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Science Education in the New Millennium

by
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Abstract

The last decade of the 20th century produced a flurry of reform activity in science education in the US and around the world. Documents like the National Research Council's National Science Education Standards and the American Association for the Advancement of Science's Project 2061 attempted to reinvent science education in response to changing technology, current educational theory and research, and the perceived continued poor performance of students on standardized tests. Consensus documents are rarely cutting edge, and there are regressive aspects to standards-based reform, however, there is growing recognition among practitioners of the educational potential of the new technologies and a need to reconceptualize the roles of student, teacher, school, and community in the educational process. Science educators at the turn of the century are also increasingly aware of humanity's present ecological predicament. The crunch between resource depletion and scarcity and population growth will play itself out early in the 21st century, and science education must now address this situation.

SCIENCE EDUCATION AT THE TURN OF THE CENTURY

Here at the end of the millennium, what can we say about science teaching and learning in America's K-12 public schools? From my own thirty years of experience as a science educator I see these as among the major influences of change:

- The availability of new teaching tools and resources, including the internet, scanners, digital cameras, probeware, and all manner of creative software applications and media, as well as a new generation of science programs (FOSS, STC, AIMS, Science Alive, Scholastic Science Place, Windows on Science, CEPUP, and so forth);

- Developments in our understanding of learning from multiple lines of scholarship - brain research, epistemology, social semiotics and linguistics;

- Recognition of new curriculum content for K-12 science (e.g. topics such as energy, biotechnology, the state of the environment, ethical issues, and the history and philosophy of science);

- Curriculum prescription by state standards, and, to a lesser extent national standards (Board of Education, 1995, National Research Council, 1996) and reform documents (e.g. American Association for the Advancement of Science's Project 2061);

- Socio-cultural influences, including the transition from an industrial-manufacturing economy to a post-industrial society (e.g. from goods to services, from a growth economy to a no-growth economy, from print media to electronic media), and shifting cultural assumptions and beliefs (e.g., from modernism to post-modernism).

These changes are represented graphically in Figure 1. I would like to comment further on a couple of these factors, but I think our discussion should be framed in relation to the last of these influences – the cultural shift that is underway. Clearly, the American milieu at the turn of the millennium can be characterized as transitional.

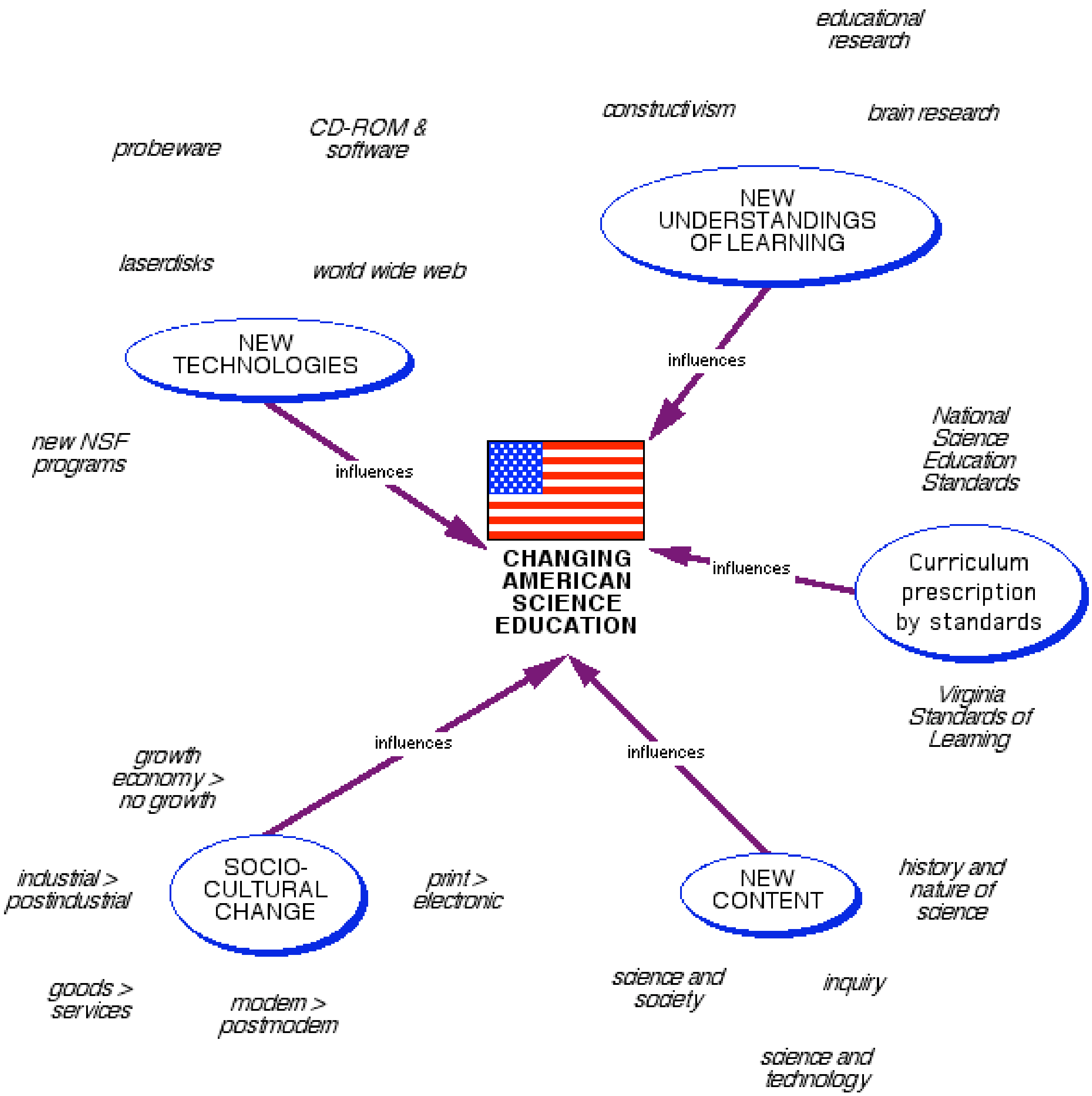

Figure 1: Factors currently affecting the face of American K-12 science education.

In his 1995 Royal Bank Lecture at Queen's University in Canada, Professor Leonard Waks of Temple University posed the following analogy:

$$\mathbf{A : B :: C :} \; x$$

Where *A* is industrial society, *B* is industrial era education; *C* is postindustrial society and *x*, the unknown, is the postindustrial education system. Waks challenges us to contemplate citizenship in the two social contexts, then "solve for *x*." What "*x*" should be is not at all obvious, but I don't think Waks had in mind the current *standards-based reform project*, which bears all the marks of industrialism/corporatism/modernism, rather than postmodernism.

In fact, over the past decade, standards-based reform has become the most salient characteristic of the status quo in science education. With the passage of the Goals 2000 legislation in 1994, requirements for standards for every state are now national policy for education, written into the Elementary and Secondary Education Act (ESEA). In this state we have the Virginia *Standards of Learning* (Board of Education, 1995) and its annual SOL assessment, a high-stakes test in which, in some cases, several years of a child's science studies are judged on the basis of 40 or 50 multiple-choice questions.

Note that I raise no objection to standards *per se*. Every teacher worth his or her salt establishes standards for student achievement. But when it comes to standards one size *doesn't* fit all - children are different in lots of ways that need to be taken into account. Standards-based reform is founded upon discredited and fallacious modernist assumptions, including the fallacies of universalism and regularity (Elkind. 1997). The standards approach aims to establish a uniform curriculum content to be learned by all students regardless of their personal characteristics. This intention is plainly stated in the NRC (1996) Standards: "The *Standards* apply to all students, regardless of age, gender, cultural or ethnic background, disabilities, aspirations, or interest and motivation in science." (p. 2) Gerald Fourez (1997) argues, however, that "…no particular knowledge is absolutely necessary, in itself, to enable one to live in our society." (p. 920) Jay Lemke (1993) unambiguously identifies standards-based reform as regressive:

Recent efforts to (justify a particular selection of information as THE curriculum) have either been reactionary attempts to return to the curricula of pride and prejudice, or else fanciful flights of abstraction seeking to teach non-existent, universally applicable intellectual processes (pseudo-universal problem-solving skills, higher literacy skills, etc.). Both essentially deny the diversity of human experience and seek to substitute for it impossible claims of universality.

David Elkind (1997) observes that, "What has come to the fore in postmodern times is the awareness of the importance of *difference*" (emphasis added, p. 243), and Heinz von Foerster (1992) speaks of the purpose of education as being the *multiplication of potentialities*. As each child progresses through his or her years of school s/he should be becoming more unique in knowledge and skills, rather than converging toward sameness. Thus, as I see it, achievement standards are most appropriately set at the classroom and school level. They are a matter of professional judgement and should be negotiated within the learning community.

The current standards-based reform project is regressive because it is a top-down technocratic approach to school improvement, compatible with "state agendas to provide more effective teacher education and steering of classroom processes" (Popkewitz, 1991, p. 168). This agenda includes giving status to expert knowledge and narrowing the decision-making processes within teachers' work (Popkewitz, 1991). This agenda also includes a way of conceiving of the work of the teacher. Many educators have criticized this view of the work of the teacher, since, among other things, it promotes prescription rather than negotiation and, therefore, ignores the reality that teaching practices are embedded in the assumptions and professional motivations of the teacher. As Pedretti and Dodson (1995) point out:

> "...the frequent and sometimes spectacular failures of top-down curriculum development can be laid at the door of the basic assumption about the relationship between developer and teacher: that teachers simply receive and then act upon the 'curriculum wisdom' transmitted by the developers. This approach ignores that teachers are people, too, who bring to the curriculum their own ideas, experiences, perceptions and values. Teachers possess a range of curriculum knowledge, skills, and attitudes..." (p. 476)

With standard-based reform also comes a reframing of the purpose of science education. According to the NRC (1996) *Standards*, one of the four goals for science education is to, "increase their [students'] economic productivity…" (p. 13). Relating the purpose of science in the curriculum -- both for the child and for the society, to economic productivity, is a confusing message at best, as many of our most pressing environmental problems relate directly to the overconsumption of resources fostered by a growth-dependent economic system.

Almost any teacher you ask will tell you that much time and effort has been required of them to "retool" their classroom curriculum to conform to new standards. This kind of work distracts these educators from the more intractable problems of schools, that is, as Eisner (1995) emphasized, "from 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). Standards-based reform, with its attendant accountability system, deflects attention away from the central purposes of education, the multiplication of potentialities and the development of children as competent social actors, while perpetuating a widely held view of the teacher's role, that teachers do not have to *enact* curriculum but only *execute* it.

Thus we can expect a number of undesirable outcomes as a result of standards-based reform, including a reduction in the diversity of teaching practice and local curriculum innovations. The downside of standards-based reform is illustrated in Figure 2.

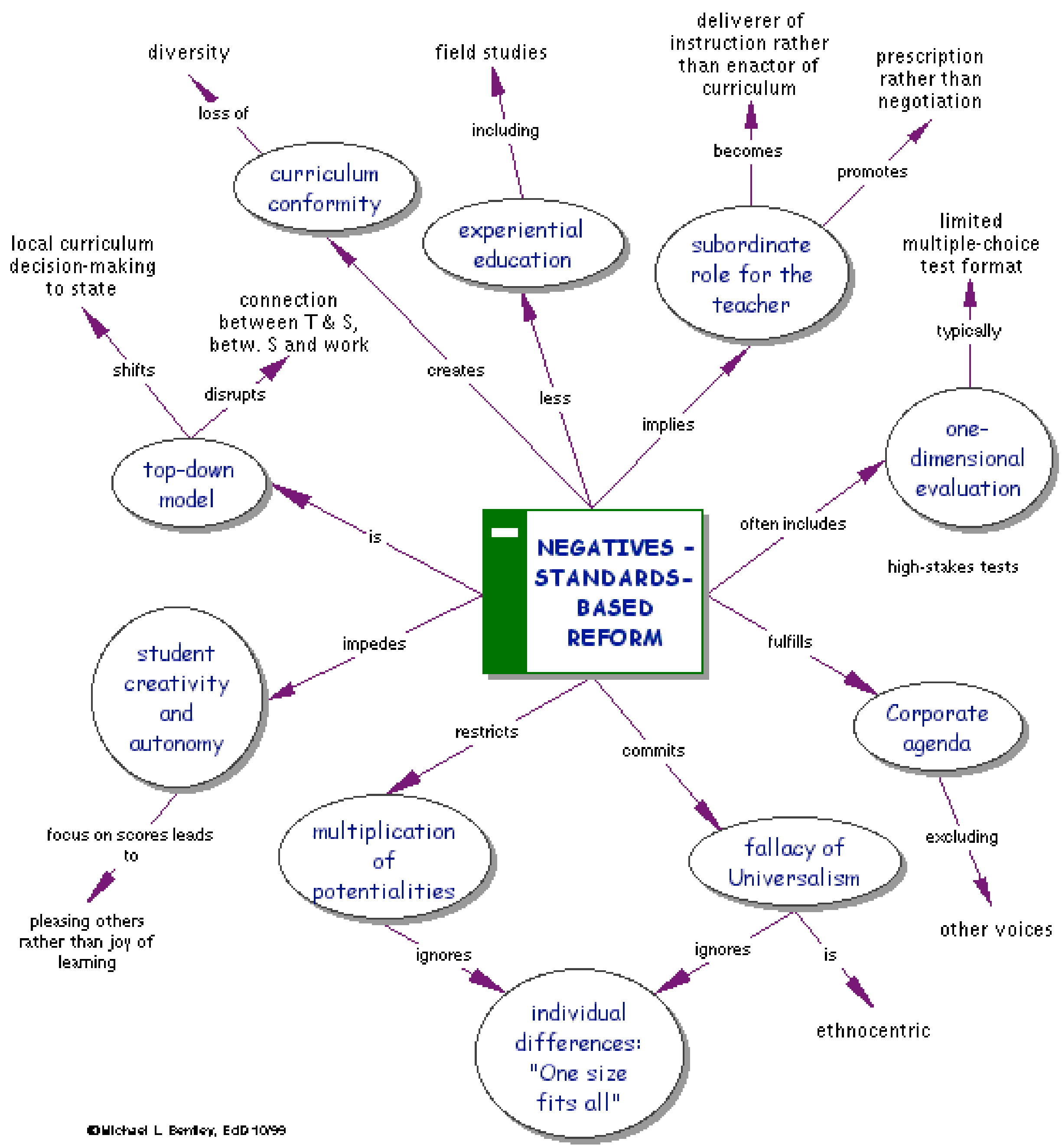

Figure 2. Negative impacts of current national education policy.

While not illustrated in Figure 2, one more negative impact of standards-based reform is the fear and anxiety being generated in the hearts and minds of some of our children. Ironically, many policy makers proudly support high standards and tough tests, yet these high-stakes tests produce few winners and many losers.

WHERE WE MIGHT BE HEADING IN THE '00s

The internet and world wide web are new technologies with truly astonishing educational potential. "Cyberspace is the new public sphere" (Jenkins, 1997, p. 35). What will cyberspace technology and the concurrent opening of a major new discursive space mean for science education? Just such a question is addressed by Jay Lemke (1993). He challenges us to think of education and learning as parts of an *epigenetic system*, that is, as "processes in the development of more inclusive systems that must be defined across many scales from our DNA and its biochemical interactions with a cellular and organismic environment to our human-scale semiotic and material interactions with other humans and with the rest of our ecosocial environment." In other words, Lemke conceives of learning as contextualized within an ecological and sociocultural milieu:

> 'Learning' is not a process that takes place INSIDE the system we call a human organism; its semantics is highly misleading. People do not learn. Learning is not an internal process. People participate in larger systems and those larger systems undergo developmental processes; in interaction with their own relevant environments, they create the conditions for their own further change along evolved, type-specific and individuating trajectories. Some things change inside people as they participate in these processes, and other, internal developmental processes of the same kind are going on within us among our own subsystems, coupled to our participation in these larger processes. What fundamentally changes, what we call learning, is how people interact with and participate in the larger ecosocial systems that sustain them. (Lemke, 1993).

From this sociocultural-constructivist perspective, it is a mistake to think of learning as a mental or a cognitive process. Rather "cognition and the mind (are) themselves essentially interactional processes extending beyond individual human organisms -- as social and transactional phenomena, in which individual brains and bodies participate, but which do not take place 'in' individuals, but only between them and their ecosocial environments."

For this to make sense, Lemke suggests we synthesize the notions of cyborg (unitary machine-human individual) and of eco-social system (unitary material-semiotic, ecological-social community). He says, "We need a notion for a system of material-processes-that-are-also-sometimes-semiotic-cultural-practices, rather than a system of individuals. We need a notion of system as token, not type. We (need) a notion of a system within which individuals are constituted, and which is itself constituted in part by the actions of individuals."

Lemke proposes an Ecocybersystem (ECS) Model. Looking at education from the perspective of this model, Lemke envisions radical changes in the years ahead, including the gradual disappearance of the 19th century institutions we call schools. He argues that schooling "is not likely to continue to function as the dominant form of education." He notes signs that the schools are starting to unravel and reminds us that decades ago Ivan Illich (1971) envisioned that schools could be replaced by libraries. This replacement process can already be discerned:

> Any inexpensive computer, with another $50 for a telephone modem connection, can already link to a worldwide amateur network (Fidonet) of bulletin-board systems (BBSs) that are pioneering the cultural practices which establishment institutions (the Internet) will follow, just as the "Ham Radio" of the 1950s pioneered the Global Village long before satellite television. BBSs are themselves often run on very inexpensive, jury-rigged computer systems. And they already have graphics, and music, and CD-ROM on-line. Video and virtual reality (VR) await only the fiber-optic cable network (or digital telephonics, or super data-compression schemes) that will replace present telephones lines and television (broadcast and cable, picturephones and HDTV). (Lemke, 1993).

Anyone who has kept up with the technological changes that have taken place has to be struck by the rapid pace of change and the continuously enlarging educative potential of the new technologies. One example: the Virtual High School (VHS), a national consortium of high schools offering Internet-based courses (http://vhs.concord.org) has been funded by a $7.4 million grant from the US Department of Education. The primary function of the new site is the delivery of internet-based high school courses to participating students. By logging on, students have access to specialized courses. Currently 33 schools from 13 states are participating in VHS.

With the perfection of virtual reality technologies, Lemke (1993) speculates that society's dominant educative institutions will indeed become libraries and museums (but not those we know today):

> Libraries will exist in cyberspace, and they will contain, not printed text-only books, but all electronically stored information which is publicly accessible. …The library will merge with the bookstore, and both with the electronic database, which will hold not just text and numbers, but pictures, graphic representations, videos, music, and virtual realities. Television, telephones, and computers will be absorbed into the new institution as well (while continuing to exist independently in the patchy way of uneven ecosocial development). (Lemke, 1993).

When this transition is complete, we will finally recognize von Foerster's "multiplication of potentialities" as the principal purpose of education: "People will create for themselves and others unique and distinct educations."

Lemke (1993) makes an additional important point. He states that, "The highest good which discourse can frame is not the good of the individual, nor of the family, the tribe, the city, the nation, or even of humanity, but the good of the Whole." He says we as a species must evolve "toward Gaian values that put ecosystem interests above human interests, and value other species and even abiotic systems for their contributions to the Whole…" Only by so doing, he claims, by learning to interact differently with the rest of the Whole, will human culture survive.

While Lemke might be right that the importance of schools in public education is on the wane, I believe we will likely have schools with us for many years to come, if for no other reason than their socially essential custodial function. Our young people will continue to spend a substantial amount of their time in school classes. What can be done to optimize children's' and adolescents' experience of schooling? Standards-based reforms represent a wrong-headed approach that will do little to improve the conditions of schooling, but we do know part of the answer. We have useful educational theories based upon constructivist epistemologies and models of childhood development. We know how to constitute educative environments.

One useful referent for educational theorizing is Csikszentmihalyi's theory of complexity and optimal experience (Csikszentmihalyi, 1991, 1994; Csikszentmihalyi, Rathunde, & Whalen, 1993). Many theories of development show direction toward complexity of consciousness. Csikszentmihalyi speaks of the dialectical processes of integration and differentiation, each separately and together dominating successive stages in the child's development. These processes, as they spiral in the thesis-antithesis-synthesis manner, lead to increasing complexity. People who are on a steep learning curve may also experience what Csikszentmihalyi calls "flow," a complex of positive feelings that fosters auto-telic experience. Csikszentmihalyi et al. (1993) point out that "…the quality of experience will to a large extent determine whether an activity will be repeated or not." (p. 125) Of course, educators can create classroom environments that provide opportunities for balance between integration and differentiation, and for positive, flow-type experience:

> Intellectual and artistic gifts do not grow by themselves or in a vacuum. They must be constantly nurtured in the context of a social field, and they have to grow within the rules of a complex symbolic domain, or they will not flourish. If students do not enjoy operating in the field and the domain-if they fail to derive intrinsic rewards from using

> their talent-the likelihood of their continuing to develop their gifts is greatly reduced. (1993, p. 125)

However, many science classrooms are characterized by overdifferentiation. Students experience science as fragmented - “Such students feel they are showered with decontextualized dates, names, discoveries, and ideas that make little immediate sense to them.” (Csikszentmihalyi et al. 1993, p. 118) Too often teachers discount the importance of intrinsic motivation and personal relevance. “Teenagers respond more intensely to concrete evidence, to events that have direct implications for their lives, and to issues that they care about,” and “…the adults who are in charge of the various fields of learning often forget that joy is the best teacher.” (Csikszentmihalyi et al. 1993, pp. 115, 116)

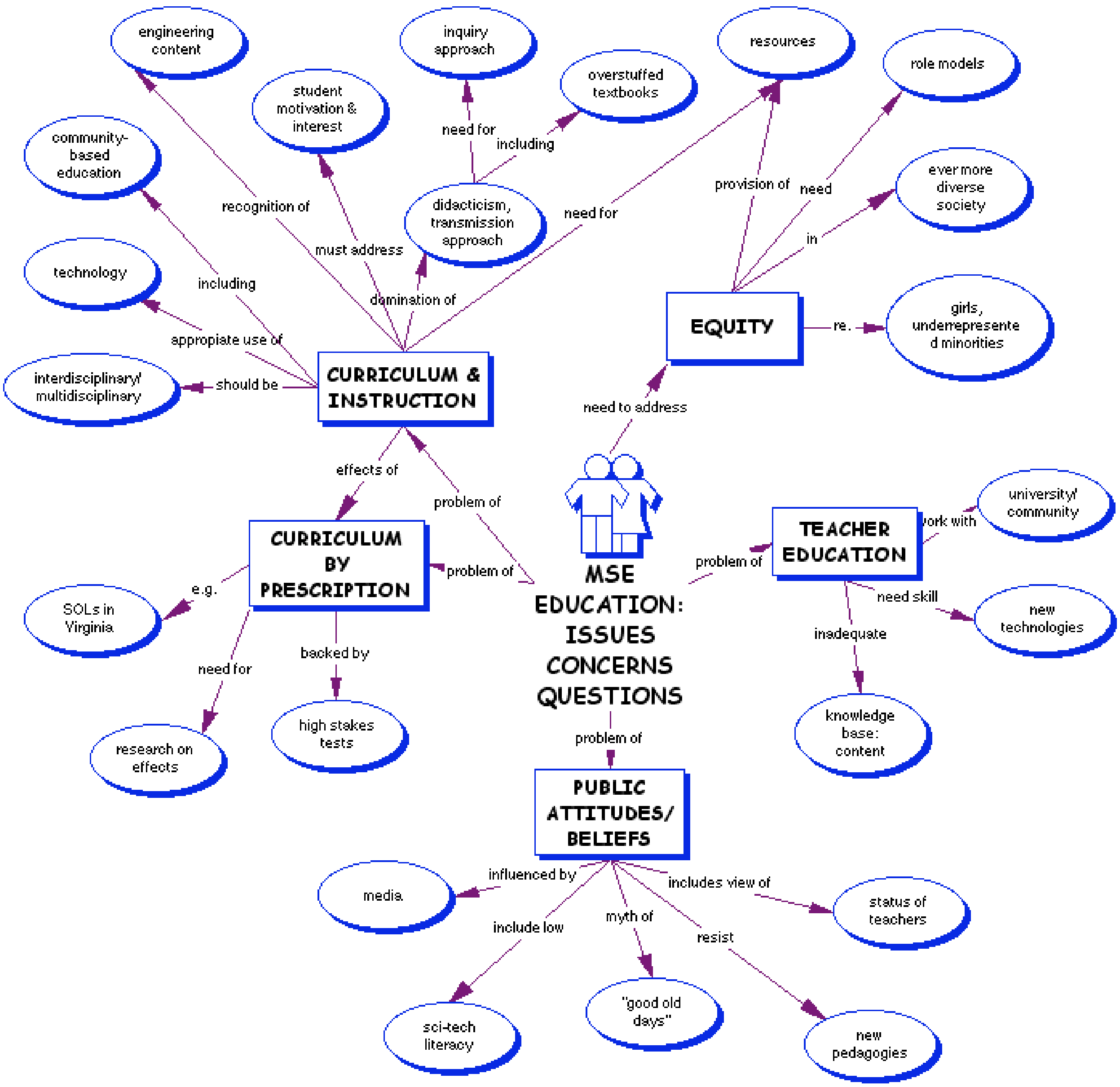

Figure 3: A graphic representing current issues and concerns in science education in the US.

CONCLUSION

As we begin a new millennium, science educators consider a number of issues and concerns (Figure 3). Dominating everything else, school science in the US is dominated by regressive standards-based reform. While coping with standards and high-stakes testing, science educators also are beginning to respond to changing technologies and current educational theories and research. Researchers such as Lemke argue that the educational potential of the new technologies can only be realized if we reconceptualize the roles of student, teacher, school, and community in the educational process. He sees the dominance of schools in education shifting to other social institutions. The work of Csikszentmihalyi suggests how we can enhance students' experience of school science and optimize learning. Science educators at the turn of the century are also increasingly aware of the planet's present ecological situation and the survival value of biocentrism as opposed to anthropocentrism.

FOR FURTHER STUDY

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