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VON GLASERSFELD'S RADICAL CONSTRUCTIVISM: A CRITICAL REVIEW[1]

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> Give up the requirement that knowledge represents an independent world, and admit instead that knowledge represents something that is far more important to us, namely what we can *do* in our *experiential world.* [EvG, 1995, p.6]

ABSTRACT: We explore Ernst von Glasersfeld's radical constructivism, its criticisms, and our own thoughts on what it promises for the reform of science and mathematics teaching. Our investigation reveals that many criticisms of radical constructivism are unwarranted; nevertheless, in its current cognitivist form radical constructivism may be insufficient to empower teachers to overcome objectivist cultural traditions. Teachers need to be empowered with rich understandings of philosophies of science and mathematics that endorse relativist epistemologies; for without such they are unlikely to be prepared to reconstruct their pedagogical practices. More importantly, however, is a need for a powerful social epistemology to serve as a referent for regenerating the culture of science education. We recommend blending radical constructivism with Habermas' 'theory of communicative action' to provide science teachers with a moral imperative for adopting a constructivist epistemology.

INTRODUCTION

Ernst von Glasersfeld is well recognized as the primary exponent of 'radical constructivism', a theory of knowing that is resonating worldwide with the reformist desires of science and mathematics educators. In recent years, von Glasersfeld's cogent arguments concerning the 'constructed' nature of our knowing and its relativist status have been endorsed and subject to critical analysis. In writing this paper, our intention was to portray the central themes of von Glasersfeld's radical constructivism and to consider their implications for teaching and learning activities. In an attempt to develop a deep understanding of the evolving patterns of thought that underpin von Glasersfeld's theory of radical constructivism, we read many of the writings he has

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published over the past 25 years and examined some of the criticisms of radical constructivism that have been published recently.

Although our readings were conducted in the spirit of critical inquiry, it is important that we reveal our sympathy for von Glasersfeld's position and state clearly the nature of our own interpretive frameworks. We are science and mathematics educators who have been using radical constructivism as a referent for developing our own pedagogies in teacher education, research supervision and school teaching (Hardy, 1996; Taylor, in press; Taylor & Dawson, in press; Milne & Taylor, 1995a). In that process, we have been testing the viability of radical constructivism and its fit with other epistemological theories such as Habermas's critical social theory. Unlike most recent critical accounts of radical constructivism, we are able to ground our criticisms within the context of our own practical teaching experiences. These experiences have illuminated both the power and the paucity of radical constructivism and, in this paper, have given us cause both to celebrate the strengths of this radical theory of knowing and to recommend further elaborations of the theory so that it can serve as a more powerful referent for teachers interested in transforming the cultural climates of their science and mathematics classrooms.

Needless to say, we emphasise that what follows is a product of our own interpretations and, as such, it is destined to reflect imperfectly von Glasersfeld's intended meanings.

CONSTRUCTIVISM VS OBJECTIVISM

> Since constructivism is explicitly instrumentalist, it holds that . . . conceptual construction is carried out not for the sake of representational knowledge of a 'given' world, but to enlarge the map of viable pathways in the world constituted by the subject's experience.
>
> [EvG, 1992b, p.383]

As an offspring of the 'subjective empiricism' of Locke and Berkeley, radical constructivism is a theory of knowing proposed as an alternative to the long-dominant epistemological theory of objectivism (von Glasersfeld, 1986, 1991b, 1992a). Objectivism assumes that reality has an inherent, observer-independent and, therefore, objective structure. By means of rational thought processes governed by the rules of propositional logic, it is possible to attain 'true' or objective knowledge, that is, knowledge which is congruent with reality's objective structure (Johnson, 1987; von Glasersfeld, 1986). However, these assertions give rise to a paradox: in order to verify one's knowledge, one must be able to compare that knowledge with objective reality and, hence, have ascertained the structure of objective reality prior to gaining knowledge of it (von Glasersfeld, 1986, 1987).

Radical constructivism does not deny the existence of objective reality; however, it does posit that we do not have any method of attaining objective knowledge (von Glasersfeld, 1992a). Principally, we do not have access to a 'God's-eye' privileged view of the universe (von Glasersfeld, 1981, 1986, 1991a). From a radical

constructivist perspective, knowledge consists of mental constructs which have satisfied the constraints of objective reality. The learner constructs knowledge from his experiences in an effort to impose order on and, hence, make sense of those experiences. Moreover, the sole function of knowledge is to allow one to impose such order on one's 'experiential flow' (von Glasersfeld, 1981, 1984, 1987, 1989b, 1991a).

It is essential to understand that von Glasersfeld's use of the term 'knowledge' sets it well apart from the conventional use of the term. Traditionally, knowledge has been taken to mean a representation of some aspect of the physical world around us, and its truth status has been taken as a measure of how well the said knowledge corresponds to, or represents, an observer-independent world. By contrast, von Glasersfeld uses knowledge in Piaget's 'adaptational' sense "to refer to those sensory-motor actions and conceptual operations that have proved viable in the knower's experience" (von Glasersfeld, 1992b, p. 380).This distinction is one that seems not to be well understood by critics of radical constructivism who fail to distinguish between knowledge and experience and whose arguments are framed implicitly by objectivist assumptions.

VIABILITY

> The shift to this postepistemological way of thinking has multiple consequences. The most important is that the customary conception of *truth* as the correct representation of states or events of an external world is replaced by the notion of *viability*. [EvG, 1995, p.7]

It is the concept of viability that makes radical constructivism an 'instrumentalist' theory of knowledge and that sets it apart from traditional representationist epistemologies. In arguing that knowledge consists of those mental constructs that satisfy the constraints of objective reality, radical constructivists are asserting that knowledge does not 'match' the world's actual structure, but 'fits within' or 'slides between' its constraints. Borrowing from biology, radical constructivism characterizes such constructs as 'viable'. More clearly, a viable construction is any mental or physical action that is consistent with one's experiences AND fulfills an intended purpose or, to use von Glasersfeld's words, a construct that "stands up to experience and enables us to make predictions and to bring about or avoid, as the case may be, certain phenomena" (von Glasersfeld, 1984, pp. 8-9; see also von Glasersfeld, 1981).

A cursory inspection of the radical constructivist position might lead one to posit that it falls prey to the 'solipsism' of the idealists: the world is as each of us dreams it to be. However, the concept of viability prevents radical constructivism from such a treacherous descent (von Glasersfeld, 1986). Contrary to any misleading surface appearances, an individual is not at liberty to characterize ANY construction he or she desires as viable. The ever-present socio-physical context in which one is situated constrains the range of viable constructions (von Glasersfeld, 1989b, 1989c). Moreover, a mental construct is viable only as long as it continues to fulfill its intended purpose (von Glasersfeld, 1981, 1984, 1986).

Experiential constraints limit the realm of viable cognitive constructs very much like Darwin's evolutionary theory suggests that experiential constraints limit the realm of viable life forms (von Glasersfeld, 1981, 1984). Correspondingly, any construct that

satisfies the constraints of experience is viable. Similarly, any mental construct that fails to satisfy the constraints of one's socio-physical environment is unviable and, once a construct is so characterized, it is discarded or altered during the ensuing quest to create a viable construction (von Glasersfeld, 1981, 1984).

Because any construct that accomplishes its intended purpose is viable, there are potentially infinitely many solutions to a problem. Moreover, one solution to a problem cannot be more viable than another since effectiveness is the only criterion for determining viability. Therefore, if a qualitative distinction between solutions is to be made, it must be made on the basis of some other criterion of assessment (von Glasersfeld, 1984). We return to this important point in the final section on communicative ethics. But first we consider what radical constructivism says about the process of learning.

LEARNING: A COGNITIVE MODEL

> Learning is not a stimulus-response phenomenon. It requires self-regulation and the building of conceptual structures through reflection and abstraction. Problems are not solved by the retrieval of rote-learned "right answers". To solve a problem intelligently, one must first see it as one's own problem . . . as an obstacle that obstructs one's progress toward a goal. [EvG, 1995, p.14]

Whatever a conception of learning may be, it should be consistent with the assertions that knowledge serves to order one's flow of experience and that knowledge consists of viable mental constructs that one has abstracted from one's experiences. Accordingly, radical constructivists consider learning to have occurred when the learner has neutralized a perturbation by reorganizing both his or her model of experience and the activities associated therewith (Cobb, 1994; von Glasersfeld, 1987).

After conceiving of learning in this way, von Glasersfeld endeavoured to create an explanation of the cognitive constructive process that incorporates Piaget's concepts of 'assimilation' and 'accommodation'. During the course of his efforts, von Glasersfeld realized that, in asserting that knowledge is abstracted from experience, constructivists assume that it is possible to recognize experiential recurrences and that temporally distinct experiences will be consistent (von Glasersfeld, 1984, 1987). On the basis of these realizations, von Glasersfeld concluded that before one can characterize any experiential phenomenon as regular or invariant, one must compare distinct experiences and judge them to be similar (von Glasersfeld, 1984, 1986). The ability to create an internal regeneration of an experience, or the ability to 're-present' (von Glasersfeld, 1989a), is an indispensable component of this process; as it is not possible to compare noncoincident experiences without re-presenting at least one of them (von Glasersfeld, 1984).

By noting that comparison, re-presentation and judgement of similarity are all actions that learners intentionally engage in, and by relating these actions to the learning process, von Glasersfeld provided substantiation of the constructivist claim regarding the learner's intentionality. Von Glasersfeld provided additional support for this premise in realizing that experiences are not inherently similar; rather, it is the

learner who chooses and compares aspects of experiences, judges them to be similar and, thereby, imposes on them a 'relation of similarity' (von Glasersfeld, 1986).

Von Glasersfeld argued that there are two forms of similarity: 'equivalence' and 'individual identity'. Both are concepts and, as such, must be abstracted from experience. However, when making a comparison, a learner constructs the existence of one relation or the other based on the perceived nature of the compared experiences, not on the outcome of the comparison (von Glasersfeld, 1984).

The ability to judge phenomena as equivalent is the basis for the creation of categories and the categorization process itself; however, categories are dependent for meaning upon concepts and re-presentations (von Glasersfeld, 1989a). Even so, once a learner has constructed the relation of equivalence, he or she is prepared to assimilate experiences (von Glasersfeld, 1986).

On the other hand, individual identity is the basis of, what Piaget termed, 'object permanence' (von Glasersfeld, 1986) which plays an important role early in the process of accommodation (von Glasersfeld, 1984, 1986). When a physical or mental action fails to produce the desired or expected result, a perturbation arises and the accommodation cycle begins (von Glasersfeld, 1987, 1989b). The experience is distinguished from its unperturbing counterparts, and the learner strives to resolve the perturbation. During this quest, the learner re-presents and compares experiences in an effort to determine what was unique about the perturbing experience and why her or his initial model of experience failed to account for it (von Glasersfeld, 1984). Further, the learner often examines consciously her experiential model, that is, engages in 'reflected abstraction', in order to understand why her initial action produced an unexpected or undesired result. Regardless, while synthesizing a viable solution the learner utilizes reflected abstraction to reorganize his or her model of experience and the activity that model guides (von Glasersfeld, 1987, 1989a, 1989b). Once a viable solution is constructed, the perturbation is neutralized and cognitive equilibrium is re-established.

Hence, von Glasersfeld constructed a cognitive model of the learning process, a model that incorporates Piaget’s processes of assimilation and accommodation and that has strong explanatory power. In particular, it explains the constructivist teaching strategy of 'cognitive conflict' favoured by conceptual change researchers (Driver & Erickson, 1983; Driver, 1995), and helps us to understand the well-documented resilience of chidren's 'alternative frameworks'. Accommodation of children's existing schemas (towards, for example, a counter-intuitive scientific conception) is a notoriously difficult teaching goal to attain. It is a cognitive process that can withstand laboratory-based 'hands-on minds-on' personal empirical inquiry (Duit, 1995) and that is likely to be dependent upon the socio-cultural background of the students (Baker & Taylor, 1995). Perhaps this is why constructivists recently have turned their attention to the role of interpersonal negotiation in attaining the 'holy grail' of cognitive accommodation. What does radical constructivism say about the social dimension of learning?

THE SOCIAL DIMENSION OF KNOWING

> Kant wrote that we can only conceive of another subject by imputing our own subjectness to another entity. . . you construct "others" out of elements of yourself, and soon these others contribute to the image of yourself. [EvG, 1995, p.12]

Although it has been termed "the epistemological adventures of Robinson Crusoe" (Davydov, 1990; in Confrey, 1995) and is alleged to portray the individual as nearly "hermetically sealed in a privately constructed experiential world" (Ernest, 1993), radical constructivism does not deny the social component of learning. On the contrary, von Glasersfeld maintains that "Every individual's abstraction of experiential items is constrained (and thus guided) by social interaction and the need of collaboration and communication with other members of the group in which he or she grows up" (von Glasersfeld, 1991a). Von Glasersfeld argues further that social interaction is both the most frequent source of perturbation (von Glasersfeld, 1989b) and the most powerful method for testing the viability of one's constructions (von Glasersfeld, 1991b, 1993). Hence, "it is precisely the social aspect (of one's environment) that furnishes the key to the solidification of the individual's experiential reality" (von Glasersfeld, 1989c).

Clearly, radical constructivists do identify the social as an indispensable component of the learning process. Nevertheless, the cognitive learning model of radical constructivism does not proffer an adequate explanation of how the socio-cultural and the personal components of learning interact (Cobb, 1994; Confrey, 1995). Accordingly, such interaction needs to be investigated further. However, it is worth realising that neither the social nor the individual components of learning necessarily supersedes the other. A more pragmatic position for teachers is that the two are complementary, and that each can serve interchangeably as the background against which the other's development can be foregrounded (Cobb, 1994).

Language

> Texts contain neither meaning nor knowledge; they are a scaffolding on which readers can build their interpretations. [EvG, 1993, p. 30]

Another favorite target of critics of radical constructivism has been the role its adherents allocate to language in the development of abstract thought (Ellerton & Clements, 1992; Lerman, 1993; Suchting, 1992). We believe this criticism to be due largely to the infrequency with which radical constructivists expound upon the role of language in the development of abstract thought and to the critics' failure to explore radical constructivism's roots in linguistic analysis and language acquisition (von Glasersfeld, 1991b).

In 1971, von Glasersfeld argued that language could be linked to conceptual structures and that such links were vital to the construction of understanding (von Glasersfeld, 1971). Later, he asserted that "once 'language' has developed, it will quickly acquire its function as an instrument of reflection and an almost indispensable tool of thought" (von Glasersfeld, 1976, p. 218; see also 1991b). That is, language is the tool one utilizes both to conduct one's thinking and to impose a repeatable structure on one's cognition. In light of these arguments, it seems reasonable to

conclude that radical constructivism acknowledges a critical role for language in the development of abstract thought.

However, language is responsible neither for our capacity for thought nor for its own development (von Glasersfeld, 1976). On the contrary, it is constructed through social interaction. Further, language is comprised of symbols which have no inherent meaning and must, therefore, be interpreted. Accordingly, neither symbols nor linguistic expressions acquire meaning prior to being associated with one or more concepts, and since concepts are internal to the knower so are linguistic and symbolic meanings (von Glasersfeld, 1971, 1974, 1990, 1992a; Wheatley, 1991). Nevertheless, such meanings are abstracted from and adapted through social interactions (von Glasersfeld, 1976, 1989c, 1992a), which again highlights the importance of the social component of learning.

When one considers the social development of language in conjunction with its use as a tool of reflection and for structuring thought, one might conclude that much of a person's self-image is constructed from her or his social interactions. Indeed Von Glasersfeld argues thus: "Indeed out of the manifold of these frequent but nevertheless special (social) interactions, there eventually emerges the way the developing human individual will think both of 'others' and of him- or herself" (von Glasersfeld, 1989b). Attacked for seeming to invert the relationship between the individual knower and the "community of subjects/others that constitute individual subjects" (Suchting, 1992, p. 238), von Glasersfeld counters that, pace Piaget, he is interested in explaining the very young infant's initial separation of self from the objects that populate her experiential world. Thus, he limits the social construction of self to later levels of development, and argues that the young child utilizes her sensory input initially to distinguish herself as a unique experiential entity (von Glasersfeld, 1989c, 1992b). Although social interaction performs a vital role in the construction of self, one's concept of others cannot be taken as an 'ontological given' but must be constructed from one's experiences (von Glasersfeld, 1989b).

Although we do not disagree with these claims, we maintain that it is important to remember that from the time one’s conscious cognitive activity begins, one's experiential field includes other people and one's interactions with them. Therefore, the construction of self and knowledge entails interwoven and inseparable personal and social 'threads'.

Shared Meaning

> By talking to an audience I cannot give people any new concepts, but I can prod them to combine in different ways the concepts that they have associated with the words I am using.
>
> [EvG, 1993, p.32]

Criticisms of the radical constructivist position on language are not limited to its alleged failure to recognize language as playing a critical role in the development of abstract thought. Also receiving fire has been radical constructivism’s assertion that language does not have the capacity to serve as cognitive Tupperware. That is, one cannot use language to package and convey meanings, concepts or knowledge to a recipient who unpacks the exact meanings, concepts or knowledge that one has endeavoured to communicate. Intimately associated with this claim is the assertion that meanings cannot be shared in the sense that individuals construct identical

meanings. Like its counterpart, this claim has received intense criticism (Ellerton & Clements, 1992; Strike, 1987). Apparently, the fundamental objection to radical constructivism's denial of both the objective existence of identically shared meanings and the role of language as a transmitter of meaning is that its critics believe such assertions defrock people of communicative ability.

From a radical constructivist perspective, communication necessitates not identically shared meanings, but compatible meanings. Compatibility of meaning is demonstrated when no participant of a communicative process engages in an action that is unexpected by the other participants (von Glasersfeld, 1987, 1990). The absence of unexpected action perpetuates within each participant a sense that the interaction was understood and, thereby, promotes an illusion of identically shared meaning.

Radical constructivists' denial of the objective existence of identically shared meanings is founded on the premise that each of us assigns meaning to linguistic symbols and, although strongly influenced by the social, meaning is abstracted from our individual subjective experiences (von Glasersfeld, 1987, 1989b, 1989c, 1993). Therefore, the meanings we create are never identical or shared, in the literal sense of the term (von Glasersfeld, 1989a, 1992a). Rather, compatible meanings have a socially negotiated 'interpersonal fit' (von Glasersfeld, 1989b, 1989c).

However, we prefer to adopt a pragmatic perspective from which we argue that the construction of identical meanings is within the realm of possibility. Nevertheless, even if identical meanings are constructed, the limitations inherent in language and the human condition (von Glasersfeld, 1986) preclude the verification of this alleged match, which renders as moot the question of whether knowledge or meanings can be congruent. The bottom line is that there is no privileged God's-eye perspective from which to judge congruence between individual meaning perspectives.

TRANSFORMING THE CULTURE OF TEACHING

Finally, we consider the viability of radical constructivism as a referent for transforming teachers' pedagogies. In the process, we identify limitations of radical constructivist theory as it is construed currently and argue for its elaboration by coupling it to compatible theories drawn from the philosophies of science and mathematics and from critical social theory.

Uncertainty

> Science, having to a large extent replaced religion in the 20th century, is all too often presented as the way to absolute truth. . . If mathematics were explained as a way of operating with a particular kind of abstractions and science as a way of building models to help us manage the world we experience, some of the latent resistances might be allayed. [EvG, 1995, p.6]

In the world at large, the epistemological relativism lying at the heart of radical constructivism is highly susceptible to being colonised by the prevailing culture of objectivism. For as long as teachers of science and mathematics continue to subscribe implicitly to objectivist models of the nature of science and mathematics, they can be

expected to engage in teaching practices which indicate that they pay only 'lip service' to a radical constructivist theory of knowing. While the historio-cultural myths of ‘cold reason’, ‘naive realism’, ‘value neutrality’, ‘confirmatory experiments’ and ‘infallible knowledge’ continue to constrain the experiential realities of science and mathematics classrooms, radical constructivism is likely to serve only as a handmaiden to objectivism (Milne & Taylor, 1995b; Taylor, in press).

Already in science and mathematics education we hear much of 'student-centred learning' and 'learning as conceptual change' as teachers, curriculum developers, and educational researchers articulate their interests in reforming from a constructivist perspective the teaching of science and mathematics. What seems to be common amongst these 'progressive' educational approaches is a purported concern for enabling students to 'construct' their own knowledge. However, the issue of the status of students’ constructed knowledge, which is of central concern to the relativist epistemology of radical constructivism, is curiously silent. It is this silence that allows the tradition of objectivism to attach the status of infallibility to knowledge that students ‘construct’ in science and mathematics classrooms.

Of course, radical constructivist theory extends to include a conception of scientists, themselves, as learners who use the constructed tool of mathematics to generate tentative theories, or viable explanations, of the phenomenological world. However, it is unrealistic to expect radical constructivism to provide teachers with sufficient impetus to deconstruct the objectivist myths concerning the nature of knowledge, learning, mathematics and science which have pervaded both the society and the profession into which they have been enculturated and for which they function as agents of enculturation. The power of myth lies in the sense of naturalness that it inspires, and in its ability to conceal its presence (Barthes, 1985; Malinowski, 1944). For many teachers, it seems natural that mathematics and science are privileged ways of knowing and constitute journeys along the 'royal road' to revelation of the ultimate secrets of Nature.

We believe that part of the solution to deconstructing the myth of objectivism is for science and mathematics education to empower teachers with rich understandings of the historical development of scientific and mathematical ideas and methods, especially the emergence during the twentieth century of relativist views of science (e.g., Feyerabend, 1975; Kuhn, 1970; Toulmin, 1972) and fallibilist views of mathematics (Ernest, 1991; Kline, 1982; Tymoczko, 1986). Until teachers become aware of the mythical nature of the ontological and epistemological claims of objectivism in relation to science and mathematics, they will be intellectually and emotionally unprepared to consider seriously the prospects of adopting radical constructivism as a referent for reconstructing their well-established theories of teaching and learning.

Communicative Ethics

> The cultural and social reality would be a more livable and fruitful one if we could do away with the notion that we have the "truth" and others had better believe it. [EvG, 1993, p.32]

> There will always be more than one way of solving a problem or achieving a goal. This does not mean that different solutions must be considered equally desirable. However, if they achieve the desired goal, the preference for a particular way of doing this cannot be judged by its rightness, but only with reference to some other scale of values . . . [EvG, 1995, p.8]

But why *should* teachers of science and mathematics adopt radical constructivism as a referent for their pedagogies? Can a moral imperative be associated with an otherwise instrumentalist theory of knowing that values knowledge on the basis of its usefulness for attaining goals? The argument that it is highly compatible with contemporary philosophies of science and mathematics might be enough to convince some, but hardly constitutes a compelling case for resisting the considerable momentum of tradition. After all, objectivism offers the morally-respectable position of a 'God's-eye' view of the cosmos. In the world of competing values, particularly in the crowded curriculum world of competing 'content', radical constructivism needs to offer a moral compulsion for its adoption.

As it is currently articulated, radical constructivism values explicitly constructive processes that resolve cognitive perturbations aroused by a failure to attain a desired goal state of meaning making or problem solving. Although radical constructivism recognises that a knowledge construction process is constrained by the social environment in which it occurs (by means of language and interpersonal fit), it does not provide an explicit moral basis for differentiating between competing knowledge claims, other than the self-regulating mechanism of determining the ‘consensual fitness’ of one's position. But what of the moral basis of the consensual viewpoint? Is that to be taken as fixed, as unproblematic, or as uncontestable? If so, the individual is at the mercy of the whim of the group. If we are to avoid the worst excesses of social determinism, it seems wise to broaden radical constructivism's instrumentalism by building a moral dimension into, or complementary with, the notion of viability that safeguards the interests of the individual while building a coherent consensual community. One way of doing this is to couple radical constructivist theory to Jurgen Habermas's 'theory of communicative action' (Habermas, 1972; McCarthy, 1984; Pusey, 1987), a social epistemology that posits an avowedly ethical approach to the social construction of knowledge.

For Habermas, the highest moral form of human endeavor is rational 'communicative action' oriented toward constructing a society in which truth, freedom and justice prevail. In particular, the intellectual autonomy of the individual should be safeguarded from the coercive influence of arbitrary power exerted by self-serving competitive interests. To achieve this democratic goal, we need to value social relations that strive for achieving hermeneutic, or mutual and reciprocal, understanding. Habermas identifies language as the vehicle for attaining this goal. However, a problem with language is that it has an ideological dimension and can serve, therefore, as a medium of power and oppression, especially in its role as the 'reservoir of tradition' which conceals and legitimates arbitrary power: "the most sincere efforts at understanding often serve only to tighten the grip of ideologically laden ascriptions of roles and responsibilities" (Pusey, 1991, p.64). Communication that is 'systematically distorted' prevents us, therefore, from reaching a truly consensual understanding.

Systematically distorted communication is inherent in 'instrumental' and 'strategic action'. The former concerns actions that are oriented toward the control of impersonal problems, such as the technical exploitation of Nature and the efficient functioning of institutions, whereas the latter fuels a spirit of competitive individualism oriented toward achieving success and domination over others. Both forms of action are justified in terms of an instrumentalist ethic in which the pre-determined end justifies the means. In the mathematics or science classroom, instrumental and strategic actions

give rise to an attitude in which the objects of pedagogical interest are the seemingly independent mathematical or scientific laws and theories that are believed to mirror Nature. An instrumentalist ethic attaches greater value to these objects than to the social relations amongst teacher and students. Further, teacher and students are constituted as objects serving complementary strategic interests in the main 'power game' of delivery and reception of expert knowledge and the reproduction of the normative values underpinning their social roles. The prevailing instrumentalist ethic assigns, therefore, a privileged value to teacher control, student conformity and social reproduction.

For the most part, ‘validity claims’ (or standards of truth and rightness) associated with instrumental and strategic actions are legitimated by the authority vested in the teacher by the institution. Thus, systematically distorted communication occurs because traditional validity claims (e.g., value-neutrality, amorality, uncritical obedience) underpinning both school science and mathematics and the institutionally-sanctioned social roles of teaching and learning go unexamined and unchallenged. Worse still, these official validity claims displace those that underpin the lifeworld knowledge that students bring with them from their out-of-school lives. Thus, the everyday classroom discourse that validates official knowledge and its generative social actions serves as a normalising influence. In the absence of an opportunity to engage in critical and self-reflective discourse about the legitimacy of competing validity claims, the distorting influence of tradition remains both invisible and irresistible. It is little wonder that the discursive practices of science and mathematics classrooms perpetuate so successfully amongst students the socially-repressive myth of objectivism.

On the one hand, radical constructivism is clearly antithetical to the objectivist epistemology of instrumental action inasmuch as it identifies knowledge, meaning-making and concepts as the objects of scientific and mathematical inquiry, and regards the socio-physical environment as a constraining influence on the viability of these thought objects. In contesting instrumental action, radical constructivism's notion of viability recaptures the essentially fallible human nature of scientific and mathematical knowledge. On the other hand, however, radical constructivism's somewhat instrumental view of the social environment — as a collection of individual subjectivities — does little to safeguard the social construction of scientific and mathematical knowledge from the amoral excesses of self-serving strategic action, especially by the most powerful others, be they teachers or other students.

It is at this juncture that Habermas’s theory of communicative action is helpful. It posits a means of counterbalancing instrumental and strategic actions by working towards the deconstruction of systematic distortions preventing mutual and reciprocal understanding. Communicative action offers a metalanguage for teachers and students of science and mathematics to examine conjointly the validity claims underpinning their established social roles and epistemologies. This is demonstrated in part by Cobb et al. (1993) who argue for two interlocking classroom discourses — ‘talking mathematics’ and ‘talking about talking mathematics’ — in which the social norms that constrain the way that students make sense of their mathematical learning experiences become the subject of critical appraisal, negotiation and renewed consensus-building.

Thus, by advocating conditions for examining underpinning validity claims, communicative action complements radical constructivism by providing a moral basis — a discourse ethics — for examining the worth of knowledge. The outcome of

educational discourses based on communicative action is unlikely, however, to be a 'neat and tidy' singularity. Indeed, science and mathematics education is likely to witness the re-emergence of dialectical rationality (in which competing ideas are held in essential tension) as the status of scientific and mathematical knowledge is assessed in terms of not only its technical usefulness but also its value to the construction and attainment of society's utopic goals.

However, there is a cost to the establishment in school science and mathematics classrooms of communicative action. Effort must be expended by teachers and students on developing empathetic and trusting relationships that nurture a risk-taking educational environment in which sincere self-disclosure and caring criticism can flourish. Existing social norms must be subject to critical examination against the explicit backdrop of tradition. Principles of equitable access and participation must govern classroom discourse. Moreover, and because consensual communities cannot be prescribed by authority, teacher and students must negotiate jointly new groundrules for the development of their own dialectical learning communities.

CONCLUSION

We have attempted to summarize Ernst von Glasersfeld's construction of radical constructivism, to examine the legitimacy of common criticisms of it, and to consider it's implications for teachers of science and mathematics. Our investigation has revealed that recent criticisms of the radical constructivist position on language and the social dimension of learning are unwarranted. Nevertheless, we believe that radical constructivism does need to explore further the socio-cultural context of knowledge construction and to incorporate a moral imperative for altering teaching practices if it is to serve as a viable referent for transforming the pedagogies of teachers of science and mathematics. We argue that integrating Habermas's theory of communicative action with radical constructivism's concept of viability offers a promising avenue for empowering educators with a moral imperative for deconstructing traditional objectivist conceptions of the nature of science, mathematics and knowledge, and for reconstructing their personal epistemologies, teaching practices and educative relationships with students. The incorporation of Habermas's theory of communicative action offers a promising safeguard for the integrity of the individual student against the overly deterministic influence of the technical imperatives of the educational institution by setting out conditions for establishing a dialectical learning community.

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