solving, classroom management, and creating social constructivist learning environment in a large class (generally students number would be greater than 40-50). Now, I realize that those classes had some elements of social constructivism because of our involvement in sharing ideas, making comments and critiques of other’s ideas in a respectful environment, and negotiating for common grounds to stand on in many issues. Any teaching-learning method or pedagogical aspect has both pros and cons. Though I tried to maintain a socially balanced and creative learning environment guided by constructivist philosophy, many times I was frustrated from the problems and issues in the class. Some students misinterpreted such classroom practices as lazy teacher’s agenda of teaching less and engaging students more. Even they blamed me of not providing enough reading and learning materials. In many cases, I did not have examples to provide them in the form of demonstrations of such classes through videos.

In many cases, we depended on limited resources to build our understanding of cooperative and collaborative learning. I think, there is no one best approach for teaching

and learning mathematics and science. We should be able to apply multiple approaches of teaching and learning mathematics and science in the class depending upon student number, available resources, and the general trend in the school system. Social constructivist learning is effective in small class size where there are enough resources to use and enough time to engage students in creative and constructive activities. Depending upon student expectation and curricular structure (rigid or flexible), we can choose methods of teaching flexibly in order to provide an opportunity to learn fundamental facts and figures to complex ideas. Social constructivist learning is so personal and so subjective that it can not be confined within a structure of a framework. Also, to me, such learning environment is illusive in the sense that for one student it can be creative and constructive environment, whereas for another student it can be disturbing. It can be disturbing in the sense that the student prefers self-learning rather than group activities. Student rating on social constructivist learning environment would be greatly different from person to person and averaged score may stand nowhere among their opinions.

While coming back to reviews of papers, it was a terrific learning experience to review an article by Drivers et al. (1994). The most essential thing that I could learn from the article are: science as interpretation of nature through constructs of the scientific community through personal to the social level of construction of knowledge; the process of constructing shared knowledge becomes a socially accepted and socially constructed knowledge by bringing the personal to the social and social to the personal for further thinking and construction of new knowledge. Also it was interesting to know about metaphor of learning as enculturation and metaphor of learning as discovery. I came to know that learning as enculturation points to the nature of learning in a group through dialogic or dialectical thinking, and making a common meaning of things or phenomena. The metaphor of learning as discovery assumes that learning is as an individual process through which individual makes meaning of things or phenomena, and constructs ideas out of them. Learning as discovery, to me, is more positivistic and post positivistic approach of learning. I am not being able to understand why individual construction of knowledge is similar to discovery learning. I don't think the social construction exists at isolation without individual construction or vice versa. Many individuals' construction of common or differing ideas may contribute in the social construction of knowledge. Construction of ideas, to me, actually may originate from an individual or a group. Enculturation is a populist term, but it is not a fully constructivist term to me. Enculturation, in many cases, kills individual creativity, and it simply helps individuals to follow the tradition as an unquestionable system. I agree that there should be a balance in construction and enculturation. Enculturation only does not help society and individual to make a radical change or progress. Enculturation to me is similar to Darwin's theory of evolution in which change is a gradual process. If we accept and continue following the same traditions, or same practices of knowledge, we will not be able make progress further or even if it is made then it will be a slow process. Knowledge construction becomes evolution but not a revolution. Next crucial thing that I could learn from the paper is the role of a teacher as an interventionist is essential for enabling students to construct 'cultural tools'. These different cultural tools may be associated with certain ways of doing things (such as using formula), writing symbols, defining things or phenomena, making assumptions, and using tools and techniques to solve problems. Also, teacher's intervention is necessary in order to make sure that students are spending

time in productive learning, not just wasting resources in the name of group projects.

I think conceptual change and conceptual profile are recent topics under discussion in the academic arena. Conceptual change as learning and forming new conceptual profile as learning are both debatable. To me, students can have different experiences of the same objects or phenomena in different contexts, and consequently they may have differing 'conceptual profiles' developed in their mind (in thinking). These conceptual profiles may even be contradictory to each other, may exist as separate entities, and students can utilize appropriate profile depending upon the situations they come to deal with. These conceptual profiles may have different views of the same object or phenomena, and they exhibit them wherever they feel comfortable. The idea of conceptual change emphasizes change in the conceptual schema when students learn things and build up idea from basic to complex cognitive levels. In this sense, original or previous conceptual frame is overridden by the new or modified conceptual schema. Whereas, the existence of conceptual profile means that a new or modified conceptual frame (profile) is formed without overriding the previous conceptual frame.

Social constructivism is based upon assumptions about reality, knowledge, and learning. Social constructivists assume that reality is not out there but it is constructed through social interactions of individuals. According to Ernest (1999), knowledge is a construction or product of human interactions through social and cultural activities. Then, learning is a social process through social activities. Then, there is certainly no absolute rule for pedagogical practices or pedagogical choices in order to foster constructivist learning. Constructivist learning focuses on construction of knowledge by students themselves through their active participation in learning. Some constructivist educators prescribe different stages of constructivist lessons, but I think constructivist view of learning actually does not prescribe any order or sequence of activities for learning.

Constructivist learning assumes that a learner actively constructs knowledge instead of passively receiving it from the teacher or his/her peers. Therefore, learning involves participation in open and critical discourse on a topic or idea through appreciation and critiques to different views, opinions, and knowledge. To me such discourses help individuals to construct meaning of phenomena or objects of discussion. Dawson and Taylor (1990) bring out the challenges of social constructivism in science class. Dawson's teaching experiment in the science 'ethics' class shows many strengths of social constructivism together with problems and challenges in creating such a learning environment under the conditions in which students may not have such experience before in other classes. Certainly it was a good experience to learn about teaching from a social constructivist perspective in Confrey's (1990) paper. Confrey emphasizes high-quality reflection in three steps: the problematic, courses of actions, and reflections. Reflective practices have been a common and popular jargon in education these days. Does reflective practice promote learning? Just revealing what I am thinking during the course of an action may not be a productive learning. Just unveiling what one's inner feelings, thoughts, and ideas would not constitute learning unless he or she is able to add new ideas and practices in the next cycle of thinking and reflecting. Then I think it is beneficial to retrace and review thinking through critical reflection with a new solution path and negotiation of a tentative solution path (Confrey, 1990).

Radical Constructivism: A Pedagogical Choice

I think there are many pedagogical implications of radical constructivism. Von Glasersfeld focuses on “construction of knowledge” by an individual student rather than transfer of knowledge as commodity from one person to another. Before further discussion of pedagogical implications of radical constructivism, it can be a good idea to review fundamental insights of this philosophy, epistemology, and theory of knowledge and knowing. The first insight of radical constructivism is that “knowledge is not passively received, but is actively built by the cognizing subject” (von Glasersfeld, 1989a, p. 182). This insight clearly implies for pedagogy. Steffe (n.d.) clarifies that “the first principle is based on the fact that the only contact that any human being has with what might be ‘out there’ is through the sensory channels--the visual, auditory, olfactory, tactile, palatal, and kinesthetic” (p. 2). I think, these sensory channels are the means to communicate between environment to person or person to person, and person to environment. The way a person perceives, and makes meaning out of the information he or she receives and interprets the information and constructs knowledge out of it, is dependent on *coding*, *transmission*, and *decoding* of information. This coding, transmission, and decoding process seem to be mechanical, it looks a kind of structured phenomenon. Is there actually coding and decoding going on in the brain when we make sense of something? I think learning is beyond coding and decoding. We can not just reduce the phenomenon of learning in the actions of coding and decoding. This again connotes with behaviorism.

The coding-decoding metaphor of learning may indicate that the process of construction of knowledge is related to how the brain decodes and adjusts into cognitive experience. But here, I do not agree with Steffe that learning can be reduced in the process of coding and decoding. There is a lot more going on in the learner’s brain. Coding-decoding metaphor does not reflect the internal complexities and processes going on in one’s brain. If learning is coding and decoding, then there would be rules of such coding and decoding (like in computer simulations), but I think learning is not rule-bound, and it is not a linear process simply as coding and decoding. However, I agree with Steffe that knowledge cannot be carried from the head of a teacher into the head of a student by means of language. The barrier in language is that only the thing that travels from the teacher to the students are the semiotics (in the form of speech sound or text or any symbol) a student converts into nerve impulses and these impulses through ear or eyes or any sense organs are transmitted to the brain. Then, we can conclude from this principle that knowledge is actively constructed by the cognizing individual. Here too, I would like to caution that language is a necessary condition for learning, but not a sufficient part of it. Language is a means of learning, and it is never an end of learning.

The role of teacher and students can be clearly identified from this insight. It rejects the behaviorist’s perspective that knowledge can be transmitted from the teacher to the learner, and learning is associated with change in behavior of learners. Instead, knowledge is actively built up by the cognizing subject through the cognitive process of assimilation and variation to the prior experiences. “The role of the teacher is then assumed to provide guidance to the students, but their guidance is tentative and cannot ever approach absolute determination” (Von Glasersfeld, 1990, p. 37). This clarifies that the teacher can not dictate for one right answer, but s/he can help students for possibilities

of multiple solutions to a problem. I think a better problem is one that allows multiplicities of solutions and interpretations to the solutions. The teacher creates an environment in which students get enough opportunity to develop their ideas through participation in activities, experiments, or observations. The role of students is active learners. They do not just follow the teacher's instruction, but they also participate in activities to explore ideas themselves with fellow students and the teacher. Students and the teacher do not only seek right answer to a problem, but they distance from the problem and look at it from different possible perspectives, theories, and philosophy.

The second insight of radical constructivism (by von Glasersfeld) states that "the function of cognition is adaptive, and serves the subject's organization of her experiential world, not the discovery of an objective ontological reality" (Heylighen, 1997, n.p.). To me, this insight is more epistemological than pedagogical. We cannot stop discussing pedagogical implication from this insight because epistemology has a direct impact on pedagogy. A child learns something means s/he constructs knowledge through the cognitive function of self-adaptation of new ideas to the existing experiential knowledge. In this process, if a child's current experience is new in relation to past experience of something or some phenomena, then his or her new cognitive construction adapts to the existing cognitive construction or existing cognitive construction adapts to the new cognitive construction whichever the child values more or whichever takes him or her to the zone of comfort. This process, though seems personal, is impacted by teaching and learning environment in class. His or her reorganization of the experiential world based upon the adaptive phenomena of self-constructed cognitive experience makes him or her aware of the new knowledge and prior experiences. While doing this the child does not simply discover the reality out-there (ontological reality), but s/he constructs new knowledge through subjective experience about an object or phenomenon. The teacher in the process becomes a part of intervening force for the child's cognitive adaptation. His or her intervention in the learning process is simply like a guide to encompass the direction and pace of learning.

I think the main pedagogical implication of radical constructivism for Ernst von Glasersfeld is associated with clarity and description of the role of teacher and students. The role of a teacher is simply like a facilitator or guide for learning and creating a learning environment, and the role of students is like active learners who construct knowledge by active involvement in the learning process. The students' role as learners is more important as constructors or co-constructors of knowledge with the teacher and colleagues than simply as receivers of knowledge. This construction or co-construction process is more a personal subjective phenomenon than objective reality, though the students get involved in social interaction within or out of class. Ellerton and Clements (1992) discussed some pluses of radical constructivism in mathematics education like "ownership of mathematics learning by the learner, quality of social interaction as a basis for quality of mathematics learning, and principles for improving the quality of mathematics teaching and learning" (pp. 4-7).

Cobb (1990a, p.8) summarized the effectiveness of radical constructivism in mathematics teaching and learning in five points. His first point states "it is ridiculous to claim that students cannot discover mathematics on their own" (p.8). This means students can construct mathematics even without the cooperation of experienced peers or adults. Construction of mathematical ideas by the students is dependent upon their prior

experiences and interactions with others and the environment. His second point states that “students do not learn mathematics by internalizing it from objects, pictures, or the like” (p.8). The notion of internalizing is somewhat linked to the repeated practice and rote learn so that students can reproduce the ideas they learnt as if they are used to it. Instead, students actively construct and build upon ideas they already have when they acquaint with new knowledge. The third point states that “the pedagogical wisdom of the traditional pattern of first teaching mathematics rules and skills, and then providing opportunities to apply these in real-life situations, is questionable” (p.8). This point clarifies that there may not be a fixed pattern or sequence of learning like learning rule at first and then applying them in context. It can be just a reverse too, that is learning from context or experiences and deriving a rule from it. The fourth point considers that “the teacher should not legitimize just any conceptual action that a student might construct to resolve a personal mathematical problem” (p.8). Mathematics and science teacher should offer flexible and reasonable learning opportunities for students. However, the teacher should be cautious about students’ personal constructs which sometimes might mislead them to a wrong assumption and solution to a problem. And, his last point maintains that “mathematical thought is a process by which we act on conceptual objects that are themselves a product of our prior conceptual actions” (p. 8). These points clearly capture Ernst von Glasersfeld’s idea of pedagogical implications of radical constructivism. Then radical constructivism has many ideas to offer in teaching and learning of mathematics and science that social constructivism does not have. However, this will not discount the importance of social constructivism to solidify the learning through negotiation and sharing.

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