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Radical Constructivism Has an Answer - But This Answer Is Not an Easy One

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> Context • In spite of its advantages and its ability to make valid responses to objections, radical constructivism is not mainstream. **> Problem** • Extolling the virtues of radical constructivism and responding logically to the objections does not work. We know this from the evidence of many attempts. Our theoretical stance, radical constructivism, also suggests this approach is not likely to have much influence on realists. We cannot transmit understanding in the signals with which we attempt to communicate. How can we in radical constructivism enable those outside of RC to understand our explanation of human knowing? **> Method** • Examine our understanding of radical constructivism itself, because it is an explanation of how, why and under what circumstances people change their understandings of their experiential worlds. **> Results** • We must find ways to direct the attention of others to situations that they cannot explain with their existing understanding of the world. Then we must create conditions conducive to their revising and testing new understandings for fit with the evidence of their experience. **> Implications** • Since radical constructivism is a theory of human knowing, it tells us how humans develop knowledge, hence it is an answer to the questions central to this special issue. This answer is not one to be used to win in debates with realists. Radical constructivism gives us an answer to the problem of engaging realists in understanding our position, but strategies consistent with radical constructivism are not easily carried out. Developing and executing such strategies is the work at hand. **> Key words** • **History of science, paradigm change, physics education research, realism, folk theory of teaching, cognitive equilibration.**

… it seems to me that the resistance [met by Vico, Piaget and Ceccato] is not so much due to inconsistencies or gaps in [radical constructivism's] argumentation as to the justifiable suspicion that constructivism intends to undermine too large a part of the traditional view of the world.

Ernst von Glasersfeld (1984: 17)

Introduction

The term "answer" in the title of this paper does not refer to an answer to the realists' objections in order to convince them they have lost the debates. Instead, it refers to an answer as to why our efforts to respond to realists in these debates seem to be so ineffective and an answer as to what we should be doing instead. As the subtitle suggests, this is not an easy answer. It is an answer that we in radical constructivism (RC) have available to us for use in our efforts, if we wish to have realists at least understand our position.

This paper addresses two questions raised by the guest editors in their editorial.

- Why are the advantages of RC not strong enough to convince more scientists and philosophers?
- Can the objections to RC be refuted in a way that makes RC more attractive to scientists and philosophers?

Both questions are asking why a disappointingly small change in understanding RC has happened. In short, why is RC not more mainstream? RC itself offers a way of understanding why scientists and philosophers have not joined our ranks, but not if we take the propositions given in the editorial as defining RC at face value:

1 | Knowledge is not passively received, but is learnt through a process of active construction by the knower.

2 | The function of this process of learning is adaptive, and serves the knower's organization of her own experiential world, not the discovery of an objectively existing ontological reality.

If we are going to take two basic propositions to define RC, then we need propositions that are more at the root of RC.

The first principle obviously gives rise to the label "constructivism," but this proposition is a *consequence* of a more fundamental issue. When we miss the more fundamental issue, we may fail to deploy the strength of RC as an explanation of our world.

Why does knowledge have to be constructed and why cannot it be passively received? Because the knowledge referred to here is our conceptions of how and why the world around us works, in short our working explanation of the world. Following Max Jammer (1957: 2–4), this knowledge can be called "explanatory knowledge," as opposed to experiential knowledge. A fundamental principle in RC is that explanation exists only in the mind. We construct such knowledge in our minds. This constructed explanatory knowledge does not exist in any physical way in the world around us in any form that we can directly experience. Piaget put it in these ways at various times:

"Knowledge is not a copy of reality. To know an object, to know an event, is not simply to look at it and make a mental copy or image of it. To know an object is to act on it." (Piaget 1964: 177)

"It is clear there is an undeniable role played by experience in cognitive development; however, the influence of experience has not resulted in a conception of knowledge as a simple copy of outside reality." (Piaget 1972: 8)

"To understand is to invent." (Piaget 1976)

The first proposition is merely a consequence of this more fundamental principle of RC. In other words, if this knowledge cannot exist other than in the mind, then it cannot be transmitted in any physical way and, thus, can only be constructed by human beings in their minds.

One could also take issue with the verb, "to learn," used in both propositions. It is entirely too easy to associate learning with what is supposed to happen in the folk theory of teaching:

"…teaching is the presentation of an established canon by approved methods for the benefit of the deserving." (Dykstra 2005: 54)

In this folk theory if a teacher presents correct elements of a canon of knowledge by an approved method and if an intended receiver of this transmitted knowledge has sufficient mental ability and diligence of effort, then the listener will successfully receive the knowledge into her mind. This is a description of the most prevalent use of the verb, "to learn," in English and no doubt in other languages with the equivalent verb. Hence it seems it is too easy for the average reader to "hear" a kind of mixed message in Proposition 1. Von Glasersfeld expressed this distinction between the everyday (realist) use of the verb, "to learn," and a radical constructivist view of the situation in the following way:

" When students can repeat something verbatim, it is obvious that they have learned it. Whether they have understood it is a question these tests avoid." (Glasersfeld 2001: 2)

This folk theory of teaching, transmitting the canon, does not actually work (Dykstra 2005). In the sub-division of physics known as "physics education research" (PER), this conclusion was an important early motivation in the development of the field.

"The secondary educational experience does not now promote logical thinking in most students… If colleges and universities do not try to solve the problem by assuming the responsibility for the intellectual development of their students, but continue to look at their primary purpose as the transmission of information about the several disciplines, the elementary and secondary schools will continue to fail in their mission of truly educating students." (McKinnon & Renner 1971: 1051–1052)

"Telling them the correct answers in lucid lectures, explanations, or text presentations is futile. This is what has been done before, and it has left no trace on the students' intellects." (Arons 1976: 835)

Notice that McKinnon and Renner are referring to what is now called "the folk theory of teaching" in their indictment of traditional instruction when they write, "… *but continue to look at their primary purpose as the transmission of information about the several disciplines…*" Work in this field of PER since the early 1970s continues to confirm these observations and reveals that alternatives to folk theory teaching make significant differences in ways that were suggested by McKinnon, Renner and Arons. Examples of some of these alternatives will be cited below.

Given the points made so far, a better set of basic propositions to "define" RC might be:

1 | Knowledge, in the sense of explanation, understanding, and meaning, exists only in the mind, not in any physical form whatsoever, and is intended by the knower to fit the evidence of experience but can never be known to be a veridical description of a mind-independent reality.

2 | When one becomes aware of a disequilibration between one's existing explanatory schemes and one's new experiences, one is moved to restore equilibrium by reconstructing the explanatory schemes; that is, one adapts one's explanatory schemes to fit experience.[1]

1| Under certain circumstances, usually deemed negative or unnatural, the "offending" experiences are avoided, swept under the carpet, with the hope that they do not happen again. The result is one of no development and certain destructive tensions.

In these two new propositions intended to better define RC, we have the basis for a response to the questions raised by the guest editors in their editorial. A very short answer is that the scientists and philosophers have not experienced sufficient disequilibration between their existing, realism-based explanatory schemes and their experiential worlds. Until they experience disequilibration between these two things, there is no reason, from a radical constructivist point of view, to imagine that realists should have any motivation to change what is so fundamental in their realist explanatory schemes.

Let us see how these revised propositions enable us to respond to the questions raised by the guest editors.

Why are the advantages of RC not strong enough to convince more scientists and philosophers?

The short answer is that presenting advantages of an idea is not what results in convincing anyone to change their beliefs. There is a very large body of research published in refereed journals in physics education research (PER) that shows that presenting "better" explanations to students makes no significant difference to their conceptions of physical phenomena, no matter how eloquently the story is told (Dykstra 2005) .

There are several sources that considered together can give an explanation for the issue in this question. The theory of cognitive equilibration, devised by Jean Piaget and his colleagues at the Center for Genetic Epistemology, has something to offer (Piaget 1985). The philosopher of science, Thomas Kuhn, while he was not a radical constructivist but at most a trivial constructivist, in his notions of scientific revolution and paradigms also has something to offer here (Kuhn 1962; Hoyningen-Huene 1993).[2]

Piaget was interested in the origins of human knowing. He and his colleagues

2| The distinction between trivial constructivisms and radical constructivisms is described later in this article.

found, from the very large quantity of interview transcripts collected over his 60-year career, that it is possible to describe the development of human reasoning about the world in a developmental sequence. More importantly to our issues here, he and his colleagues developed a theory of cognitive equilibration. This theory can be used to explain how and why human beings develop in their reasoning about the world around them. It also can be used to explain how, why and under what circumstances human beings construct new, more powerful understandings concerning their experiential worlds. The central issue in the theory of cognitive equilibration is well-captured in the new second proposition defining RC given in the introduction.

Kuhn is possibly the most influential historian and philosopher of science of the 20th century. He introduced the notion of paradigm and paradigm shift to explain large-scale shifts in scientific theories. He showed how other psychosocial factors are equally as important as rational logic in scientists changing from one theory to another.

Kuhn suggested that there exist paradigms, which have been established by scientists who recruit others to join them. A paradigm is organized around a world-view, an explanatory system. The paradigm has standard responses to prototypical problems addressed by the explanatory system. The paradigm becomes a complete, self-consistent package that rationally explains the range of experiences considered important. Other experience is deemed not important and unnecessary to explain. The practice of checking the prototypical examples to an even higher degree of precision is a typical activity called "normal science" by Kuhn.

A scientific revolution begins to happen when some scientists in the paradigm can no longer ignore certain experiences that cannot be explained by the explanatory system of the paradigm. The actual revolution can only be recognized in hindsight. Three examples of such experiences in physics are the ultraviolet catastrophe in explaining black body radiation, the photoelectric effect, and special relativity. None could be explained within the prevailing paradigm now known as classical physics. Initially many held that these were minor issues and would eventually be figured out within the paradigm. But, there were those who decided that they could see no way to resolve these issues within the prevailing explanatory system but they could see how to explain these "exceptions" by abandoning the old explanatory system in favor of a new ones, to explain atomic and sub-atomic phenomena (quantum physics) and to explain gravitational interactions (relativity), which became foundations of what is called "modern physics."

While Kuhn was not a radical constructivist, it appears that one can interpret his description of scientific revolutions as similar to Piaget's theory of cognitive equilibration and the new propositions describing RC given above. However, Kuhn's idea of a paradigm plays a role in explaining resistance to change in explanatory systems. If one's explanatory system already adequately explains the experiences one considers significant, then there is apparently equilibration between one's explanatory knowledge and one's experiences, hence no need or tendency to make any significant adjustments to one's explanatory schemes. This describes realists very well. They have no reason to think of the world so profoundly differently as is required in RC.

To be specific, the dominant paradigm we are dealing with is realist. This realism is illustrated in the two following descriptions.

> " . . .we postulate the objective existence of physical reality that can be known to our minds…with an ever growing precision by the subtle play of theory and experiment." (de la Torre & Zamorano 2001: 103)

> "The metaphysical realist *looks* for knowledge that *matches* reality in the same sense as you might look for paint to match the color that is already on the wall you have to repair. In the epistemologist's case it is, of course, not color that concerns him, but some kind of 'homomorphism,' which is to say, an equivalence of relations, a sequence, or a characteristic structure – something, in other words, that he can consider *the same*, because only then could he say that his knowledge is *of* the world." (Glasersfeld 1984: 20–21, emphasis in the original)

Within realism the folk theory of teaching completely explains the experience of teachers in the classroom. This is what a good paradigm does. The teacher's responsibility is to know the canon correctly and to present it using an established method. The teacher then checks to see if the students "got" what was presented by testing to see if they can reproduce what was presented in some manner on exams. The students who seem to have "gotten" what was presented are considered deserving, that is, apparently of requisite mental ability and diligence of effort. Students, who did not "get" what was presented, apparently are not deserving, that is, do not have the requisite mental abilities or even with the requisite mental abilities did not work hard enough.

In this realist paradigm exemplified in the folk theory of teaching, all is accounted for. There is no disequilibrium. RC attempts to describe another explanatory system and urge that a realist change paradigms. From the realist's point of view, there is no need and the cost of change is too great.

This paints a rather bleak picture for RC's chances against the hegemony of realism current today. Yet, when a need is perceived, costs can be surmounted. Needs, costs… what are these all about? In this situation we are referring to the disequilibration-driven need to change one's explanatory schemes to fit new experiences that cannot be explained with existing schemes, as in the new Proposition 2 concerning RC given in the "Opening" section. Such changes in explanatory schemes rarely leave one's whole structure of explanatory schemes intact (Carey 1987). Changes ripple through the whole network as it is adjusted to be internally consistent.

The costs are the costs of change. There is the change of certain aspects of one's self-image. There is the change in one's particular place in the social order in which one exists. Ego plays a large role here. If we are talking about teaching and learning, there are the costs associated with the development of a whole new pedagogical practice and the consequent development of new instructional materials and activities, none of which happen in a short period of time without any problems. Yet, these costs are borne out of necessity because the new explanatory schemes cannot be reversed or rescinded. The person has constructed a new world with which the old ways are incommensurate and new ways, for example, new pedagogical practices, now make perfect sense.

Eric Mazur, a physicist on the faculty at Harvard, relates his conversion story in print and in presentations. Mazur had come across the work of Ibrahim Abou Halloun and David Hestenes (Halloun & Hestenes 1985a, 1985b, 1987; Hestenes 1987).

"[A]fter a couple of months of physics instruction, all students can recite Newton's third law and most of them can apply it in numerical problems. A little probing, however, quickly shows that many students do not understand the law. [M]y first reaction was 'Not *my* students…!' … I decided to test my own students' conceptual understanding, as well as that of the physics majors at Harvard.

"The first warning came when I gave the … test to my class and a student asked, 'Professor Mazur, how should I answer these questions? According to what you taught us, or by the way I *think* about these things?' [T]he results of the test came as a shock: the students fared hardly better … than on their midterm examination. [T]he Halloun and Hestenes test is *simple*, whereas the material covered by the examination … is, or so I thought, of far greater difficulty." (Mazur 2007: 3)

Surprised that the Harvard students fared no better than students at other, less prestigious universities on the conceptual inventory tests composed by Halloun and Hestenes, Mazur decided to compose some pairs of exam questions to use in his own course. One member of each pair was a "simple qualitative question" and the other a "more difficult quantitative problem on the same physical concept" (Mazur 2007: 4). Mazur gives an example pair of exam questions with the results of scoring the students' performances on the two exam items. The students in general did worse on the "simple qualitative question" than on the "more difficult quantitative problem." These results were repeated throughout the course. In a number of cases students scored zero on the qualitative question and 10 out of 10 on the quantitative problem.

Mazur's initial responses are the following:

"This simple example exposes a number of problems one faces in science education. First, it is possible for students to do well on conventional problems by memorizing algorithms without understanding the underlying physics. Second, as a result of this, it is possible for a teacher, even an experienced one, to be completely misled into thinking that students have been taught effectively. Students are subject to the same misconception: they believe they master the material and then are severely frustrated when they discover that their plug-and-chug recipe doesn't work in a different problem." (Mazur 2007: 5)

At about the same time as Mazur was first realizing this, another Harvard faculty member in education, Howard Gardner, was publishing very similar observations.

"…what an extensive research literature now documents is that even an ordinary degree of understanding is routinely missing in many, perhaps most students. It is reasonable to expect a college student to be able to apply in a new context a law of physics, or a proof in geometry, or the concept in history of which she has just exhibited 'acceptable mastery' in her class. If, when the circumstances of testing are slightly altered, the sought-after competence can no longer be documented, then understanding – in any reasonable sense of the term – has simply not been achieved. This state of affairs has seldom been acknowledged publicly…" (Gardner 1991: 6)

Mazur goes on to point out that a number of his experiences teaching physics and observing the results of physics teaching, which his existing explanatory schemes did not exactly account for, now fell into place with his new explanatory schemes about learning. He was moved to devise a new pedagogical practice for himself and to write about it (see Mazur 2007).

I cannot vouch that Mazur, Gardner, Halloun or Hestenes are RC. In fact from their other works, from direct interaction with them, and interaction with students of Hestenes, I can say that neither Halloun nor Hestenes would accept RC as a label of their views of the nature of knowledge in science or in physics education. However, this does not disallow a radical constructivist explanation of Mazur's conversion experience. His attention was directed to some new evidence he found he could not deny. He could not explain this evidence using his existing notions of teaching and learning physics. His response to his disequilibration was to construct new notions of teaching and learning physics, which resulted in a new pedagogical practice.[3]

It is not a matter of the advantages of RC or even what some specific advantages might be. When people are well-entrenched in the normal science of an existing paradigm, *it is not sufficient to show them a new paradigm and extol its virtues.* If such folk theory teaching actually worked, then Mazur and members of the PER community would not find the evidence of no change in understanding that they have indeed found. Folk theory teaching does not result in change in understanding. It is no surprise, then, that the same approach does not work when we try to interact with realists about our position.

It is not about the logic we present to them. Safe in their paradigm, everything fits the evidence they have. They have to perceive flaws in the paradigm themselves, that there is undeniable, unavoidable evidence not accounted for by the paradigm. In other words, they have to realize for themselves a disequilbration between their existing notions of the world and new experiences in the world, as Mazur did. Disequilibrations drive the need to change world-view. Conditions have to be safe for them to reconstruct and test their notions of the world so that they can proceed to do so.

If we wish scientists and philosophers to construct for themselves an effective understanding of RC, we need to direct their attentions, in effective ways, to evidence (new experiences for them) that they cannot account for with their existing explanatory schemes. And, we must establish conditions that make it sufficiently safe for them work on constructing and testing new explanatory schemes.

3| One RC-based pedagogy has been described in some detail (Dykstra 2005). It is briefly described later in the paper in the section on pedagogical objections to RC. Mazur describes his pedagogy in (Mazur 2007).

Can the objections to RC be refuted in a way that makes RC more attractive to scientists and philosophers?

The short answer to this question is: No. In their editorial the guest editors give a list of objections frequently expressed about RC, which include logical, ethical, social, pedagogical and scientific objections. All of these objections make perfect sense and really are valid, but only from a realist position, not from the position of RC. It has been pointed out that the basic assumptions on which realism is based are profoundly different than those on which RC is based (Dykstra 2007). The two philosophical positions are incommensurate. What is meant here by realism is described in quotations by de la Torre & Zamorano and by von Glasersfeld in the previous section. Von Glasersfeld has in several places set forth a description of the difference between tradition (realism) and RC. Here is one example:

"What differentiates Radical Constructivism from the tradition is the proposal unequivocally to give up the notion that knowledge ought to be a veridical 'representation' of a world as it 'exists' prior to being experienced (that is, ontological reality)." (Glasersfeld 1991: 16)

For the reader who might be a scientist or philosopher, it should be noted that a highly respected historian and philosopher of science still active today, Jammer, suggested essentially the same thing in 1957, not so much to establish a new philosophy, but as a result of his examination of the histories of ideas in physics.[4] In the first two sentences below, Jammer writes essentially the same notion about the nature of knowledge as Von Glasersfeld does above. Then, Jammer goes on to describe implications for the status of explanatory knowledge in science:

"As a result of modern research in physics, the ambition and hope, still cherished by most authorities of the last century, that physical science could offer a photographic picture and true image of reality had to be abandoned. Science, as understood today, has a more restricted objective: its two major assignments are the description of certain phenomena in the world of experience and the establishment of general principles for their prediction and what might be called their 'explanation.' 'Explanation' here means essentially their subsumption under these principles. For the efficient achievement of these two objectives science employs a conceptual apparatus … This conceptual apparatus consists of two parts: (1) a system of concepts, definitions, axioms, and theorems, forming a hypothetico-deductive system, as exemplified in mathematics by Euclidean geometry; (2) a set of relations linking certain concepts of the hypothetico-deductive system with certain data of sensory experience. With the aid of these relations, which may be called "rules of interpretation" or " epistemic correlations," an association is set up, for instance, between a black patch on a photographic plate (a sensory impression) and a spectral line of a certain wavelength (a conceptual element or construct of the hypothetico-deductive system) …

"The adoption of rules of interpretation introduces … an arbitrariness in the construction of the system as a whole … In other words, arbitrary modifications in the formation of the conceptual counterparts to given sensory impressions can be compensated by appropriate changes in the epistemic correlations without necessarily destroying the correspondence with physical reality. In consequence of this arbitrariness, scientific concepts 'are free creations of the human mind and are not, however it may seem, uniquely determined by the external world.' (Einstein & Infeld, *The Evolution of Physics*, 1938)" (Jammer 1957: 2–4)

One might ask, "What more do the objectors need?" An appropriate response to this question is to point out that until the objectors have been able to at least suspend their realism-based judgment and have the opportunity to construct a different understanding of the nature of knowing and knowledge we know as RC, essentially *none* of what we (or Jammer, Piaget, Von Glasersfeld, Ceccato, Vico, etc.) have to say in response will have any real effect on the objector's thinking at all.

We have seen, in the pages of this journal and in countless debates on-line and at meetings, that what we have to say in response to the objections has no impact on their thinking and they frequently do not really hear what we are saying or patently refuse to accept the simplest of statements we have to offer. We say, for example: We are not looking for objective truth. They say in response: Yes, you are. You must be. From such examples, can it be more clear that they only know the world from a realist point of view, hence they can only interpret what we say from that same point of view?

Going back to the revised Proposition 1 describing RC, we must recognize that neither we, as RC, nor the objectors to RC, can in any way receive from outside ourselves by any physical means an explanation of the world either in a realist or a radical constructivist way of thinking. We can only each construct our own explanations of any attempt at communication based on our own experiences, not those of the originator of the communication signal.

Our situation interacting with realists appears to be different than the realists' situation. We have a repertoire of at least two ways of thinking about knowing. We all grew up immersed in a culture in which realism is taken as given. Augmented by our experiences in the RC vs. realism debates, we have an understanding of how realism works. This understanding of realism is necessary. Without this understanding we have no way of predicting when a realist might find an experience a disequilibrating surprise. Our understanding of RC enables us to imagine possible experiences that can be explained by RC but are not explained by realism. Instead of debaters or combatants, we need to be teachers who can use their understanding of both RC and realism to induce disequilibrations and then facilitate constructive responses as the realists attempt to resolve the disequilibrations. The answer is not folk theory teaching, realist-style debates. The answer is RC pedagogical practices exercised in the public sphere.

Let us examine possible RC understanding of the five categories of objection and consider our understanding in relationship to the realism of the objectors.

Logical objections

The apparent assumption in these objections as expressed in the list above is that the point of all discussion and debate

4| Jammer studied the histories of concepts in physics including: force, mass, time, simultaneity and quantum theory.

is to establish the truth of a proposition or position. Humberto Maturana presents a radical constructivist view of the purpose of establishing the truth of a proposition or position:

> "Whenever we want to compel somebody else to do something according to our wishes, and we cannot or do not want to use brutal force, we offer what we claim is an objective rational argument." (Maturana 1988: 26)

This rational argument is supported by the expectation that "the other cannot refuse what our argument claims because its validity as such rests on its reference to the real" and the realist claim that "that the real is universally and objectively valid because it is independent of what we do, and once it is indicated it cannot be denied" (ibid: 26).

Furthermore, "whoever does not yield to our rational arguments is arbitrary, illogical or absurd, [because] we have a privileged access to the reality that makes our arguments objectively valid" (Ibid: 26).

While this attempt to establish the truth need not be accompanied by physical violence, it is nonetheless psychologically and cognitively violent.

The problem with the assumption in the objection is that it has no place, no status in RC. From the RC position, there can be no objective, mind-independent truth attributed to any explanation. In RC neither the realist explanation of knowledge nor the RC explanation of knowledge can be argued as truth. Instead in RC we assess the fit of an explanation to the experiential evidence we have. Better fit means a better explanation, but better fit has no bearing on the truth, relative truth or lack of objective truth of such an explanation. Because, in the realist paradigm, there is only the issue of objective truth, then anything else just has no status. Until realists can see things from the RC position, this distinction is totally lost on them.

Technically, realists do not have to abandon their old paradigm. But, they do need to be able to see how an alternative such as RC works and how to use it. Still, to do this they must disequilibrate over evidence that cannot be explained in their existing paradigm. Revised Propositions 1 & 2 tell us this.

Ethical objections

Here the realist response to the RC position that objective truth cannot be known is that without objective truth there is no basis for decisions with respect to anything. Here in particular, with respect to ethics, from this realist position RC is the ultimate in relativism, a kind of polar opposite to realism. Hence the realist characterization of RC: anything goes, *laissez-faire*. This realist characterization of RC is the only alternative the realist has to objectivism. This is a realist construction of the world. Sadly, this construction does not allow the realist to understand RC from within realism.

Realists are so focused, by blinders, on truth that they fail to *hear* in RC the part about formulating an explanation that fits evidence. This means there are necessarily limits on explanations in RC, which would include ethical theory. The only ideology, theory, or explanation that a radical constructivist can support is one that fits the evidence, experience in the field.[5] If that happens to be a different ideology than that promoted by another as truth, then that person might label the RCs ideology as reactionary, but then the RC could say the same about the other. Such labels are vacuous and *non sequitur*.

Yet again, we see in this type of objection realists who cannot see the world from any other position than their own, but this is exactly what is necessary for them in order to understand the RC response. Revised proposition 2 addresses what will be necessary in order for the realists to develop another point of view than the one they are working with.

Social objections

"Cannot" is quite a different claim than "has not," but "cannot" would logically include "has not." The claim, "has not," cannot be applied until all the necessary scholarship has been carried out. In fact, there is work in sociological studies and in ethics from RC's and related points of view (e.g., Piaget 1995; Maturana 1988).[6] Hence, the claim that RC cannot explain social structures and society is the result of poor scholarship at best.

It is possible that this objection is the result of additional poor scholarship. In the English-speaking science education community, Piaget's work first became known in the 1960s. Piaget's focus was on the origins and development of human knowing. In the 1980s Vygotsky's work was becoming known in the English-speaking science education community. Vygotsky studied the cultural influence on learning via established cultural interactions between mother and child, teachers and students, children playing with each other, etc. Piaget's work led him to develop a different notion of the nature and results of human knowing. Vygotsky apparently did not question the accepted realist nature of knowledge. Thus, Piaget was RC and Vygotsky remained realist.

Those who did not understand Piaget from the RC point of view found objections to Piaget's ideas. When Vygotsky's work was introduced to them, his work easily found a home with them. Because of the chronological order in which they were introduced, many decided that Vygotsky came after Piaget then extended and corrected his work from the individual to the social. This misses the points that Piaget was RC and Vygotsky was realist and that both considered and studied both individuals and social situations. Significantly, both Piaget and Vygotsky were born in the same year, 1896, but Vygotsky died in 1934 while Piaget lived and worked until 1980.[7]

5| Maturana wrote an extensive document that touches both on ethics and social interactions (Maturana 1988). There are some small distinctions between Maturana's position and RC, but there is little if any for a radical constructivist to disagree within this document.

6| In RC all explanatory knowledge exists only in the mind. For it to exist there, since it does not exist independently of the mind, it must be constructed in the mind. It is constructed to fit experience. This experience can be physical, social or internal. In physics we engage students over their explanatory knowledge of the experiences of the physical "world." We construct what culture and social interactions are to us in the same way and for essentially the same reasons as we construct understanding of the physical world. Our internal experiences are our experiences with our own thinking.

7| What appears here is an abbreviation of a more extensive discussion on the work of Piaget and its relationship to Vygotsky's work, which can be found in Chapter 13 in Fuller et al. (2009).

While better scholarship on the part of all would help resolve this situation with respect to social objections to RC, it is still the case that to understand RC work and theory in social structures and society, one needs to understand the RC position. This can only happen if revised Proposition 2 is taken into account.

Pedagogical objections

These objections to *constructivist teaching* are one of the many strategies used to discourage people who work in the field of education and teacher preparation from leaving the folk theory of teaching. While it is the case that there may be those who have actually advocated and tried to practice such idiocy as *laissez-faire* in the classroom, such a notion of teaching and learning is distinctly not RC. As was pointed out above, in realism there is only truth and not truth, maybe in addition something like closer-to-the-truth, but nothing else. The realist reaction to RC, without understanding RC, is to assume absolute solipsism and relativity are what RC is about, hence the anything goes or *laissez-faire* idea. For the realist, the notion of unknowable objective reality screams so loudly in the mind that the notion of explanation that *fits* experience is completely drowned out. This requirement of fit renders any RC pedagogy decidedly not *laissez-faire*.

A more detailed discussion of RC-consistent pedagogy, its contrast with folk-theory (realist) pedagogy and a comparison of the learning results of both can be found in Dykstra (2005). Clearly there is a role for the teacher, but that role is not that of presenter or arbiter of truth or even what is closer to truth, as we can see from the quotations from McKinnon & Renner and from Arons in the opening section of this paper. Instead the assignment of the teacher is to:

- direct the students' attentions to their own conceptions that they apply to a new experience to make a specific prediction when this experience does not behave as they expect,
- make it safe for the students to construct or reconstruct explanatory schemes to account for these surprising experiences,
- keep students attending to the fit between their explanatory schemes and all of their experiences subsumed by these schemes, and
- engage the students in using the power of interactions between each other over their ideas and the testing of their ideas against the evidence.

Again, from this type of objection, we see the evidence that RC activities are critiqued from the traditional realist paradigm. Our revised Propositions tell us what we have to facilitate: the realist must disequilibrate over a self-identified perception of a mismatch between his explanatory schemes and his experiences, then work to construct and test new explanatory schemes against the experiences. *RC does not give us any alternative to this*.

Scientific objections

Again, we see in the scientific objections to the view that there is no truth, then we have no anchor and all is lost. This is realists seeing RC as absolute solipsism and total relativism because RC denies that we can know the truth of any explanation we make up and test against evidence. Realists apparently know only, and can see nothing else but, truth and gradations from true all the way to, and only to, not true. For realists, nothing else exists. It is as if they need a security blanket of truth to have any idea about the physical world.

A second, but equally important, part of the objection is buried in the idea that mere constructs of individual human minds could not possibly be successful at guiding engineers and at having the predictive power the scientific community relies upon. This notion is indicative of a kind of destructive elitism amongst many scientists. We, the true practitioners of science, are smarter than the rest of a society which cannot really understand the science we have figured out.

When a *scientist* approaches you with this elitism, beware. For such a *scientist*, his or her ego is far more important than anything or anyone else. Such notions are part of the indoctrination into science delivered largely via folk theory teaching with its emphasis on the notion that only certain people are truly deserving or capable of science (cf. Dykstra 2007: 54).

The problem with these notions for scientists is that for such an idea, science works on the basis of discovering truth; there is *no evidence* in all of the history of science that any explanatory system survived the challenges of all subsequent experience with the phenomenon in question. This "scientific" objection is another failure in scholarship.

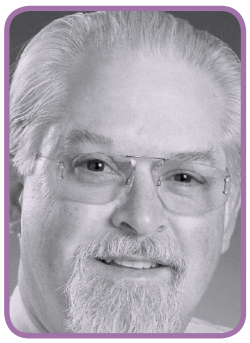
One might think that the designation, Ph.D., Doctor of Philosophy in a field, would require such scholarship. Sadly, most Ph.D.s today are doctorates in the technical practice of a field. Not only is there no explicit philosophy of the field, such philosophy is actively shunned, avoided, and discouraged in the indoctrination of new scientists.

Nonetheless, it is entirely consistent with all we know of the history of science when we argue that scientists struggle to construct explanations that fit the evidence and have predictive power. This is entirely consistent with the revised Propositions of RC.

One more time, the revised Propositions of RC tell us what has to happen in order that realists might understand our characterization, our explanations, to see how our responses refute their objections. Just as we are able to understand how the realist paradigm works, as well as our own, the realist must be able to do the same. Our propositions tell us that disequilibration is required of the single-paradigm realist. Our only hope is to find ways of effectively directing the realist's attention to something that she cannot explain from her realist paradigm.

Conclusion

The proposal herein to revise the propositions defining RC in part is an effort to emphasize the adjective "radical" proposed by von Glasersfeld. He suggested that we categorize the constructivisms into two groups according to the scholarly meaning of the two proposed labels. For constructivisms that depart little, if at all, from the basic assumptions of realism, von Glasersfeld proposed the label "trivial", not in the sense of insignificant as a whole, but to mean no real shift away from realism in its basic assumptions about the nature of knowledge. What is meant here by realism is given in several places already in this piece. The other category of constructivisms makes fundamental shifts away from the basic assumptions about the nature of knowledge at the roots of realism. There are profoundly different basic



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is Professor of Physics and Coordinator of Physics Teacher Education in the Physics Department at Boise State University in Boise, ID. His first disequilibration on the path to RC happened shortly after he started teaching in 1969. This initial disequilibration was resolved 8 years later when he read an article on Piaget (Fuller, Karplus & Lawson 1977). Understanding Piaget's theory of cognitive equilibration opened the door to radical constructivism. His work as a physicist has engaged him in studies of how, why and under what circumstances student change their conceptions of physical phenomena. He has applied conclusions from these studies, testing his understanding of RC, to the development of an RC-consistent pedagogy and instructional materials.

assumptions about the nature and status of knowledge at the root of the matter for realism and for RC. Von Glasersfeld proposed the adjective "radical" in the scholarly sense of differentiated at its root from realism, for the category of constructivisms that fit this description. The quotation given above near the beginning of Section III, gives Von Glasersfeld's view on the RC departure from realism.

The guest editors suggest that today "the literature is populated by a large number of different theories, which are often in mutual disagreement, that all label themselves as some variety of 'constructivism.' They all seem to agree with proposition 1, but to a much lesser degree with proposition 2" (Riegler & Quale 2010: 1). Following von Glasersfeld's classification scheme, a constructivism that agrees with the original proposition 1 but not proposition 2 probably is not a radical but a trivial constructivism. To accept a consequence of RC does not require an acceptance of what necessitates the consequence in the first place. Such a constructivism, at its heart, can still hold that objective truth is knowable and that there are right explanations in science and philosophy. This is particularly easy to discern when one examines a proposed "constructivist" pedagogy. Among the clues for a trivial constructivist pedagogy are the notions that student's conceptions are taken as wrong and need to be corrected to the right answer, that students discover the truth out there in nature, or that students must be guided to the truth or right answer because they could never figure it out for themselves.

In the editorial to this issue, the guest editors write: "It appears that the theory of RC is simply (too) provocative for many people" (Riegler & Quale 2010: 2). Why is this?" First, one could point out that any paradigm would appear provocative if it is not understood. Why is RC provocative to many people? Obviously, many people do not understand RC and have never really experienced coming to see the world from another position. This is a very sad outcome of the folk theory that passes for education.

What is the answer to these problems and challenges we face? RC explains not only why these problems and challenges are happening, but also what can be done about them. If we recognize that understanding, meaning, and explanation exist only in the mind and not in any physical form, then we have to accept that our understanding, meaning, and explanation cannot be presented so that others without sufficiently similar understanding, meaning, and explanation will "get" what we present. This is no different when we are presenting RC than when we try to present the meaning of force when teaching about Newton's laws. As Arnold Arons points out above, such presentations are futile. They leave no impression on the intellect of the listener.

What then must we do? RC tells us why and under what circumstances people change their explanatory schemes for the world. They change their explanatory systems in response to their perception of disequilibration between their explanatory schemes and their experiences in the world in order to restore equilibrium. Until this re-equilibration happens, people "see" and "hear" the world through their previously existing explanatory schemes.

If we try to interact with them using RC explanatory schemes that do not match theirs, it is certain they will not experience the interaction from a radical constructivist position but from a realist position instead. Under these circumstances we are doomed not to be understood. The listeners have to construct for themselves new understandings that sufficiently appear to match our RC understanding before we can expect the interactions to indicate they are taking our contributions to any debates in the radical constructivist sense we intend.

Again, this is no different than a radical constructivist pedagogy in which students construct new understandings of motion and force (Dykstra 2005). The problem in our arena is that we do not have the teacher-student relationship with our realist colleagues. This requires more patience, more persistence, and more resourcefulness in creating situations in which our realist colleagues might disequilibrate.

Will RC become mainstream? The skeptics first wrote their ideas nearly 2500 years ago, although these ideas were probably not continuously available in western society for that full time. In the Buddhist culture, an equivalent philosophy to RC, called "the Middle Way," has also been available for 2500 years, probably nearly continuously in their culture. In neither setting can we call RC or the Middle Way mainstream.

We can safely say that if RC became mainstream, the world would be very different. Most of us would also agree that if this

were to happen, that different world would be a much better place for all to live in.

Why does realism have such hegemonic hold? It is impressed on everyone by language and our cultural institutions, not the least of which today are our schools. RC tells us that change in how we see the world can happen. We see evidence that there have been such changes, at least, in the history of science.

Will RC ever become mainstream?
Not unless we actually use RC instead of falling into the realist trap of debates.
If we don't use what RC tells us about change in understanding,
then who will? If not now, when will we try?

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