RADICAL CONSTRUCTIVISM IN SCIENCE EDUCATION

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ABSTRACT

Radical Constructivism in Science Education

by

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Radical constructivism is a popular version of constructivism. It is introduced as an unconventional approach to knowing and learning by its leading representative Ernest von Glasersfeld.

In my thesis, first, I present von Glasersfeld's conception of knowledge in general and scientific knowledge in particular and their implications for science education. Then, I critically examine the radical constructivist theory in the light of the following questions:

1. Does radical constructivism present a valid theory of knowledge and scientific knowledge?
2. Can radical constructivism fulfill the main aims of science education as a theory of learning and teaching?

Finally, I conclude that radical constructivism is not only a poor substitute for traditional epistemology but also fails to meet the main objectives of science education as a theory of learning and teaching.

KISA ÖZET

Fen Eğitiminde Radikal İnşacılık

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Radikal inşacılık, inşacı (constructivism) yaklaşımın yaygın bir çeşididir. Önde gelen temsilcisi Ernest von Glasersfeld tarafından gelenek dışı bir bilme ve öğrenme kuramı olarak ileri sürülmüştür.

Tezimde, öncelikle, von Glasersfeld'in bilgi kavramını, bilimsel bilgi kavramını ve bunların fen eğitimindeki etkilerini tartışıyorum. Sonra, radikal yapısallaştırıcılık teorisini aşağıdaki sorular ışığında eleştirel olarak inceliyorum:

1. Radikal inşacılık, geçerli bir bilgi ve bilimsel bilgi teorisi sunuyor mu?
2. Radikal inşacılık, bir öğretim ve öğrenim teorisi olarak fen eğitiminin temel amaçlarını karşılayabiliyor mu?

Sonuç olarak, inşacılığın sadece geleneksel bilgibilimine zayıf bir alternatif oluşturduğu değil, aynı zamanda da bir öğrenme kuramı olarak fen eğitiminin temel amaçlarını da karşılayamadığı sonucuna varıyorum.

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1. INTRODUCTION

Constructivism is an influential attempt to establish an epistemological theory where human experience is the only input. In contrast to the traditional account that sees knowledge as a passive reflection or a copy, constructivism holds that knowledge is a sort of active construction. In addition to making epistemological claims, constructivism also explains how humans acquire knowledge. Therefore, constructivism is not only a philosophical account of knowing but also a popular theory of learning in education.

There are various kinds of constructivism. In the educational literature, it is possible to discern at least three kinds of constructivism: namely, metaphysical constructivism, cognitive constructivism and epistemic constructivism (Grandy, 1998).

Metaphysical constructivism is the view according to which "the furniture of the world" is constructed either by individuals or by society. In both cases, the independent existence of the world from the mind is denied. So, metaphysical constructivism makes no room for an observer-independent world. Thus, it contrasts with metaphysical realism that postulates the existence of an

observer-independent world. Therefore, it falls into an undesired position of idealism and for that reason metaphysical constructivism is considered the most radical version of constructivism.

The second kind of constructivism is the cognitive one. On this account, individual cognizing subject constructs representations to understand his environment. It is a very commonsensical view that aims to specify the role of human mind in obtaining the knowledge of the external world. The main problem with this view is the difficulty in explaining how it is possible to have an objective knowledge of mind-independent world on the basis of our subjective representations.

In epistemic constructivism, the constructions of mind are called knowledge that is claimed to be a kind of conceptual construct. Here, there are two options to explain the relation between knowledge and the external world. First, one can say that constructed knowledge matches with the knowledge of external world. So, being an epistemic constructivist is not an obstacle for being a realist according to whom there exists a mind-independent reality. Second, one can choose to break the relation between the external world and knowledge. So, instead of keeping knowledge as the representation of an

external world, it asserts that knowledge is the representation of the world as it is experienced. On this approach, knowledge only serves for the organization of our experiences so that we will be able to both explain and predict our further experiences.

In epistemic constructivism, the subject of constitutive activity can be determined either as the individual or as the society. In the former, knowledge is necessarily a conceptual construct of individual cognizing subject. Also, it is important to notice that although the emphasis is given to individuals, social interaction between individuals is not totally denied. However, in the latter, the existence of knowledge is essentially dependent on society.

In my thesis, I will critically examine radical constructivism that can be considered as an example of individualistic epistemic constructivism. This version of constructivism is presented as an alternative theory to traditional epistemology and traditional learning theories. Therefore, von Glasersfeld, who is the most referred radical constructivist, claims that it will be misleading to use the traditional terms such as "epistemology" or "the theory of knowledge" for radical constructivism:

> "They [the terms epistemology and the theory of knowledge] tend to imply the traditional scenario according to which novice subjects are born into a ready made world, which they must try to discover and 'represent' to themselves" (von Glasersfeld, 1995:2).

Here, von Glasersfeld emphasizes that traditional account of knowledge assumes the existence of an observer-independent world and defines knowledge as the representation of objects, processes or events in such a world. On the other hand, although the radical constructivists seem to agree upon the existence of such an observer-independent world, they are skeptic about the possibility of acquiring knowledge of observer-independent world. This contrast is also the main reason why von Glasersfeld calls his theory "radical". In other words, radical constructivism breaks the conventional relation between knowledge and external world by claiming that knowledge does not represent the world itself but represents only human experiential world, i.e. the world as it is experienced.

The first part of my thesis aims to explain why von Glasersfeld tries to establish a new theory of knowing against the traditional theory of knowledge. He claims

that as long as truth is kept as a necessary condition of knowledge as in traditional accounts, we cannot have any knowledge. To solve this problem, von Glasersfeld suggests to rebuild these fundamental concepts on the basis of the ideas developed against the traditional epistemology.

The second part of my thesis concerns a more detailed analysis of the alternative conception of knowledge presented by radical constructivists. According to radical constructivism, there are three basic principles of knowledge. First, knowledge is an active construction out of human experiences. Second, conceptual constructs based on our experiences continuously evolve and change. Third, these conceptual constructs represent our experiences of the world rather than the world itself.

The third part of my thesis aims to clarify the notion of scientific knowledge in radical constructivism. Von Glasersfeld holds that scientific knowledge, like other kinds of knowledge, does not represent an objective reality. Instead, in radical constructivism, scientific knowledge is defined as "socially negotiated understandings of events and phenomena" (Tobin, 1993: 4). On the basis of this interpretation of scientific

knowledge, it becomes extremely difficult to distinguish between scientific knowledge and commonsense knowledge.

Radical constructivism is a widely accepted learning theory in science and mathematics education. For this reason, the fourth part of my thesis is concerned with the implications of radical constructivist principles in science education. According to radical constructivism, experience, preexisting conceptual structures, and interaction with other individuals are the three fundamental constraints that a teacher must be aware of. Radical constructivists also argue against the traditional view that knowledge is a stable entity that can be transferred from teachers to learners. Instead, learning is construed as constructing viable and negotiated conceptual structures. Hence, the main role of the teacher is changed from being a transmitter to being a leader who provides an appropriate learning environment for the students that enable them to make such constructions.

In the last part of my thesis I will criticize radical constructivism. First, I will show that von Glasersfeld' s argument against traditional conception of knowledge is not valid. Second, I will argue that the alternative conception of knowledge presented by radical

constructivists lead to more problems than it solves. Finally, I will show that although radical constructivist strategies are considered successful by most of the educators, radical constructivism can hardly fulfill the aims of science education.

2. RADICAL CONSTRUCTIVISM AND ITS HISTORICAL SOURCES

Von Glasersfeld is the leading representative of radical constructivism. Therefore, in this section I will examine his ideas and its historical sources in order to understand radical constructivist theory.

First of all, von Glasersfeld claims that the reason for an attempt to establish a new model of knowledge is the paradox involved in the traditional epistemology. He says:

> "The paradox arises, because the works of philosophers by and large imply if not explicitly claim, that they embody a path towards truth and true representations of the world, yet none of them has been able to provide a feasible test for the accuracy of such representations" (1991:13).

Here, von Glasersfeld seems to have in mind the correspondence theory of truth as the traditional conception of truth. This theory asserts that "true" means correspondence to facts where "correspondence" is used in the sense of accurate representations and "facts"

are the elements of an observer-independent world, namely reality (Urmson and Ree, 1995). In other words, a statement is called true when it represents the reality like a perfect picture and it is false otherwise.

Von Glasersfeld emphasizes that the correspondence theory of truth requires an ability to make a comparison between a statement that belongs to human experiential world and reality that is prior to and independent of human experience. He says:

> "It is logically impossible, however, to compare a representation with something it is supposed to depict, if that something is supposed to exist in a real world that lies beyond our experiential interface" (1995:93).

Von Glasersfeld follows Kant that space and time are not the properties of real world, but the characteristic forms of human experience. He points out his idea about space and time in his following words:

> "the space and time in which we move, measure and above all, in which we map our movements and operations, are our own construction; and no

explanation that relies on them can transcend our experiential world" (1995:74).

It will be agreed that, any kind of experiencing requires a frame of space and time. From von Glasersfeld's point of view, it is impossible to experience reality as it is; we experience it always by imposing space and time. That is, space and time are the tools that we use to organize our experiences in order to make sense of them. Hence, we are always under the limits of our experiences while we are trying to understand reality on the basis of our experiences. Therefore, Von Glasersfeld emphasizes that:

> "From the constructivist point of view, the subject cannot transcend the limits of individual experience"(1995:2).

So, according to radical constructivism, it is impossible to go beyond our experiences. Hence, we cannot compare our statements with reality and say that one corresponds to the other. This means that we cannot know by experience whether our statements are true i.e. correspond to mind-independent facts.

On the other hand, traditionally, knowledge has been defined as justified true belief. Hence, truth in the traditional account is a necessary condition of knowledge. Von Glasersfeld interprets this to mean that "s knows that p" (where p is a proposition and s is the cognizing subject) requires that s must know that p is true. However, argues von Glasersfeld, it is not possible for s to determine the truth of p if truth is understood in the correspondence sense. In that case, we can never attain knowledge because we can never know whether our propositions are true on the basis of our experiences. Therefore, we must either give up truth as a necessary condition of knowledge or revise our conceptions of truth and knowledge. Von Glasersfeld does the latter by suggesting to construct a new theory of knowledge, called radical constructivism, according to which knowledge:

> "… cannot reflect the ontological reality of which traditional philosophers dream. Radical constructivism does not speak of this dream: its purpose is to show that a relatively stable 'experiential reality' can be built up without presupposing an independent world in itself" (1995:88).

Von Glasersfeld claims that it is possible to establish a consistent and a useful epistemology without referring to any ontological reality that is supposed to exist independent of experience. Thus, from the radical constructivist point of view, knowledge does not have to match with the objective facts any more. As von Glasersfeld says:

> "It[radical constructivism] starts from the assumption that knowledge, no matter how it to be defined, is in the heads of persons" (1995:1).

So, the task of radical constructivism is to develop a conception of knowledge on the basis of an experiential world that is the world as it is experienced. To this end, von Glasersfeld draws upon the ideas of a number of philosophers and scientists such as Vico, Kant and Piaget who have been critical of traditional epistemology.

As I mentioned before, from the radical constructivist point of view, it is not possible to establish a relation between what we propose and what there is in the actual world. Von Glasersfeld points out that the same idea also appears in both Kant's distinguishing of metaphysics into two domains as transcendental and transcendent and Vico's distinction

between what is mystical and what is rational. Von Glasersfeld quotes from Kant that transcendental philosophy is:

> "understanding and reason itself as a system of concepts and principles that regard objects in general without the assumption of things that might be given (ontology). The second [the transcendent] regards Nature, i.e., the sum of given objects" (Kant, 1787:873 cited in von Glasersfeld, 1995:38).

Von Glasersfeld explains that like Kant, Vico distinguishes what is mystical from what is rational. Mystical knowledge lies behind the tangible world and rational knowledge pertains to everyday experience. For von Glasersfeld, whether we call transcendent or mystical, anything beyond experience is speculative and unknowable whereas what is transcendental or rational that is in the limits of experience is knowable and serves us to understand and to reason. Hence, in radical constructivism, experience is considered as the only source for knowledge.

Von Glasersfeld is highly influenced by the idea of cognitive construction that is elaborated by both Vico

and Piaget independently. According to Vico, in order to know something, one has to know how and out of what it is made. So, only God can know the reality as its creator and man can only know his own artifacts. Moreover, Vico holds that humans produce knowledge by reason. Following Vico, von Glasersfeld, too, believes that man can only know what he has constructed using his reasoning.

On the other hand, according to von Glasersfeld, radical constructivism also owes a great deal to the studies of Piaget. First of all, to the idea that cognition is construction, Piaget adds the idea of adaptation, which he borrows from Darwin's evolutionary theory. According to Piaget:

> "…adaptation must be described as an equilibrium between the actions of organism on the environment and vice versa" (Piaget, 1963:7).

In relation to equilibrium, Piaget talks about two types of interaction. First, "the action of the organism" in its surroundings; this he calls "assimilation" (Piaget, 1963:7). Second, the action of the environment on the organism that he calls accommodation. In the case of assimilation, he says:

> "… physiologically, the organism absorbs substances and changes them into something compatible with its own substance. Now, psychologically, the same is true, except that the modifications with which it is then concerned are no longer of a physico-chemical order, but entirely functional or the interplay of real or potential actions (conceptual operations, etc.)" (Piaget, 1963:8).

On the other hand, adaptation is:

> "equilibrium between assimilation and accommodation, which amounts to the same as an equilibrium of interaction between subject and object" (Piaget, 1963:8).

Von Glasersfeld agrees with Piaget about both cognitive construction and equilibrium between subject and object. From the radical constructivist point of view, each individual constructs his own conceptual schema as a result of his cognition. In addition to cognition, assimilation and accommodation provide a self-regulating system in order to reach and maintain equilibrium. In other words, the subject establishes equilibrium between his experiences and his conceptual

schema by making necessary changes or additions in his previous constructions (von Glasersfeld, 1995). Therefore, assimilation and accommodation are the mental processes that explain the adaptive characteristic of cognitive constructions, namely knowledge. So, both cognitive construction and adaptation process are the essential elements in the development of the conception of knowledge in radical constructivism.

Von Glasersfeld also agrees with philosophers who reject the traditional conception of science. Generally, science is defined as the discipline that gives us the most reliable knowledge about the world by giving an accurate representation of it, i.e. by producing truths about the world. Thus, it has an epistemological superiority over other disciplines such as arts, literature, religion and so on. But, some philosophers are critical of this standard conception and argue that science can be considered as an instrument for the prediction of our experiences but no more than that. In this way, they advocate an instrumentalist position with respect to science.

Von Glasersfeld is in full agreement with this instrumentalist view. As he states:

> "Scientific knowledge, then, provides more or less reliable ways of dealing with experiences, the only reality we know; and dealing with experiences means to be more or less successful in the pursuit of goals" (1995:117).

So, in radical constructivism, science provides us with an economic and useful organization of our experiences. This organization enables us to form expectations related with specific actions and serves us to realize our aims.

3. THE CONCEPTION OF KNOWLEDGE IN RADICAL CONSTRUCTIVISM

My primary purpose in this chapter is to examine the conception of knowledge in radical constructivism, its nature, grounds, source and limits. By "knowledge", von Glasersfeld means:

> "ways and means of acting and thinking that allow one to attain the goals" (1991:17)

So, radical constructivism has an instrumentalist view of knowledge. That is, any conceptual structures like beliefs, laws and theories used like a tool in order to attain goals are called knowledge.

Moreover, under the influence of Piagetian cognitive construction, von Glasersfeld argues that one of the fundamental principles of radical constructivism is that:

> "Knowledge is not passively received either through senses or by way of communication; knowledge is actively built up by the cognizing subject" (1995:51).

According to this formulation, all knowledge is constructed rather than received. Since the construction takes place in the mind of the constructor, the process can be called a cognitive one. Moreover, by its nature, construction is an active process rather than a passive one. It is active in the sense that the mind shapes and coordinates the experiences rather than copying them as they are. For example, as it is mentioned in the previous chapter, von Glasersfeld believes that space and time are imposed into our experiences. Von Glasersfeld points out that:

> "the realist believes his constructs to be a replica or reflection of independently existing structures, while the constructivist remains aware of the experiences role as originator of all structures" (1987:104, cited in Matthews, 1994:104).

Now, according to radical constructivism the mind has certain powers that facilitate the construction of concepts and their relations. Von Glasersfeld agrees with the Piagetian model of knowledge according to which both concepts and their relations are abstractions from experience. Concepts are the result of abstraction from seeing or sensing while relations are abstracted from the

mental operations carried out during seeing or sensing. As von Glasersfeld says:

> "I suggest that we are quite able to abstract general ideas from experience. We do this by substituting a kind of placeholder or variable for some of the properties in the compound sensory structures we actively build up to form particular things from the flow of experience. I see no reason why the resulting operational structure that has the function of generative programme, should not be called a concept" (1995:93).

So, abstraction is a highly developed ability of the mind that enables us to generalize the common things in our experiences so that we can construct concepts.

Another fundamental principle of radical constructivism is the adaptive character of knowledge. Von Glasersfeld states, adaptation is:

> "... the result of elimination of the non-adapted, the non-functioning and that consequently anything that manages to survive is 'adapted' to

the environment in which it happens to find itself living" (1991:17).

Moreover, adaptation is not something that we can control its results. It is limited by the environment in which it is found. In the context of radical constructivism, since environment refers to the individual experiential world, the adaptation of knowledge is limited by the world in the way it is experienced by the individual.

Also, it is important to note that the process of adaptation does not occur accidentally. It has a direction or an aim that von Glasersfeld emphasizes in as follows:

> "the function of cognition is adaptive, in the biological sense of the term, tending towards fit or viability" (1995:51).

So, during the adaptation, the conceptual structures that involve contradictions or conflicts are eliminated in the sense that they are not used anymore or they can be modified in a way that the contradictions or the conflicts are vanished. So, the mind is also active in checking the consistency between previous experiences and

his new experiences. The cognizing subject continues to use the conceptual structures that are consistent and continues to develop new ones on the basis of his new experiences in the way that they do not disturb internal consistency. These consistent conceptual structures are called viable procedures. As von Glasersfeld says:

> "knowledge refers to conceptual structures that epistemic agents, given the range of present experience within their tradition of thought and language, consider viable" (1991:119).

According to von Glasersfeld, knowledge consists of conceptual structures that are viable, and a conceptual structure is viable if it "fits the purposive or descriptive contexts in which we use them" (1995:4). Therefore, viability appears as a distinguishing characteristic of knowledge and is:

> "tied to the concept of equilibrium. … In the sphere of cognition, though indirectly linked to the survival, equilibrium refers to a state in which epistemic agent's cognitive structures have yielded and continue to yield expected results, without bringing to the surface the conceptual conflicts or contradictions" (von Glasersfeld,

1991:120).

Let me now turn to the question of what the extent of knowledge is according to radical constructivism. As von Glasersfeld has pointed out repeatedly, what radical constructivism says in this context differentiates it from the trivial constructivist positions. Von Glasersfeld argues that knowledge is not something that exists "out there" and ready found. From the perspective of radical constructivists, neither the viable procedures nor the concepts that result from abstraction have to match with reality. He says:

> "cognition serves the subject's organization of the experiential world, not the discovery of an objective ontological reality" (1995:51).

Von Glasersfeld uses an analogy of a box and a hole to make the point more clear. In this analogy, a person who experiences a small square box passing through a hole cannot derive the conclusion that the hole has the shape of the box. This is because he cannot go beyond his experience to see if his experiences match with the world as it is. One must be aware of the fact that there is an infinite possibility for its actual shape such that it might be a big circular hole or an elliptic one, etc. The

only thing that the observer can say is a square box passes through a hole in his experiential world.

To sum up, in radical constructivism, knowledge is introduced as a pragmatic concept that bears no necessary relation with the reality. The viable conceptual constructs are established on the basis of individual experiences rather than a representation of an observer-independent world by the individual cognizing subject. Certainly, such a change in the conception of knowledge also requires a new understanding of science and scientific knowledge that will be discussed in the next chapter.

4. THE CONCEPTION OF SCIENTIFIC KNOWLEDGE IN RADICAL CONSTRUCTIVISM

In this chapter, I will start by explaining how radical constructivists argue against the traditional notion of science and scientific knowledge. I will then present the meaning of science and scientific knowledge in the context of radical constructivism. Lastly, I will argue how radical constructivists answer two problems resulting from their conception of scientific knowledge, namely, the problem of distinguishing scientific knowledge from commonsense knowledge and falling into solipsism.

According to traditional approaches, science is a discipline that tries to reveal the facts about an observer-independent reality and scientific knowledge represents such a reality. In contrast, radical constructivism asserts that science is a discipline that produces viable conceptual constructs based on our experiences and consequently, scientific knowledge is the representation of an experiential world.

Von Glasersfeld emphasizes that many great scientists like Einstein and Heisenberg share the idea that science

involves theories and laws that are invented by human mind rather than discovered. This means that science is a human activity.

> "Physical concepts are free creations of human mind, and are not, however it may seem, uniquely determined by the external world. On our endeavor to understand reality, we are somewhat like a man trying to understand the mechanism of a closed watch. He sees the face and moving hands, even hears its ticking, but he has no way of opening the case. If he is ingenious he may form some picture of a mechanism that would be responsible for all the things he observes, but he may never be quite sure his picture is the only one, which could explain his observation. He will never be able to compare his picture with the real mechanism and he cannot even imagine the possibility or the meaning of such a comparison" (Einstein and Infeld, 1967:31 cited in von Glasersfeld, 1997:3).

> "In the nature of sciences, then, the object of research is no longer as such, but a nature confronted by human questions, and in this sense,

here too, man encounters himself" (Heisenberg, 1955:18 cited in von Glasersfeld, 1995:21).

For von Glasersfeld, it is natural that there are other scientists who believe that what they deal with is a part of reality. According to von Glasersfeld, it is a psychological need for a scientist to start a scientific study when the scientists experience a problem that is called 'the problematic experiential situation' by von Glasersfeld. In other words, scientists are motivated to do a hard work by believing the possibility of acquiring knowledge about external world. He believes:

> "only when he has solved it [the problematic experiential situation], may he adopt a philosophical attitude and conclude that his solution is an instrument for the organization and 'explanation' of experience rather than a representation of reality" (1995:21).

So, von Glasersfeld argues that in radical constructivism science is a tool derived from experiential world and serves to deal with experiences. However, this is an epistemological issue on which there does not necessarily have to be a consensus among scientists to carry out their scientific work.

Von Glasersfeld believes that Darwin's evolutionary theory motivates philosophers to construct the instrumentalist view of science. The theory supports an understanding of science that continuously evolves or adapts itself due to various constraints. For example, according to Darwin, the environment given is the main constraint and it is interpreted as experience by both pragmatists and radical constructivists (von Glasersfeld, 1995). On the basis of this view, whereas pragmatists redefine truth as what works in the experiential world, radical constructivists prefer to use the term viability i.e. the fitness of the construction to the experiences:

> "Radical constructivism is uninhibitedly instrumentalist. It replaces the notion of 'truth' with the notion of 'viability' within the subjects' experiential world" (von Glasersfeld, 1995:22).

> "The value of scientific knowledge, thus, is not dependent on 'truth' in the philosopher's sense, but on viability" (von Glasersfeld, 1995:117).

In radical constructivism, scientific knowledge is seen as a more reliable way for dealing with experiences. But as it is mentioned in the previous passage, this

reliability is not the result of its being true, but it is reliable "because of the way in which it[science] is built up is explicit and repeatable" (von Glasersfeld, 1995:117).

Von Glasersfeld argues that in case of traditional epistemological theories that consider truth as a criterion, there is a problem in using a theory that is believed to be false but useful. However, in radical constructivism since truth is replaced by viability, a theory can be used as long as it works. For instance, Newtonian laws are useful in making calculations while sending a man to the space. Though they are not considered true anymore, radical constructivism can use them since they are not refuted in the sense that they do not work for certain situations.

To see if scientific knowledge represents reality or experience, von Glasersfeld suggests looking at the scientific method. He claims that all the steps in the scientific method are related with experience. As a scientist, the first thing is to make the conditions of observing or experiencing explicit. The next step is to propose a hypothesis that is also based on experience. Then, scientists make predictions, and predictions are nothing but what we expect to experience. Lastly,

scientists test their predictions in the domain of their experience. For this reason, von Glasersfeld says:

> "Scientific method does not refer to … the notion of ontological reality. It operates and produces its results in the experiential domain of observers" (1995:117).

On the other hand, according to traditional epistemological theories, scientific and technological success supports the view that scientific knowledge is getting closer to reality. If our knowledge did not more or less accurately represent reality, scientific and technological success would be a miracle. For Von Glasersfeld, this success is not enough to justify the validity of our knowledge. He says:

> "The fact that scientific knowledge enables us to cope does not justify the belief that scientific knowledge provides a picture of the world that corresponds to actual reality" (1991:127).

> "Science is no longer seen as the path towards 'a true' understanding of real world, but as a tool of adaptation" (von Glasersfeld, 1997:3).

One must also consider that in radical constructivism, scientific knowledge like any other kind of knowledge is the construction of individuals on the basis of their experiential world. According to von Glasersfeld (1995), experience is "what the thinking subject coordinates", and he points out that:

> "coordination, thus, is a strictly internal affair and, therefore, it is always subjective to the coordinator"(1995:72).

Accordingly, von Glasersfeld argues that since all types of knowledge is based on experience that is an internal coordination, knowledge in radical constructivism is committed to subjectivity.

Eliminating objectivity from the conception of knowledge leads to two main problems. First, some philosophers criticize radical constructivism for falling into solipsism. Second, it becomes very difficult to distinguish commonsense knowledge from scientific knowledge.

For the first criticism, von Glasersfeld argues that subjective understanding of knowledge does not have to deny the existence of an external world. On the contrary,

radical constructivism sees the external world as one of the constraints for the experience of the individuals. In other words, external world is used to explain why individuals are not free to construct whatever they want. However, although it limits or affects our experiences, we cannot know the world as it is since it is beyond our experiences.

Von Glasersfeld also argues that solipsism is a metaphysical statement about the nature of the world. On the other hand, radical constructivism is a theory of knowing that makes no claim about the ontological structure of the world. As von Glasersfeld says, "it is intended as a theory of knowing, not as a theory of being" (von Glasersfeld, 1995:113).

In comparing the two kinds of knowledge namely commonsense and scientific knowledge, von Glasersfeld says "the second [scientific knowledge] is mostly held to be more solid" (von Glasersfeld, 1995:116). Actually, he does not want to lose the distinction between scientific knowledge and commonsense knowledge and objectivity totally. It is undesirable to say that scientific knowledge gained as a result of scientific work has no difference from commonsense beliefs and opinions. So, he introduces the notion of intersubjectivity as "the most

reliable level of experiential reality" to substitute the notion of 'objectivity' from traditional epistemology.

> "As the term [intersubjective] implies, the uppermost level arises the corroboration of other thinking and knowing subjects. The introduction of 'others' might seem to be in flat contradiction with the constructivist principle that all knowledge is subjective. However, the apparent contradiction will disappear if I am able to show that, although the others are the individual subject's construction, they can nevertheless provide a corroboration of the subject's experiential reality" (von Glasersfeld, 1995:119).

Here, it seems that von Glasersfeld's strategy to distinguish commonsense from scientific knowledge depends on the constructions of others who act or think like the observer. In this way, he tries to establish a basis for the interaction or corroboration between individuals to provide a more reliable knowledge that he calls "higher level knowledge". This interaction and corroboration is also the basis for the generation of equilibrium between individuals. It is to be noted that 'others' are also

constructed on the basis of the observer's experiences by the observer himself; therefore, there is no contradiction with the constructivist principle that we cannot know anything that is beyond our experiences.

Von Glasersfeld defines social corroboration in such a way that others' acts are also consistent with the viable conceptual schemes of the observer. He calls the viability of these kinds of conceptual schemes as "a second order viability". The second order viability determines the more solid or stable conceptual schema in the observer's experiential schema. So, if we differentiate scientific knowledge as the more solid conceptual schema then it means that scientific knowledge is the viable conceptual schema that is shared by more than one individual (von Glasersfeld, 1995:119-120).

On the basis of radical constructivist view of scientific knowledge and science, radical constructivists propose an alternative way of teaching science. I will discuss these implications in the following chapter.

5. THE IMPLICATIONS OF RADICAL CONSTRUCTIVISM FOR SCIENCE EDUCATION

According to von Glasersfeld, radical constructivism is not only a theory of knowledge but also a theory of learning. This is because, the epistemological claims of radical constructivism also lead to some strategies or methodologies for teaching science. In this chapter, I aim to examine the implications of radical constructivism for science education.

Since radical constructivism asserts that all knowledge is constructed on the basis of individual experiences, we cannot think of science instructions without thinking learners. First of all, learners will interpret any language or any perceptual material used to represent the content of science. In other words, students try to understand what they see or hear in terms of their preexisting conceptual structures that are constructed due to their own previous experiences. Therefore, it is not surprising that there will be situations in which everything is obvious for teachers and nothing is clear for students. To overcome this problem, von Glasersfeld suggests that:

"…the teacher keeps in mind that the words he or she uses have, for the listeners, associative links to their own experiential worlds and not to an independently existing reality that would be the same for all" (1995:182).

Radical constructivism encourages teachers to develop instructions that enable students to apply their own constructions or to verbalize their constructions in their own words. In this way, first, students who experience the advantages of using these ways and means are motivated to learn more. Second, teachers can have an idea about students' preexisting conceptual structures. Third, teachers can frequently check the students' understanding in their own words or in their own ways of acting to see that at least what they have in mind is consistent and compatible with the tachers' own.

As it is mentioned before, a fundamental principle of radical constructivism is the adaptive character of knowledge. That is, knowledge adapts itself in the way that it keeps equilibrium. Accordingly, a student who is in equilibrium does not need to develop a new conceptual schema or to make any changes in his existing schema. Therefore, the best strategy for initiating learning is to create a conflict or a contradiction that leads to a

perturbation in the student. Students, like any other individuals, have the tendency to maintain the equilibrium. Therefore, when they experience a perturbation, they try to establish a new conceptual schema or to modify their existing ones that work and explain all of their experiences including the ones that lead to perturbations.

On the other hand, in the light of Piagetian cognitive theory, that involves processes of assimilation and accommodation, radical constructivists claim that both environment and previous conceptual structures of students constrain the students' understanding and learning. In other words, a student tries to understand his environment on the basis of his previous conceptual structures; he also modifies his preexisting conceptual structures on the basis of his new experience of his environment. Therefore, in addition to being aware of students' preexisting conceptual structures, teachers are also responsible for providing the appropriate experiences in order to lead the student to viable constructions or to make them aware of their misconceptions.

According to radical constructivism, another constraint for construction of knowledge is the acts and

thinkings of others. It is believed that what others say or do is also a source for mutual change in the ways of thinking and acting of individuals. Therefore, another strategy of radical constructivism in science education is group learning. This is because, first, it is supposed that the constructions of the members of a group mutually change in group work since others' behaviors are effective in assimilating or accommodating the mental conceptual schema of the individuals. Second, group learning provides a medium where students verbalize the problems and solutions in their own words: hence, teachers can see whether these are consistent.

Briefly, there are three fundamental constraints resulting from the conception of knowledge: experience, preexisting conceptual structures of the students and interactions with others. Being aware of these constraints, science teachers are responsible for preparing a learning environment from which students can abstract the necessary fundamental elements and relations from their experiences.

Moreover, from a radical constructivist point of view, learning science requires an active construction in the sense that "building a coherent network by assembling conceptual structures and models that are mutually

compatible" (von Glasersfeld, 1995:116). Therefore, teachers should guide and lead the class with the appropriate student activities, discussions, questions and experiments, etc. to enable them to make the necessary associations or to make new conceptual constructions that are viable. In addition to the role of leading, science teachers should work to encourage and to motivate the students to make their own individual constructions.

In radical constructivism, justification of knowledge is provided by the criterion of viability. There are two ways for obtaining viability. The first one is to have various experiences in order to produce consistent conceptual structures. Therefore, radical constructivists claim the necessity of various experiences to increase the viability of constructions.

The second way for obtaining viable constructions is to provide consistency with other individuals' ways of acting and thinking. In this regard, group learning involving conversations, discussions, doing experiments are suggested as the best strategies for creating a medium where learners make sense of the environment and construct viable conceptual structures. Radical constructivists call this process 'negotiation of meaning

and knowledge'. Von Glasersfeld defines it as "a reciprocal accommodation to establish a medium of compatibility" (1995:191).

On the other hand, it is difficult to accept all viable constructions as knowledge even in the educational settings. For instance, memorization to the extent to which it is involved in the conceptual structure of the student is not accepted as knowing. However, radical constructivism cannot distinguish memorization from knowing since both are viable constructions. So, some radical constructivists suggest distinguishing strong or powerful constructions and weak constructions. According to this distinction, rote learning is also accepted as a way that leads to weak constructions. However, as radical constructivists also agree this distinction still requires a lot of work; both conceptual and empirical for describing them and to reveal the ways that lead such constructions.

6. AN ASSESSMENT OF RADICAL CONSTRUCTIVISM

The main aim of this chapter is to discuss the strengths and the weaknesses of radical constructivism. I will argue that radical constructivism misrepresents the traditional conception of knowledge and truth. I will also show that radical constructivism's own alternative epistemology lacks clarity with respect to its conception of knowledge and its only criterion, namely, viability.

On the other hand, although radical constructivism is subjected to serious criticisms as a theory of knowledge, there seems to be widespread acceptance of the theory in the educational settings. Its emphasis on the learner, especially on the learner's background knowledge, experience and interaction with others underlines the fact that the learner is arguably the most important component of the learning process. The attention given to the learner brings the frequent usage of the strategies or methodologies that are learner-centered such as discussions, collaborative learning, making experiments, writing reports etc. However, it is dubitable whether radical constructivism is the right paradigm for realizing all the goals of science education.

Before discussing von Glasersfeld's argument against the traditional conception of knowledge, let's look at the following two examples of knowledge statements, where S is the knowing subject.

(1) S knows how to swim.

(2) S knows that the earth is round.

Notice that the object of the verb in statement (1) is a skill, whereas the object of the verb in statement (2) is a proposition. On the basis of this sort of difference, traditional philosophy distinguishes at least two kinds of knowledge: know-how, that is, knowledge of how to do something and know-that, that is propositional knowledge in which the object of verb is always a proposition, which is either true or false. Traditional epistemology emphasizes the latter and analyzes it as follows:

For any individual S and any proposition p,

S knows that p if and only if

(1) S believes that p

(2) p is true

(3) S is justified in believing p.

This is known as the justified true belief (JTB for short) theory[1]. According to JTB theory, propositional knowledge has both an objective and a subjective side. Condition (1) requires that a subject must believe the proposition. So, obviously, this condition makes knowledge subjective in the sense that it is dependent on the subject's mental states. On the other hand, the second condition is independent of anyone's mental states and provides an objective benchmark for knowledge. For instance, whereas someone's belief that the earth is round, qua being a belief, is a subjective issue, whether the earth has that property in the actual world is an objective matter that does not depend on anybody's beliefs, wishes, feelings etc.

The third condition is the requirement of justification in believing p. There are two kinds of justifications; experiential and inferential. Radical constructivism only talks about experiential justification via viability, but ignores inferential justification. On the other hand, traditional philosophy,

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[1] Gettier cases show that the three conditions of JTB theory are necessary but not sufficient. On the other hand, the addition of a fourth condition does not affect our criticism of radical constructivism.

in addition to experiential justification, makes use of inferential justification via deductive and inductive arguments. Both types of arguments have established rules. It should be noted that even though the rules for making inductive inferences are somewhat controversial, they are nevertheless non-subjective. These established rules, both for deductive and inductive arguments, secure objectivity in our justifications.

Let us now turn to von Glasersfeld's argument that explains why he defends a subjective conception of knowledge instead of an objective one. First, von Glasersfeld assumes that realists are committed to the correspondence theory of truth according to which a proposition is true if and only if it corresponds to facts. Then, he argues that it is impossible to compare our propositions with facts since facts are beyond our experiences, so, he claims, one cannot know the truth of a proposition[2]. Thus, von Glasersfeld interprets the truth condition in JTB theory as requiring that S must know the truth of p. On the basis of this misinterpretation, he claims that one cannot attain any

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[2] I give a more detailed explanation of Von Glasersfeld's argument against traditional conception of truth and knowledge in Chapter 2.

knowledge of reality if the traditional conception of knowledge is accepted and writes:

> "traditional epistemology could no longer be maintained" (1995:18).

Thus, von Glasersfeld defends the necessity of constructing an alternative conception of knowledge that requires no truth condition and that is completely subjective.

However, von Glasersfeld is mistaken about his belief that realists are committed to the correspondence theory of truth. In traditional epistemology, there are other theories that do not require a correspondence and can be used without any problem (Nola, 1998). For example, there is Tarskian conception of truth according to which:

> For any sentence S,
> The English sentence "S" is true if and only if S.

As an example, the English sentence "snow is white" is true if and only if snow is white. This means that if the sentence "snow is white" is true, then snow is white; and, if snow is white in the actual world then the sentence "snow is white" is true. It is important to note

that this theory, unlike correspondence theory of truth, does not employ concepts like "representation" and "correspondence". This gives the realists an alternative conception of truth.

Moreover, von Glaserfeld's interpretation of truth condition for knowledge is also not valid. If it is claimed, as von Glasersfeld does, that s must know the truth of p, then obviously the definition of knowledge becomes circular: Von Glasersfeld's claim amounts to the requirement that in order to know p, s must know the truth of p. Traditional epistemology does not suffer from such a defect. In the JTB theory, the truth condition is that p must be true. This condition, unlike von Glasersfeld's interpretation, requires no necessary relation between the knower and the truth of the proposition.

Another problem for von Glasersfeld is that he confuses our claims to truth with truth itself. When we look at the history of science, it is evident that there are cases such that science has been mistaken about the existence of objects, events or processes. Consequently, there are scientific theories, such as phlogiston theory, that are false. In phlogiston theory, the process of burning is explained by the removal of an alleged

substance called phlogiston. Today we explain combustion in terms of oxygen consumption. So, in contrast to phlogiston theory, burning is not a removal of phlogiston from a substance but it is the addition of oxygen to a substance. For von Glasersfeld, these examples show that we are unable to attain truths. However, these examples only show that in the past we were mistaken in our claims to know, not that we never attain knowledge and truth or get closer to truth.

A scientific proposition may be false, strictly speaking, but yet be a very good approximation to reality. Newton's laws of motion are a case in point. Hence, one can admit the fallibility of scientific propositions and at the same time claim that a scientific proposition is closer to truth than another one. Indeed, progress in science usually takes this form of verisimilitude.

In an interview, von Glasersfeld answers a question related with progress in the following way:

> "Constructivism would be rather foolish to deny that we know more today than did, say, the pre-Socratics or even Newton, but the growth of knowledge concerns knowledge of how to do things.

> The fact that we can send a man to the moon and can have a phone conversation from our moving car does not mean that the conceptual structures and action programs we have developed are any more a representation of ontological reality" (1993:27).

Here, von Glasersfeld claims that there is progress in the knowledge of how to do things. So, he admits that we acquire knowledge in the sense of know-how. However, it is difficult to explain within the limits of radical constructivism how we successfully have acquired knowledge of how to do things without appealing to propositional knowledge.

As a proof of progress in know-how knowledge, von Glasersfeld gives examples such as going to the moon or making a phone call from a moving car. These are some of the examples that show there is a progress in the technological field. But how would von Glasersfeld explain why such technological gadgets successfully work without appealing to the at least approximate truth of scientific theories underlying them? For example, how will radical constructivists explain the sending of rockets to the space successfully? Since they cannot appeal to the truth or approximate truth of scientific theories behind the workings of rockets, radical

constructivists must see such technological success as a miracle.

By contrast, realists can explain the success and the developments in technology by inference to the best explanation. The inference goes like this:

Theory T explains phenomenon E well.

No other theory explains E as well as T.

Therefore, T is true (or at least, approximately true) and the entities that it postulates are likely to exist.

On the basis of the inference to the best explanation, realists can argue for the truth of theories underlying technological success and account for such success by appealing to the existence of entities (such as electro-magnetic fields, electrons, etc.) that ground it.

Now, let me discuss viability that is presented as the only criterion in von Glasersfeld's alternative conception of knowledge. Recall that, von Glasersfeld defines knowledge as conceptual constructs that are viable.

When we look at von Glasersfeld's writings, viability involves being in a state of equilibrium. That is the state in which the individual has no conflicts and no contradictions. In other words, von Glasersfeld defends some sort of coherence in the sense that a conceptual structure is viable *if and only if* it coheres with all the experiences of the individual. But coherence does not always provide us with truth. For instance, more than 2000 years ago, in order to explain motion Aristotle claimed that every object in the universe has a natural place and that each object has a tendency toward its natural place. On the basis of this view, Aristotle explained the upward movement of steam, for example, by saying that steam is a form of air and that the natural motion of air is upwards. Similarly, he explained the motion of earthy substances by claiming that their natural place is downward. Aristotle's explanations are certainly viable with certain experiences at that time but, of course, that is not enough for a theory to be true.

In order to defend viability, von Glasersfeld writes:

> "If a prediction turns out to be <u>right</u>, a constructivist can only say that the knowledge from which the prediction was derived proved

viable under the particular circumstances of the case" (von Glasersfeld, 1993:26).

But what does he mean by "turning out to be right"? It could only mean that our prediction came out to be true! (Nola, 1998) So, his attempt to replace truth by viability as a criterion for knowledge ends up referring to truth as a criterion for viability after all!

Another problem is von Glasersfeld's relativism that results from his subjective conception of knowledge. It is possible that a conceptual structure is viable for an individual but not viable for some others. In those cases, there is no way for either a consensus or a rational discussion between individuals to settle the issue. This is because from von Glasersfeld's perspective, there is no objective reference point for discussion. Worse yet, there can be more than one viable conceptual structure for the same domain. For instance, future of the universe must follow one of two courses: either eternal expansion, or reversal into contraction at some point in the distant future. Both accounts can be considered as viable conceptual structures. Von Glasersfeld himself accepts the possibility of having more than one viable conceptual structure for the same domain and says that:

> "no inference about a 'real' world can be drawn from this viability, because a countless number of other scheme might have worked as well" (1995:73).

Von Glasersfeld does not tell us how one could make a rational decision between these "countless numbers" of viable conceptual scheme. As Osborne states:

> "Constructivism fails to elaborate any mechanism by which one theory can be considered more 'viable' than another" (1996:58).

When there are no such criteria:

> "science becomes a set of meanings and concepts which evolve from socially negotiated understanding and not from a process of examining whether such inventions are supported when tested against the real world" (Osborne, 1996:59).

Thus, science becomes a discipline of constructing conceptual structures that are consistent with each individuals' daily experiences. This means that it is possible that a student constructs that 'the sun is moving around the world' on the basis of his daily

experiences such as observing the sunrise from the east and the sunset in the west. Since this is consistent with his everyday experiences, he may not feel a need to change his model.

Moreover, even if we apply some radical constructivist strategies in science class such as group discussions, it is possible that members of the group may come to the conclusion that "the sun is moving around the world". Then, will the teacher go along with this false belief simply because it has been "socially negotiated" in the class?

Matthews states a similar problem as follows:

> "…the educational issue is to determine what follows from the recognition of this discrepancy: do we improve our teaching so as to eliminate this discrepancy, or do we accept the child's misconception 'alternative framework' or just plain error?" (1998:144).

So, it is not at all clear for science teachers how to act in cases where students develop an alternative framework. In such cases, we can think of two options for science teachers. First, science teachers can consider

these alternative frameworks as misconceptualizations and try to change them. Osborne and Freyberg (1985) also state that science instructions are designed to create a conceptual change. However, within the limits of radical constructivism, to realize such an aim seems meaningless. This is because for von Glasersfeld objectivity is a "defenseless element of a traditional epistemology[3]. Since there is no objective benchmark, it is difficult to answer questions such as: According to which conceptual structure a student's conceptual structure is considered to be a misconcepualization? And in what way do we want our students to change their conceptual structures?

The other option is that science teachers can accept these alternative frameworks. Then, we end up with an absurd picture of science classes in which students learn that the sun is orbiting around the earth! Being aware of this problem, some radical constructivists suggest looking for a harmony between the scientific community and children's conceptions. However, in radical constructivism, it is difficult to explain why we want to be in line with the scientific community. In other words, radical constructivists lack the rationale for giving priority to scientific knowledge. As Matthews writes:

> "if science is not about the real world, or is not thought to be true in any serious sense, then it becomes difficult to justify attempts to change students' understandings and beliefs when such change is at the cost of their self-confidence, is in opposition to the feeling of their parents, or is in conflict with important cultural values" (1994:159).

By contrast, realists can explain that scientific work has a methodology that provides us with objective knowledge. Therefore, we try to obtain genuine knowledge about the world using scientific methodology even if our daily life experiences contradict with the knowledge thus obtained. Indeed, science often does clash with our ordinary experiences as every student of science knows. To give a sample example, our ordinary experiences suggest that it is the sun that moves, not the earth despite the fact that it is the other way around.

Although radical constructivism cannot be considered as a successful theory of knowledge, it nevertheless has useful consequences especially in the educational

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[3] Von Glasersfeld names the constructivism that has a room for objectivity as "trivial constructivism" (1993:24).

settings. Matthews lists some of these useful consequences as follows:

> "Constructivism has done a great service to science education by alerting teachers to the function of prior learning and extant concepts in the process of learning new material, by stressing the importance of understanding a goal of science instruction, by fostering pupil engagement in lessons and, other such progressive matters" (1998:7).

We can also add that radical constructivism is an effective theory in identifying some of the difficulties that students experience in understanding science. As we just saw, the student's conceptual structure that results from his daily life experiences is not always in line with the conceptual structure of the science teacher. In such cases, it is difficult for students to learn or to construct the appropriate links between their prior constructions and the new ones suggested by their teacher.

Another difficulty in science education that is emphasized by radical constructivists is the difficulty in changing students' misconceptions (Gunstone, 1988).

Hence, some strategies or methodologies are developed in order to overcome these difficulties that originate from the learner's previous constructions. Typically, a medium where the learner can be aware of his previous conceptual schema is suggested, and a perturbation is required in order to produce a change in the previous constructions or to create a new construction.

On the other hand, when we look at the history of theories of education, we see that these strategies are neither unique to constructivism nor committed to the radical constructivist epistemology. For instance, a science teacher who believes that scientific theories are approximations to truth may also make group discussions, try to reveal students' commonsense knowledge and provide the students with situations in which they will come to see the inadequacies of relying solely on commonsense.

In contrast to radical constructivists who consider the theory as a package that consists of a learning theory and a theory of knowledge, some philosophers suggest that pedagogical part be separated from the epistemological part. Matthews explains the idea behind this separation as follows:

> "constructivist pedagogy is valuable and should be encouraged, even if the theory is debatable. This position is understandable, but it rests on a moot point: How efficacious is constructivist pedagogy in teaching science?" (1998:7).

So, any attempt to consider a theoretical base or a practical implication for science education requires also an analysis in terms of aims and intentions. In other words, if the pedagogical part of radical constructivism serves us to realize the aims of science education, then we can consider it as a useful learning theory and attempt to separate it from its epistemology. Before evaluating radical constructivism as a learning theory, let me explain the general goals of science education. Then, in the light of these goals of science education, I will examine radical constructivism to see whether it serves us as a useful learning theory to realize these aims.

The central goal of science education is to develop scientifically literate individuals. This aim can be summarized under four dimensions (Chiappetta, Fillman, Sethna, 1993):

- to teach the scientific theories as a body of knowledge.
- to teach the scientific method as a way of investigation.
- to generate an understanding of nature of science.
- to teach the relation between science and technology.

According to the first aim of science education, science classes are used to convey scientific knowledge to the students. That is, students should learn the basic concepts, principles and theories of science that are currently accepted and judged to be the best by the scientific community. However, radical constructivists argue that students can have powerful constructions only if they establish conceptual constructs on the basis of their individual experiences. Hence, radical constructivists will have severe difficulty in realizing this aim for two reasons:

First, it is extremely difficult if not outright impossible for students to construct all the scientific knowledge in a given field or topic even if a good guide is given to them. This is because most of the concepts, principles, laws and theories are too abstract and sophisticated for most students to abstract them from

their own experiences. Second, both the school conditions and the time required for science education are insufficient for such a construction. For example, if we remember that it took years to come up with the idea of an electric field even for a genius like Faraday, imagine how much time it would take for an average teenager! Matthews states this problem as follows:

> "The difficulty for constructivism posed by teaching the content of science is not just a practical one, it is a difficulty that exposes a fundamental theoretical problem for constructivism if knowledge cannot be imparted and if knowledge must be a matter of personal construction, then how can children come to knowledge of complex conceptual schemes that have taken the best minds hundreds of years to build up?" (1998:8).

Regarding the investigative nature of science, it is expected from students to learn the processes of science. It is evident that not all investigations are scientific The scientific process involves reliability and validity studies, controlling variables, operationalizing, formulating, measuring, observing, testing, predicting etc., which are absent in ordinary process of learning.

On the other hand, radical constructivism focuses only on viability, and it expects the learners to apply naturally the standards of a scientific process such as controlling variables. For example, while learning the concept of solubility, the student must control the variables such as temperature, time and surface area. But every science teacher knows, this is not a realistic expectation.

The point is that such scientific standards are not naturally possessed by the students but they have to be learned (Hodson, 1998). By not giving a special care to the standards of a scientific process, radical constructivists ignore a great part of science, in particular its well-established methodology that provides objectivity.

Another goal of science education is to develop a view about the nature of science. Traditionally, the nature of scientific knowledge is seen as tentative, public, humanistic, historic, and empirical. Radical constructivism, too, recognizes these characteristics of science. In radical constructivism, scientific knowledge is also tentative because it is open to adaptation; it is public because it gives emphasis to social negotiation; it is humanistic because it is a product of mankind; it

is historic because it emphasizes the previous conceptual structures; it is empirical since it is based on experience.

The problem with the radical constructivist's understanding of science is his overemphasis on individual constructions and his denial that these constructions are responsible to an objective reality. Although he accepts nature as a constraint for our experiences, he never tells us how. In other words, when he evaluates the result of a construction, he ignores the element coming from the mind-independent reality and he attributes the whole product to individual's constructive work without any reference to the role the mind-independent reality has played. Thus, he fails to distinguish between theoretical objects and real objects (Osborne, 1996; Matthews, 1994). Theoretical objects are the constructions of human mind, constructions that are put forward in order to understand or explain the real objects and events. However, real objects are not the constructions of any human mind but exist independently. Matthews explains the difference between theoretical objects and real objects as follows:

> "... most constructivists... go wrong in failing to distinguish the theoretical objects of science,

> which do not lie around and fall on people's heads. The real falling apple is represented in physics as colorless point mass and as a variable in equation…" (1994:52).

So, science develops theoretical objects with specified properties and real objects (or reality) are conceived with the help of these theoretical objects. But, radical constructivists fail to see that the fact that scientific knowledge is mediated by theoretical objects does not make it subjective, for the construction of theoretical objects is severely constrained by real objects in the world, and it is this feature of science that makes it objective.

Finally, science education aims to clarify the relationship between science and technology. Most technology today is driven by science, and progress in science in turn owes much to the technological innovations. For example, as a result of progress in optics, better microscopes are developed. Similarly, observations made with microscopes enable us to discover more about the microorganisms that we cannot see otherwise. In short, science and technology support each other mutually.

However, although the radical constructivists seem to be aware of the developments in technology, they refuse to talk about the progress in scientific knowledge (i.e. propositional knowledge) that underlies these developments. Therefore, they have difficulty in explaining the developments in technology without referring to the progress in scientific knowledge, which is obviously more than a tool for thinking.

In conclusion, radical constructivism is not only a poor substitute for traditional epistemology but also fails to meet the main objectives of science education as a theory of learning and teaching.

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