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Science education in a curriculum for democratic citizenship

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Abstract

Lemke suggests that "science and science education, as traditionally understood, may already have become either obsolete or overspecialized." The technology revolution, population explosion, and global economy pose new challenges in educating students for democratic citizenship. But in the science classroom, this goal is often thwarted by the reification, decontextualization, and technocratization of scientific knowledge.

"What we want is to see the child in pursuit of knowledge, and not knowledge in the pursuit of the child." – George Bernard Shaw

This session at the 2001 VAST Conference is listed as a professional development session. My paper represents the continuation and refinement of ideas presented at the Como History, and Philosophy of Science in Science Education Conference (Garrison, Bentley, Fleury, Larochelle, & Desautels, 1999). What I want to discuss has to do with the basics, the foundation of our mission as science educators in our times.

I find myself disappointed and discouraged as I see our profession pursuing a path that I believe is pedagogically unsound. I am referring generally to standards-based reform and high-stakes testing, and specifically to the Virginia Standards of Learning program and its assessment system. Standards-based reform is about knowledge in pursuit of the child. I think our efforts in the classroom should be more about facilitating the child in the pursuit of knowledge. Maria Montessori appears to concur:

> No human being is educated by another person. He must do it himself or it will never be done. A truly educated individual continues learning long after the hours and years he spends in the classroom because he is motivated from within by a natural curiosity and love for knowledge. Therefore, the goal of education should not be to fill the (student) with facts from a pre-selected course of studies, but rather to cultivate his natural desire to learn.

From what I have seen, the assessment/accountability system we now have makes the goal of education to fill the students with facts in order to pass an industry constructed multiple-choice test. Students and schools are threatened with personal and community failure if they don't pass, because everyone perceives the loss of diploma or accreditation as significant consequences.

William Butler Yeats said, “Education is not filling a bucket but lighting a fire.” In my opinion, quality science education will not be achieved in Virginia if our energies continue to be focused so predominantly on raising SOL scores, or scores on any standardized year-end test.

I am distressed that state and national efforts to raise scores will lead children to see test scores are the purpose of education, what the adult society holds of most value. I am against making fear of not making the grade the chief motivation for children to learn. There is much more to education than that. To me, what is really the important priority in our times is educating students for democratic citizenship.

Others, whose expertise is in assessment and evaluation, including Gerald Bracey, my former colleague at the Virginia Department of Education, who now writes on these topics for the prestigious Phi Delta Kappan, and Larnie Cross, a colleague at Virginia Tech, have continually criticized the validity of SOL-like tests as a measure of learning. The current issue of Rethinking Schools features an essay debunking the so-called “Texas miracle” so prominent in the last presidential election. Texas teacher Teddi Beam-Conroy (2001) writes:

I needed my job. So I learned to play the TAAS game. This year, all my students passed the reading portion of the test and all but one …passed the math. But in exchange for that “success,” I have watched my teaching deteriorate. Ihave also watched my entire school be transformed into little more than a well-oiled test-taking machine. (pp. 3, 18)

Beam-Conroy describes how the school’s ESL program was “gutted” for the test, and how after years of teaching she finds herself, “trapped into teaching to the test.” (p. 18) Her experience jives with what I hear from my three sisters, all Virginia classroom teachers. Certainly the school curriculum should be evaluated as to its ability to meet educational goals, and certainly teachers should gather data from children about what they are actually learning from the curriculum, but to do this in a valid manner requires *multiple* measures (and not necessarily data from each individual child in a classroom or school), and it needs to be done continuously, not on one day in May each year.

In this month’s Phi Delta Kappan, noted educational researcher Iris C. Rotberg (2001) finds the high-stakes testing may have seriously weakened the academic standards they were intended to raise. But my intention here is not to summarize or to dwell on more criticism of the SOLs. I want to focus on aspects of science education for democratic citizenship. I propose that an educational theory called critical-constructivism should be an important referent for efforts to improve the educational process in schools in democratic societies (Garrison, Désautels, & Fleury, 1997).

Given the statistics on the participation of Virginians in elections, juxtaposed to the significant environmental issues today, I would claim that our educational efforts as a society have been misplaced. From what I can tell from the scientific literature, environmental quality is overall changing for the worse, and changing fast, due to human population growth and human behaviors in the environment. Most people are complacent now, but Ben Franklin got it right in *Poor Richard's Almanack* when he wrote that "When the Well's dry, we know the Worth of Water."

Environmental degradation, the technology revolution, overpopulation in much of the world, and globalized economy pose new challenges to schools in educating students for democratic citizenship, and science educators have an important role to play in addressing this goal. Obstacles to educators in educating students for democratic citizenship are many, including the current over-emphasis on simplistic accountability regimes. But education is a very complex enterprise, and there are subtle obstacles as well, obstacles in the "blind spot" of many teachers. These more subtle obstacles include the processes of reification, decontextualization, and technocratization of scientific knowledge, which I want to look at shortly.

But first, I want to call attention to what was said in a recent editorial in *Rethinking Schools*, a grass-roots educational journal begun by teachers in Milwaukee, the editors cited eight principles that they believe should guide genuine educational reform:

1. Public schools are responsible to the community, not to the marketplace.
2. Schools must be actively multicultural and anti-racist, promoting social justice for all.
3. The curriculum must be geared toward learning for life and the needs of a multicultural democracy.
4. All schools and all children must receive adequate resources.
5. Reform must center on the classroom and the needs of children.
6. Good teachers are essential to good schools.
7. Reform must involve collaboration among educators, parents, and the community.
8. We must revitalize our urban communities, not just our schools. (*Rethinking Schools*, 2000, 27)

I concur; this is holistic thinking about reform. Implicit in these principles is the recognition that education is a sociopolitical endeavor and teaching is an ethical act. Of all the people who are influential in the lives of a child, few persons have as many opportunities as the teacher for directing conversations about his or her construction of worlds. Every day, in the planning and enacting of the classroom curriculum, teachers are faced with moral, social, and political questions.

One of the most fundamental of such questions involves whether or not to let students in on the knowledge game itself. But, in order to even ask this question, teachers themselves must have opportunities to learn how knowledge is multiply constructed in multiple ways. Borrowing Schwartz's (1990) phrase (who borrows it from Toni Morrison), the teacher is the leverage point for making students "response-able" (p. 397).

From the perspective of an educational theory my colleagues and I have called critical-constructivism, epistemological and ontological response-ability is the central outcome of an education for democratic citizenship. Thus critical constructivism calls into question the three "idols of thinking" prevalent in today's standards-based educational reform, and also very prevalent in teacher education and curriculum and instruction in general (Popkewitz, 1991; Désautels, Garrison, & Fleury, 1998):

> (1) Reification: presenting contingent and mutable socially constructed forms of knowledge as necessary and unalterable.
> (2) Decontextualization: reformulating knowledge such that the complexities and contingencies of the social practices that produced the knowledge are concealed.
> (3) Technocratization: knowledge employed to service bureaucratization; scientism, not the sciences-in-action. (See Figure 1: Blind spots in science education.

Decontextualized, reified, or technocratized knowledge becomes distributed in textbooks and direct instruction in ways that hide issues of power and control circulating in all forms of knowledge, which Foucault has pointed out (1975). There are pedagogical, social, and political consequences of the processes of reification, decontextualization, and technocratization of knowledge (Roth & McGinn, 1998). One pedagogical consequence is that the work expectations for teachers get centered upon the (illusory) transmission of knowledge.

A child's education in science can be negatively affected if his or her curriculum is dominated by and organized around reified and decontextualized scientific knowledge. For example, the treatment of subject matter in science textbooks often conceals rather than illuminates socio-epistemological processes of backing and warranting knowledge claims, as well as the process by which these processes have become standardized. In countering these pitfalls, my colleagues and I believe that critical constructivism has the potential to have an emancipatory effect in education.

The perspective of critical-constructivism also involves the ethical necessity of applying the principle of epistemological symmetry. This takes us beyond the constructivism of conceptual change teaching to extending respect for the local knowledges of the classroom community. Epistemological symmetry means that teachers should consider "the knowledge developed by students in the context of their local culture as viable and genuine" (Désautels, Garrison, & Fleury, 1998, p. 255). Thus school knowledge is but one of the instruments that can help learners emancipate themselves from their own biographies. To reconstruct their biographies in liberating ways requires that learners participate in social practices in which new meanings and forms of knowledge can be appropriated without negating their own cultural knowledge.

In order to realize the emancipatory potential of critical constructivism, the teacher must help students "transform radically their *rapport au savoir* (relationship to knowledge)" (p. 256). This *rapport au savoir* is about the relationship of meanings and values between the student and the knowledge production processes. Students must be able to bring all they know and their *ways* of knowing, their epistemologies, to their use and evaluation of scientific knowledges. Otherwise, what may develop is a form of *rapport au savoir* that is inhibitory or disempowering.

This brings in questions about norms and values and issues of power. Value conflicts are always power conflicts about whose values/whose norms should prevail: those of the students, the parents, the community, or those of the scientific disciplines. The sciences prevail when they constrain value consideration only to epistemic values, and just to their particular epistemological norms. The social sphere in which power operates becomes less restricted, on the other hand, if the sciences and science education consider not just epistemic values, but also aesthetic and ethical values.

All this leads me to say that what is important for the improvement of schooling, as Eisner (1995) emphasized, is "paying attention to the importance of building a culture of schooling that is genuinely intellectual in character, that values questions and ideas at least as much as getting right answers" (p. 764), or as getting *standardized* answers, according to the expression of Fourez (1997). I believe that it is important in an education for democratic citizenship for teachers to facilitate learning such that emancipatory possibilities emerge for their students. I also believe that science teacher education, which now emphasizes classroom technique, can be vitalized through systematic reflection and critique. Without reflection, the contingent nature of knowledge remains invisible and the language of teaching separates content from method, feelings from thoughts, objectivity from subjectivity, teaching from learning, and, ultimately, teachers from students.

Epistemological Practice in the Classroom

Finally, I want to provide some concrete examples of epistemological practice in education. But first what do I mean by *epistemological practice*. Epistemology, as a discourse about the conditions of the production and circulation of knowledges, is the result of socially situated practices. Epistemology, therefore, is the *product* of practices and not just some theory-driven scholarly enterprise. People of all ages can do epistemology and there are many ways teachers can enact epistemological practice in their classrooms.

One teaching strategy that engages students in epistemological practice is called "questioning the author" (Beck, McKeown, Hamilton, & Kucan, 1997). Questioning the author, or QtA as it is called, uses techniques such as marking, revoicing, turning back, and modeling to engage students in dialog about a text, to challenge the notion of author as authoritative voice, to promote shared learning over teacher-talk, and to move the thinking to the students.

The work of Fasulo, Girardet, and Pontecorvo (1998) provides another example of epistemological practice in the classroom. They describe nine and ten years old children engaged in epistemological practice in a history class as they discuss their interpretations of the contents displayed in a photograph of a Viking house. They are seen trying to specify the conditions of the production of historical knowledge, and this amounts to doing epistemology.

It may not be obvious from this example that doing epistemology leads to emancipation, but when this kind of practice is enacted by older students in the context of the science curriculum and over a significant amount of time, indications of liberation may be discerned (Larochelle & Désautels, 1992; Désautels & Roth, 1999; Richmond & Kurth, 1999). Through a diversity of activities (journal writing, small group discussions, simulations, projects, etc.) students had opportunities to reflect on the "ins" and "outs" of the production of scientific knowledges. They were able to step aside and shift their focus so as to transform scientific practice into an object of inquiry. This type of inquiry may lead students to question the epistemological status accorded to scientists and scientific knowledges. In so doing, students take their first steps in an emancipatory intellectual journey.

Similarities can be seen between the discourses of two groups of students engaged in different pedagogical experiences as they become aware that school science has little to do with science-in-action. One group participated in a summer camp and collaborated with senior scientists in research activities (Richmond & Kurth, 1999). The other group, almost ten years earlier, participated in a simulation during a semester long course about the production of scientific knowledge (Larochelle & Désautels, 1992). The excerpts below show that in both cases the 16-18 years olds began to question the conventional view of science through a comparison with the sciences-in-the-making. Following the classroom experience, the students no longer believe that scientists are suddenly inspired, that discoveries are just stumbled upon, or that experiments work the first time. They come to realize that trial and error, time, and hard work are usually necessary ingredients in the production of scientific knowledges.

> Science isn't as ideal as it seems in—I guess researchers went through a lot of pain to get those facts that are in our textbooks. And it seems like an inspiration just popped into their heads and the next day they were doing an experiment, and the experiment turned out perfectly the following day, and they got it published. (Daniel, quoted in Richmond & Kurth, 1999, p. 686)

> At first, I thought it was something like an inspiration from heaven. I rapidly changed this simplistic view of the process of production. [. . .] To me, scientists were geniuses, two to three times more intelligent than us. My idea was that they woke up one morning and said to themselves "Today, I have this problem to solve." They would then sit in front of a piece of paper and their intelligence would function by itself. They then produced scientific knowledge. But, from my own experiences, I realized that it was not that way at all. You have to work, go on trials and errors; it is by working really hard that you can arrive at something. (S-9, quoted in Larochelle & Désautels 1992, p. 235)

These students came to distinguish between school science and the sciences-in-action. They are also able to analyze their school experience of science and recognize that school science is dogmatic and does not leave much room for open inquiry. Some of them come to question the formative value of school science and become quite critical of their school science education as illustrated by the following excerpts:

> Doing freelance research is far more difficult than in school. 'Cause like I said, when you're in school, the teacher gives you a lab manual, and says, "Do what it says. Write the data you collect, turn it in." And you get a grade for it. And there might be a little explanation as to what happened, and everything, but it's something that someone has already done, so the answer is already there. Right, wrong, or otherwise, gonna know what's gonna happen. So that's one thing I have definitively learned about. (Chereese, quoted in Richmond & Kurth, 1999, p. 685)

> Personally, I did not think that there could be a difference between the realization of a research and its public presentation. I thought that what was presented to us [in school]

> was truly the research itself. My perception is certainly due to the fact that science courses today are programmed and designed in advance. That is why when we carry out an experiment in any of the fields of science, we are always faced with a recipe or an outline that we have to follow step-by-step in order to come up with the expected results. This practice makes us perfect little robots that are rewarded with marks on their transcripts. I do not think that we can call that science. (S-21, quoted in Larochelle & Désautels, 1992, p. 223)

The above illustrate that doing epistemology can heighten students' sensitivity to the artificial and artifactual character of school science and lead them to question this kind of education. For instance, it is apparent that S-21 becomes aware that his experience in science education had fostered his construction of an illusory representation of sciences-in-the-making. He or she is also able to point to the fact that school science is a kind of simulacrum which conditions students to act as "robots" in valuing grades, the antithesis of reflexivity and inquisitiveness. From then on, he or she cannot only transform his or her representation of the sciences and "*rapport au savoir*," but can also call into question the legitimacy of an institution fostering this kind of overdetermination of students (Désautels, Garrison, & Fleury, 1998).

The students in the activity tackled an impressive number of topics touching upon the logical and social conditions of the production of knowledges. A good number of them could foresee that scientific knowledges were social productions and thus relative to their conditions of production (this is not the same as adopting a solipsistic position concerning scientific knowledges).

In doing epistemology children of all ages forge intellectual tools that can be used to call into question received ideas about the production of scientific knowledges. However, in the illustrations above, matters of epistemology tend to overshadow the ethical and aesthetical dimensions. An ethical dimension is embedded in knowledge production "up-stream" as well as "down-stream." Ethics is up-stream in the metaphors that guide particular research, such as 'the survival of the fittest', 'the mechanical worldview' or the idea of genetic determinism. Further, the establishment of scientific disciplines as dominant regimes of discourses necessarily excludes other forms of knowledge, which are often looked down upon as 'traditional knowledge'. Simultaneously, the people producing those knowledges become socially disqualified in the name of a set of cognitive values (Fleury & Bentley, 2000).

Jerome Bruner (1996) reminds us that, "education is not simply a technical business of well-managed information processing, nor even simply a matter of applying 'learning theories' to the classroom or using the results of subject-centered 'achievement testing.' It is a complex pursuit of fitting a culture to the needs of its members and of fitting its members and their ways of knowing to the needs of the culture." (p. 43) Science education itself is infused with moral and political norms.

This can be illustrated by citing research done in the context of other, non-Eurocentric, cultures. As many researchers have concluded (Baker & Taylor, 1995; Jegede, 1997), the imported standard science education curriculum enacted in many countries has prompted a conflict of world-views which clearly has ethical and political dimensions. To achieve in the imported science education system, students may have to deny the value of the ways of knowing and sense-making developed in their own cultural milieu, thus running "the risk of being viewed as outsiders by their family and community" (Gallard, Viggiano, Graham, Steward, & Vigliano, 1998).

Research conducted in a community living in a South Pacific island (Waldrip & Taylor, 1999) also illustrates the situation. Melanesian students were interviewed at a residential high school. The researchers were surprised that most of the fifteen students could not provide the traditional explanations taught by the village elders about phenomena, as though they had forgotten. The researchers acknowledge that the interviewer was a foreigner and that there may be taboos associated with the revelation of traditional knowledge. In interviewing, however, the researchers found that, "All students except two seemed to feel that the village stories were foolish, and, when pressed for an explanation of natural phenomenon, tended to laugh and claim not to know them." (p. 293) The fact that the students felt embarrassed in discussing the subject indicates the impact of the *symbolic violence* (Bourdieu, 1994) exerted by the school on the representation these students have constructed of themselves and their culture. Having unconsciously accepted the school science worldview as criteria to evaluate their own cultural knowledge, they re-produced the relation of domination between worldviews. Thus, in the science education experience of these students, the ethical principle of epistemological symmetry was not applied and their ways of knowing were ignored or put down. The net effect of the socialization of these students into the western scientific worldview is a form of cultural alienation. The students have been severed physically from their village and have also been severed from their culture (Désautels, Garrison, & Fleury, 1998). Many of these students' formal education will end with high school and they will return to live in their village, which is likely to be a difficult and troubling experience both for them and the community. One has to wonder about the relationship between this outcome of the scientistic curricula of the schools and the attitude some people, like Osama bin Laden, later develop toward Western countries like our own when their eyes are opened.

Ethical and power dimensions associated with science teaching are manifest in the illustrations above. They also pervade our schools, but are as invisible to us as the everyday categories we use to make decisions. Hodson (1999) and Ogbu (1999) argue that society's subgroups (cultural, racial, economic, etc.) also construct sets of values, beliefs and languages that affect their capacity to contend with a school curriculum that reflects the dominant power/knowledge relations. Thus, for a significant part of the population, the typical science education program presents an invitation to assimilate a regime of discourse which conceals itself as an expression of one particular cultural point of view. In this way, typical science education produces real victims among the students and most are not likely to recover from the symbolic wounds inflicted on them (Trabal, 1998).

Another aspect is that school science, and school knowledge in general, is not intrinsically worthwhile for most of these students. It only has exchange value: they can exchange it for the power and privilege available in the dominant culture. Clearly, there are ethical and political values and issues involved here, and not just cognitive questions (Fleury & Bentley, 2000).

Science educators are becoming more sensitive regarding these socio-ethical problems. Giroux's (1992) border crossing metaphor provides a way to take into account the ethical and political stakes involved. The "no assimilation" principle embedded in the metaphor, is expressed by Aikenhead (1996):

> Border crossings may be facilitated in classrooms by studying the subcultures of students' life-worlds and by contrasting them with a critical analysis of the subcultures of science (its norms, values, beliefs, expectations, and conventional actions), *consciously* moving back and forth between life-worlds and the science-world, switching language conventions explicitly, switching conceptualizations explicitly, switching epistemologies explicitly. (p. 41)

The no assimilation principle, equivalent to the ethical principle of epistemological symmetry, can be found in the work of a number of scholars (Eisenhart, Finkel & Marion, 1996) who each in their own way have tried to change pedagogical practices toward a more critical and democratic form of education.

For students, developing themselves epistemologically moves them toward becoming active members of a participatory democracy. In traditional practice, education for democratic citizenship actually disempowers students by emphasizing the structures and rituals of existing institutions and roles, rather than developing an understanding of how knowledges serve as a currency in negotiating personal and social power dynamics. In our day, scientific claims and statements positioned as research-based carry much weight of expertise. The ability to frame and pose questions about the validity, evidence, assumptions and implications of expert knowledge is an epistemological tool that enables non-experts to participate in policy decisions that would otherwise be left to the few, and this is a change in the direction of balancing the power of knowledges in society.

Doing epistemology involves more than just enacting one's logical capacities. Having personal experiences in knowledge-making might also engage one's aesthetic proclivities. In turn, and with reflection on the personal satisfaction of these experiences, students might develop a different posture towards what Michael Apple calls the "official knowledge" handed to them in schools.

Conclusion

All the money and attention that has gone into programs such as the Virginia SOLs and the tests only distract science educators from the critical task in our profession for our time, the task of educating students for democratic citizenship in a new social era, a task that involves creating a culture in our schools that lets students in on the knowledge game.

The technology revolution, population explosion, and global economy pose new challenges to schools in educating students for democratic citizenship. Obstacles to this goal in science teaching include the subtle processes of reification, decontextualization, and technocratization of scientific knowledge. Critical-constructivism involves also the application of epistemological symmetry, which extends respect for the local knowledges of the classroom community. As a result, the perspective of critical-constructivism illuminates the concept of "science as a human endeavor" - promoted as one of the major content areas for K-12 schooling in the National Science Education Standards (NRC, 1996).

The October 7 issue of *Parade Magazine*, which comes with our Sunday newspaper each week, reported the results of a "What would you say" contest in Marilyn vos Savant's "Ask Marilyn" syndicated column. The challenge was for readers to rewrite in their own words Shakespeare's famous quote, "Some are born great, some achieve greatness, and some have greatness thrust upon them." Ms. vos Savant selected this revision by Terry Fast of Walnut Creek, CA: "Some are born great, some achieve greatness, and some inspire others to greatness." To me, this is a great motto for science teachers.

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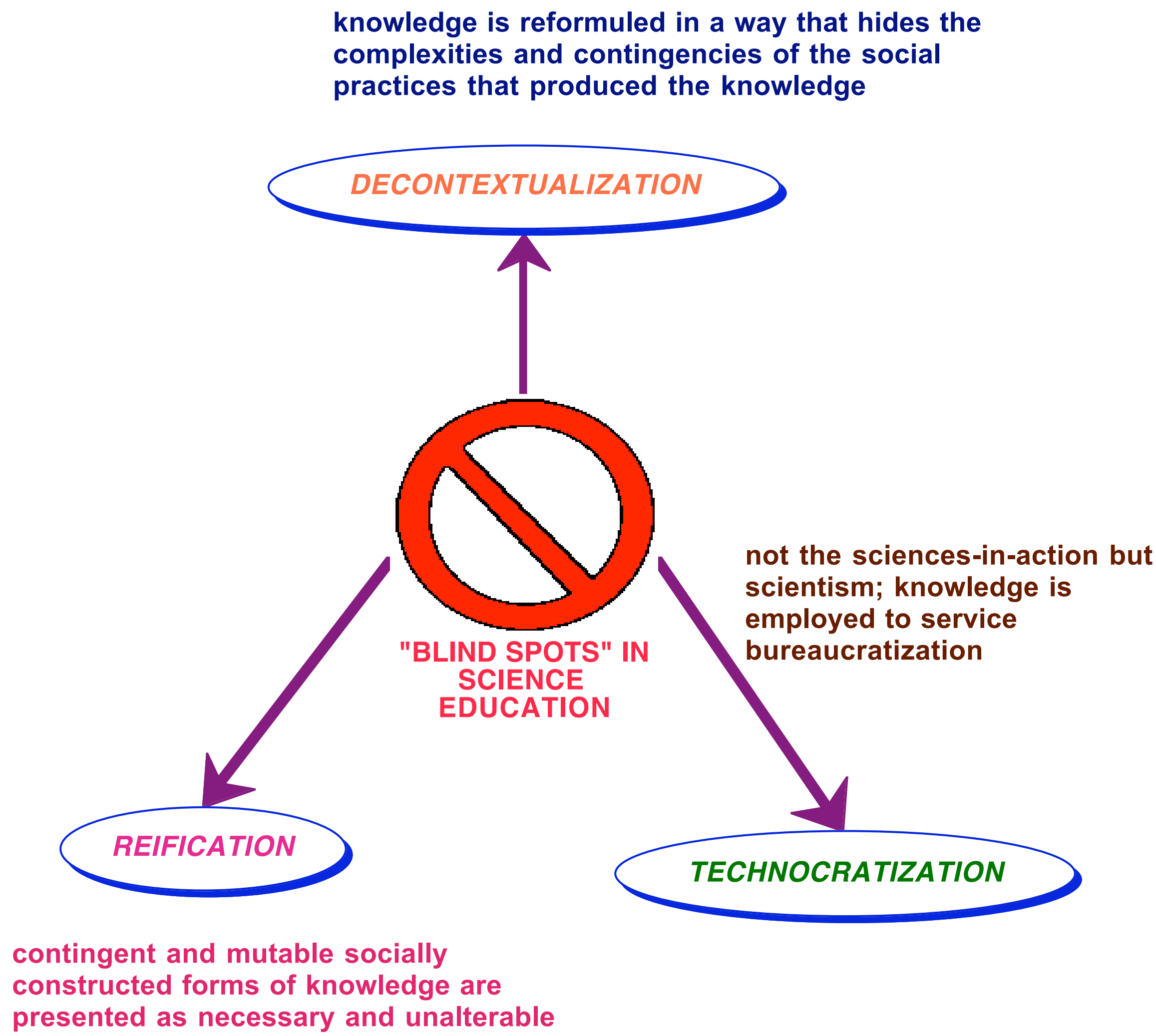

Michael L. Bentley (2001P based upon: Garrison, J., Desautels, J., & Fleury, S.C. (1996). A critcal-constructivsit manifesto. Paper presented at the International HPSST Conference, Calgary, p. 5.

Figure 1: Blind spots in science education.

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