Chapter 24
Radical Constructivism—von Glasersfeld

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Radical Constructivism

Constructivism has been hugely influential in education in all disciplines for many years (Slezak, 2014; Young & Muller, 2010). The variant under discussion in this chapter, radical constructivism, has had considerable impact in science and mathematics education, since it was first developed by Ernst von Glasersfeld in the seventies (Lerman, 1996; Olssen, 1996; Riegler, 2001; Slezak, 2010). While constructivism may have abated in influence to an extent since its highpoint in the late nineties, it continues to underpin much thought, theory and pedagogy in science education (see for example Chap. 18: Social Constructivism; Chap. 19: Lev Vygotsky). Concepts of student developmental learning and hypothetical learning pathways that originated in radical constructivism (von Glasersfeld, 2007; Steffe, 2007) have heavily influenced the underlying philosophy of the recent Next Generation Science Standards (NGSS). In many respects, radical constructivist theories about student learning have now become accepted wisdom in science education research, teaching and learning.

Constructivism emerged as a reaction to the empiricism and behaviourist psychology that dominated educational theory in the twenties and thirties (see for example Chap. 6: Classical and Operant Conditioning), and in education has its roots in developmental psychology (Matthews, 2012; Olssen, 1996), particularly the work of Jean Piaget (see Chap. 10: Jean Piaget). Von Glasersfeld defined radical constructivism as a 'theory of knowing that provides a pragmatic approach to questions about reality, truth, language and human understanding' (von Glasersfeld, 1995, Abstract). The main application of radical constructivism in science education is in the realm of learning science, and how teachers can best support their students to acquire and develop scientific concepts. The use of the word 'radical' to describe this version of constructivism reflects his notion that it is a particularly controversial theory for

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B. Akpan and T. Kennedy (eds.), *Science Education in Theory and Practice*, Springer Texts in Education, https://doi.org/10.1007/978-3-030-43620-9_24

educators to take on board. As he points out 'to introduce epistemological considerations into a discussion of education has always been dynamite' (von Glasersfeld, 1995, p . xi). Indeed the theory of radical constructivism has been quite controversial within the community of philosophers of science and science educators ever since it first emerged (Quale, 2008; Riegler & Quale, 2010).

This chapter begins with a brief biography of von Glasersfeld. It goes on to outline the epistemological issues he raised in his theory of radical constructivism, the implications of radical constructivism for learning about scientific practice, that is, how scientists come to develop new scientific knowledge, and its implications for teaching and learning science. The final section discusses some of the criticisms and limitations of radical constructivism.

Biography of Ernst von Glasersfeld

Ernst von Glasersfeld was born in Germany in 1917, and spent his early childhood in Austria. He initially studied mathematics in Zurich, and then moved to Vienna, where he was introduced to the work of Wittgenstein. He and his wife lived in Ireland during the Second World War, where he learned of the work of the Irish idealist philosopher Berkeley and of the philosopher Giambattista Vico. These thinkers, along with other philosophers, had a profound influence on his ideas. He moved back to Italy after the war, where he became part of a circle of intellectuals who were developing a theory of semantics. Von Glasersfeld went on to become one of the pioneers in the field of cybernetics, working on a project to develop machine translation. In 1967 he started working in the University of Georgia where he became interested in Jean Piaget's work on cognitive development, and became gradually more involved in the world of education, particularly in mathematics education. In 1987, he moved to work with a physics education group in the Scientific Reasoning Research Institute in the University at Amherst. He passed away in 2010.

The Traditional Epistemological View

In order to understand von Glasersfeld's radical constructivism, it is crucial to understand that he is arguing from the position that most people are tied to what he refers to as the traditional western epistemology. They believe that our knowledge faithfully reflects an ontological reality that exists independently of the observer (von Glasersfeld, 1995). Von Glasersfeld traces the ideas that underpin radical constructivism as far back as the Ancient Greek philosophers, right through to the present day, in the work of a variety of philosophers and theorists, including Vico, Kant, Berkeley, Darwin, and de Saussure. The main tradition of western philosophy is informed by metaphysics:

> A metaphysical realist… is one who insists that we may call something 'true' only if it corresponds to an independent, 'objective' reality. … most scientists today still consider themselves 'discoverers' who unveil nature's secrets and slowly but steadily expand the range of human knowledge; and countless philosophers have dedicated themselves to the task of ascribing to that laboriously acquired knowledge the unquestionable certainty which the rest of the world expects of genuine truth. Now as ever, there reigns the conviction that knowledge is knowledge only if it reflects the world as it is. (von Glasersfeld, 1984, p. 20)

This is the way in which most of us live our lives. We perceive objects or events with our senses, and we believe that what we perceive corresponds or matches to a physical reality that actually exists.

The Constructivist Epistemological View

Von Glasersfeld describes radical constructivism as being a departure from this traditional epistemology and from traditional cognitive psychology, in that it moots a different conception of the relation between knowledge and reality. Within the traditional notion, there is an iconic correspondence or match between knowledge and reality, whereas within radical constructivism, the relation is that of an adaptation or a functional fit of knowledge to reality, which can never be directly experienced. This is the constructivist aspect of his theory: we actively construct our world, our knowledge, from what we perceive, rather than passively receive sensory images of a pre-existing reality. However, this is not to say that radical constructivists deny the existence of an objective world, of reality. On the other hand neither do they say it exists. 'Radical Constructivism is agnostic' (Riegler, 2001, p. 1). It is not concerned with ontology, whether what we know actually exists, but rather how we come to know.

While we play an active part in constructing our reality, that does not mean that we can therefore construct any old conception of reality. It has to be viable. Similar to the theory of evolution put forward by Darwin, the notion of viability is not a free-for-all. Just as the environment places constraints on the living organism (biological structures) and eliminates all "variants that in some way transgress the limits within which they are possible or 'viable', so the experiential world, be it that of everyday life or of the laboratory, constitutes the testing ground for our ideas [cognitive structures]" (von Glasersfeld, 1984, p. 30). The analogy with knowledge von Glasersfeld makes is that knowledge is useful or viable if it stands up to experience and enables us to make predictions and to bring about or avoid particular events or experiences. If knowledge does not serve that purpose, it becomes questionable, unreliable or useless, and is eventually devalued as superstition. In other words, our ideas, theories, our laws of nature are structures which either hold up or not when exposed to the experiential world, from which they derive. These cognitive structures do not tell us how the objective world might actually be, rather a structure gives us one means to achieve a specific goal.

Von Glasersfeld summaries the fundamental principles of radical constructivism as:

1. Knowledge is not passively received but built up by the cognizing subject.
2. The function of cognition is adaptive and serves the organization of the experiential world, not the discovery of ontological reality (von Glasersfeld, 1995, p. 35).

Radical Constructivism and Jean Piaget

The work of the educational psychologist Jean Piaget, particularly Piaget's notion of 'genetic epistemology' was very influential in von Glasersfeld's theory of radical constructivism. Piaget suggested that we construct our concepts and our picture of the world we live in, developmentally (von Glasersfeld, 1995). Von Glasersfeld therefore utilizes the word genetic in the sense 'developmental'. In this perspective, knowledge does not exist there to be uncovered by the cognizing subject, but is constructed by them from their experiences (von Glasersfeld, 2001b).

The essence he takes from Piaget is that a cognizing organism has developed certain 'keys' or structures that allows it to achieve certain goals. The cognitive organism evaluates its experiences, and tends to repeat certain ones and to avoid others. We perceive certain regularities within the flow of our experiences, for example, that an apple is smooth and sweet and round, or that to touch a hot object is painful, and we adapt our behaviour to these experiences. It does not matter what an object might be in reality or from an objective point of view (if that were possible to have), rather what matters is whether or not it behaves as is expected of it; in other words does it 'fit' with our cognitive structures built up from our experiences (von Glasersfeld, 2001b).

Symbols and units in science and mathematics are an example of such mental constructions, or ways of organizing experience. The active experiencer creates the units, but also creates the discrete entities to be counted. The mind segments and coordinates the continuous flow of raw experiential material into such structures. We then assimilate further experiences to them, building endlessly on previous structures (von Glasersfeld, 2001b).

Radical Constructivism and Learning About Scientific Practice

Von Glasersfeld sees a number of implications for the discipline of science of radical constructivism (2001b). He argues that most philosophers would describe Piaget's theory as incorrect because it is based on what they call the 'genetic fallacy', that is, knowledge is developed over time, rather than simply there, waiting and available to be discovered by scientists. On the contrary, von Glasersfeld draws on the work of the philosophers of science, Karl Popper and Thomas Kuhn, who he says indicated in various ways in their writings that scientific knowledge does not simply emerge over time, as scientists happen to make more discoveries. Rather, scientific models are scientists' theoretical models of various mechanisms. They check the viability of their model to explain phenomena by doing experiments. Scientists use great creativity in their construction of scientific models. Non-scientists do the same in a less coherent and explicit way; in both cases the point is not to obtain a true picture of reality but rather to construct structures that allow us to manage our experiences and to explain natural phenomena (von Glasersfeld, 2001b). From a science education perspective, therefore, radical constructivism provides an explanation of how scientists develop new knowledge. It can help students to learn and understand about the nature of scientific practice, as well as providing an approach for learning science concepts.

Radical Constructivism and Science Teaching and Learning

The faculty of cognition is central in radical constructivist views of knowledge and knowing. The basic assumption of radical constructivism is that all knowledge is constructed by the individual learner for the purpose of making sense of their experiential world (Quale, 2008). Like other forms of constructivism, the emphasis is a move away from teacher-centred learning to a more student-centred focus (see Chaps. 16–26). The implications of radical constructivism for science education are that, therefore, 'the art of teaching has little to do with the traffic of knowledge, its fundamental purpose must be to foster the art of learning'(von Glasersfeld, 1995, p. 192).

This is the logical outcome of the radical constructivist notion that we, as cognizing subjects, develop or construct our own knowledge (von Glasersfeld, 2010). Creating concepts requires a form of construction; by which von Glasersfeld means reflection on mental operations: recognition of the connections made when the cognizing subject co-ordinates sensory elements or mental operations. We produce certain conceptions because of our tendency to look for something familiar in what we perceive. The significance of this for teaching is that students have to construct their concepts on the basis of their own thoughts, that is, their own mental operations and reflections, and that concepts cannot be directly conveyed by language, which is very open to misinterpretation (von Glasersfeld, 2001a). Therefore, forms of pedagogy that are centred on rote-learning or passive forms of learning are not good approaches to supporting students in developing their understanding of a given topic.

While the focus within radical constructivism is on how students learn, von Glasersfeld (2001a) provided some practical suggestions for how radical constructivism might be translated into teaching methods. The essence of a radical constructivist approach to pedagogy might be broadly encompassed by the now-familiar notion of active learning. Von Glasersfeld (2001a) suggests using conversations and asking students to verbalise their conceptual understanding as a way of both teachers understanding where the students are at, and as a learning strategy. His suggestions for creating a radical constructivist-informed pedagogy to promote student conceptual learning and development include:

- Creating opportunities for making students think.
- Teachers must have a range of didactic situations at their disposal to stimulate student creation of concepts.
- Do not tell students their work is wrong; recognize and support their efforts to learn, thereby motivating them.
- With regard to the relativity of words, teachers should pay particular attention to students' naïve conceptions, in order to influence a new train of ideas and to prevent students forming incorrect conceptions.
- Encourage students to verbalize their constructions and their thought processes in order to stimulate their thinking and creating of concepts. (von Glasersfeld, 2001a)

Initially von Glasersfeld's radical constructivism was very influential in mathematics education. He worked with a number of mathematics educators in the 1970s and 1980s on research that took a constructivist approach, in particular with Les Steffe on developing new approaches to the learning and teaching of arithmetic (von Glasersfeld, 1995). He also worked with and influenced science educators (Tobin, 2007), and wrote about teaching methods for more learner-centred or active approaches to teaching physics in the classroom. Radical constructivist methods of teaching provide students with opportunities to engage in scientific inquiry, through a process of reflecting and discussion on the outcomes of scientific activities. A practical example that he gives is that teachers could show students two routes by which a ball can travel through a chute, and ask the students which will arrive first. The counterintuitive correct outcome is that the ball arrives first by the longer route that has a steeper downhill slope for part of the route. Through discussion and exploration and reflection, the students can come to understand why this is so, and the physical concepts behind it, in a way that is not possible through simply providing them with the correct answer (von Glasersfeld, 2001a).

Supporters of radical constructivism in science education have tended to connect didactic modes of teaching directly to a belief in traditional western epistemology. Knowledge is viewed as:

> out there, residing in books, independent of a thinking being. … As a result, teachers implement a curriculum to ensure that students cover relevant science content and have opportunities to learn truths which usually are documented in bulging textbooks. (Lorsbach & Tobin, 1992, p. 1)

Therefore adopting a radical constructivist epistemology is seen by some to lead inevitably to more effective active and inquiry-based learning in the science classroom (Lorsbach & Tobin, 1992; Matthews, 1998), as in the example described above by von Glasersfeld for teaching physics concepts. Radical constructivist epistemology has hence been the inspiration for approaches in science education which focus on the learner and the role of language in negotiating meaning, both for students and for the professional development of teachers (Tobin, 2007). But for others, adopting a radical constructivist approach will have an even more dramatic effect. Andreas Quale argues that current problems in science education, such as decline of student enrolment in science subjects, can be addressed by taking the relativist epistemological and ontological perspective offered by radical constructivism. The traditional image of science projected to students is rooted in realism (there is an objective reality independent of human observation and reflection, and that it is the task of science to search for this true knowledge of this objective reality). In contrast, radical constructivism posits that all knowledge is constructed by the individual learner for the purpose of gaining understanding and control of their experiential world. Note that unlike von Glasersfeld himself, Quale does not reject relativism. Quale sees this as a more empowering position for learners that will therefore engage their interest and attention in science. If reality is not the ultimate arbitrator of truth, then humans themselves are solely responsible for their own decisions and actions. This means that students do not have to blindly accept the knowledge that is handed down to them by higher authorities, but can instead become active socio-political agents (Riegler & Quale, 2010). From this perspective, students would be empowered by the radical constructivist stance on scientific knowledge to take actions counter to traditional wisdom and authority, such as refusing to accept the unwillingness of those in power to tackle the causes of environmental degradation.

Indeed as Matthews (2012) and others point out, constructivism has had a very positive influence in science education in alerting teachers to the importance of students' prior learning and the need to be aware of their existing concepts in relation to learning new material. Radical constructivism stresses the importance of student understanding, which has fed into very progressive pedagogies that focus on engaging students in their learning. It also has highlighted the fallibility of science, the culturally determined and conventional aspects of scientific knowledge-production, the historicity of scientific concepts, and so on. While constructivism does not have a monopoly on these insights, it has certainly promoted them to the betterment of science education.

Radical constructivism has also had an impact beyond the development of active and engaging classroom pedagogies. Von Glasersfeld's collaborator Les Steffe developed the 'teaching experiment' approach to developing understanding of student learning (von Glasersfeld, 1995). This methodology, and the constructivist approach to student learning underpinning it, in turn lead to the development of mathematical learning trajectories (Clements & Sarama, 2004), a major innovation in mathematics curriculum development. Learning trajectories describe students' thinking and learning in a specific mathematical domain. They lay out a conjectured route through a set of instructional tasks 'designed to engender those mental processes or actions hypothesized to move children through a developmental progression of levels of thinking, created with the intent of supporting children's achievement of specific goals in that mathematical domain' (Clements & Sarama, 2004, p. 83). Other radical constructivists, such as Paul Cobb, one of Steffe's graduate students, went on to work with a number of eminent U.S. science educators in the further development of the teaching/design experiment methodology for developing hypothetical learning pathways of student thinking (Cobb, Confrey, Disessa, Lehrer, & Schauble, 2003). In science, these pathways are called learning progressions, the scientific equivalent of learning trajectories in mathematics (Duschl, Maeng, & Sezen, 2011). The NGSS are based on learning progressions, as outlined in the *Framework for K-12 Science Education* (National Research Council, 2012), showing the extent of the influence that radical constructivist ideas continue to have in science education.

Radical constructivism therefore may once have been a departure from the dominant theories of education that existed before the 1970s, but it now permeates most aspects of science education.

Criticisms and Limitations of Radical Constructivism

Slezak (2014) notes that there have been many critics of radical constructivism, who have argued that it has 'serious, if not fatal, philosophical problems, and further, it can have no benefit for practical pedagogy or teacher education' (p. 1024). Slezak (2010) highlights von Glasersfeld's allegiance to what he calls Berkeley's 'notorious' idealism in his advocacy of the recommendation that we give up the requirement that knowledge represents an independent world. Slezak insists that von Glasersfeld encourages the attribution of idealism through his misleading claims that the great physicists of the twentieth century did not consider their theories to be descriptions of an ontological reality. Slezak points out that Piaget himself, a major referent for von Glasersfeld's theories, does not deny the existence of an objective reality beyond our sense-data, arguing that von Glasersfeld misinterprets Piaget in this respect. Rather Piaget clearly states that the subject's thought processes depend both on an organism's internal mental constructions, but also on the fact that the organism is not independent of its environment but can only live, act or think in interaction with it. Slezak (2010) therefore states

> Thus, while von Glasersfeld is at pains on every occasion to emphasize the unknowability of reality and the need to abandon notions of objectivity and truth, Piaget by contrast, writes in an altogether different mood. …it is evident that his version of constructivism is quite different from Piaget's. (p. 104)

Several critics note that this idealist turn in radical constructivism could lead to scientific knowledge being undervalued and discredited. There is a concern that if we construct our own knowledge, then 'anything goes'. This is relativism, that is, the notion that there are no grounds on which to decide that one version of reality or knowledge is any better than or more true than another. Scientists themselves are aware that theories can change, but they do not necessarily hold relativistic views about the nature of scientific knowledge (Harding & Hare, 2000). They believe scientific knowledge is true, and they use it as the basis of further investigations. They are open-minded about scientific knowledge, but not relativist. They could not operate otherwise (Harding & Hare, 2000). And indeed not all science educators who are constructivist agree with von Glasersfeld's position on the unknowability of reality. Taber (2006) highlights that the radical constructivist view of science knowledge is inappropriate as it 'sets learner's ideas to be of equal validity to currently accepted knowledge' (p. 199). Taber presents the debate as being a question of whether constructivism is seen as being about (a) how science learning occurs (von Glasersfeld called this trivial constructionism), or (b) the nature of human knowledge (the radical constructivist perspective). Radical constructivism, Taber suggests, goes too far in the direction of giving equal weight to learners' misconceptions as to accepted scientific theories and laws.

However, von Glasersfeld refutes the charge of relativism, or that radical constructivism rejects the idea that there is such a thing as reality; rather he says that it sidesteps this issue. His argument is that we trust in the permanence and stability of objects and conditions, such as, for example, that our front door will always be where it was the night before when we wake up afresh each morning, and that we could not live otherwise (von Glasersfeld, 2001a). In addition, he insists that radical constructivism gives agency to the knower/learner in that it puts emphasis on the active role we all have in constructing knowledge, thereby giving us responsibility for our actions (von Glasersfeld, 2010).

Nonetheless for some critics his strong emphasis on the individual construction of knowledge always risks a slide into a skeptical idealism, which must inevitably present problems for teachers (Matthews, 2012; Olssen, 1996). If, as von Glasersfeld suggests, there is no basis on which to be sure that any given mental construction reflects the world as it actually is, this in turn means that the advice given by radical constructivists to teachers to orient learners in particular ways is impossible to follow. This is because there are no grounds or criteria by which teachers can decide what orientations students' constructions should take (Olssen, 1996). While it is of course important that science teachers are interested in students' individual constructions of knowledge, teachers still want students to understand the basic theories of science (Harding & Hare, 2000).

Matthews (2012) recognizes the great positives that result for students because of the value that constructivism gives to active methods of learning. However, he suggests that its over-emphasis on the isolated nature of cognition, that is, its insistence that we all construct our own knowledge is misguided, and may simply be getting in the way of good teaching

> Why must learners construct for themselves the ideas of potential energy, mutation, linear inertia, photosynthesis, valency, and so on? Why not explain these ideas to students, and do it in such a way that they understand them? This process may or may not be didactic: it all depends on the classroom circumstance. There are many ways to explain science: didacticism is just one of them. (Matthews 2012), p. 38

Most students would find it impossible to re-construct for themselves the scientific knowledge that has been developed by many scientists over many centuries, and hence taken to its logical conclusion, radical constructivist pedagogy could do students a great disservice.

Finally, Slezak (2014) insists that there is a question mark over the relevance of much of the theoretical underpinnings of radical constructivism—the focus on epistemological issues—to education, saying that 'there is a sharp contrast between such esoteric philosophical matters and the practical recommendation taken to follow from them' (p. 1024). The kind of practical advice von Glasersfeld offers teachers, includes for example, 'Asking students how they arrived at their given answer is a good way of discovering something about their thinking' (Slezak 2014, p. 1028). As Slezak notes, such insights will be familiar to all teachers, and while these are sound recommendations, they are hardly revolutionary, a view reiterated by d'Agnese (2015).

There are limitations therefore to the usefulness of radical constructivism, at least in the extreme version that some of its adherents have advocated. If von Glasersfeld's ideas were taken to their logical conclusion in the classroom, it would be very difficult for teachers to know what to teach, or for students to learn the scientific knowledge that we would like them to know. If students were to encouraged to take a relativist stance on all knowledge, they might reject accepted and proven scientific knowledge, such as that underlying climate change and evolutionary theory. Nonetheless, radical constructivism raises issues that science educators and students should be concerned about, in relation to the nature of science, such as how we can evaluate claims of scientific truth and how knowledge development comes about. Even if we do not accept the relativism and skepticism that some say is inherent in radical constructivism, its insistence on the importance of the learner's role in making sense of their world can have a very positive impact on teaching and learning processes in the science classroom. Moreover, the impact of radical constructivist ideas in curriculum development, for example, in the now widespread acceptance of learning trajectories and learning progressions, is considerable.

Conclusion

Radical constructivism has been a major force for change in science education since the 1970s. The major difference with other forms of constructivism is von Glasersfeld's emphasis on the epistemological aspects of the learning process. The basic tenets of radical constructivism are that knowledge is not passively received through the senses, but is actively constructed by the cognizing subject, the learner, and that the function of cognition is organization of the experiential world rather than discovery of an independent reality. This highlighted the need for more active methods of teaching and learning science, as opposed to the notion that students should rote-learn a body of scientific facts. Radical constructivism was instrumental in bringing about the great revolution that ushered in progressive pedagogies in the late twentieth century. However, critics of radical constructivism have argued that it places too much emphasis on the unknowability of reality, leaving it open to the charge of relativism and potentially undermining the basis on which teachers could know which scientific ideas and theories to teach students. Nonetheless, radical constructivism opened the door for teachers and students to free themselves from very rigid approaches to teaching and learning, particularly in the area of science education, where absorption of facts taught didactically was once the order of the day. Radical constructivism continues to have lasting impact through the focus on learners actively making sense of the natural world that underpins the vast majority of scientific educational research, curriculum development and teaching practice today.

Chapter Summary

- The two main principles of radical constructivism are that knowledge is actively constructed by the learner, and that the function of cognition is organization of the experiential world rather than discovery of an independent reality.
- Von Glasersfeld called for more active and engaging teaching methods to be used to assist students to constructing their scientific knowledge.
- Radical constructivism has also been very influential in the development of learning progressions in science curricula.
- Criticisms of radical constructivism include that it undermines the basis on which teachers can decide what scientific knowledge is most important for students to learn, and that it over-emphasizes the isolated nature of cognition.

Resources

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