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Cultural Aspects of Learning Science

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Over the past few decades our focus on learning science has evolved (Aikenhead, 1996; Cobern, 1993, 1994; Solomon, 1994). The psychological perspectives on the individual learner of earlier years, such as Piaget, Ausubel, and personal constructivism (West and Pines, 1985), have expanded to encompass sociological perspectives that contextualize learning in social settings; for instance, social constructivism, science for specific social purposes, and situated cognition (Goodnow, 1990; Hennessy, 1993; Layton, Davey and Jenkins, 1986; O'Loughlin, 1992; Solomon, 1987; Tharp and Gallimore, 1988). This chapter addresses the next stage in the evolution of our focus on learning science—an anthropological perspective that contextualizes learning in a cultural milieu.

Certainly psychological and sociological approaches are useful in science education, but a more encompassing perspective from cultural anthropology can provide fresh insights into familiar problems associated with students learning science, as will be evident in the research reported in this chapter. Despite sociologists' appropriation of ideas from cultural anthropology, the two disciplines (sociology and anthropology) differ dramatically, even in their definitions of such fundamental concepts as society, culture, and education (Traweek, 1992). For example, from the point of view of a sociologist, teaching chemistry tends to be seen as socializing students into a community of practitioners (chemists) who express in their social interactions certain "vestigial values" and puzzle-solving exemplars. On the other hand, an anthropologist tends to view chemistry teaching as enculturation via a rite of passage into behaving according to cultural norms and conventions—especially the way the group makes sense of the world—held by a community of chemists with a shared past and future (Costa, 1993; Hawkins and Pea, 1987). One consequence to the disparity between sociology and anthropology is the realization that the anthropological perspective described in this chapter represents a significant change in our thinking about students learning science. Unfortunately, terms such as "culture" and "socio-cultural" are found in the science education literature without the author defining what culture means in the context of the work reported. An invocation of terms does not clarify the process of learning science. Our chapter seeks to introduce appropriate terms from cultural anthropology that help conceptualize cultural aspects of learning science.

An anthropological viewpoint for science education was proposed in 1981 by Maddock when he wrote, "science and science education are cultural enterprises which form a part of the wider cultural matrix of society and that educational considerations concerning science must be made in the light of this wider perspective" (p. 10). Anthropologist Geertz (1973) metaphorically characterized cultural enterprises when he suggested that people are animals suspended in a web of significance which they themselves have spun, and he wrote, "I take culture to be those webs, and the analysis of it is not an experimental science in search of law but an interpretative one in search of meaning" (p. 5). This chapter represents an interpretative way of thinking about students learning science. Because learning is about making meaning within a cultural milieu, we must ask ourselves such questions as: Within a cultural milieu of a particular student, what knowledge is important? What knowledge is meaningful? and How does scientific knowledge relate to his/her cultural milieu?

Since Maddock (1981) articulated his anthropological perspective for science education, a body of literature on multicultural and cross-cultural science education has accumulated (for example, Allen, 1995; Atwater and Riley, 1993; Cobern, in press; George and Glasgow, 1988; Hodson, 1993; Jegede and Okebukola, 1990, 1991; Knamiller, 1984; Krugly-Smolska, 1995; Lawrenz and Gray, 1995; Lewin, 1990; Ogawa, 1986; Ogunniyi et al., 1995; Pomeroy, 1992; Swift, 1992; Urevbu, 1987). Pomeroy (1994) synthesized this literature into nine research agendas, described later in this chapter. All these investigations dealt with students who studied in non-Western countries or in indigenous societies, or with students who comprised minority groups within Western countries, groups under represented in the professions of science and technology. In our chapter we broaden this anthropological perspective for science education in two ways: (1) by including Western students in industrialized countries in our cultural view of learning science (e.g., Cobern, Gibson, & Underwood, 1995), and (2) by recognizing that these students cross cultural borders from the worlds of their peers, community, and family, into the worlds of science and school science (e.g., Costa, 1995). We assume that typical science classroom events are cross-cultural events for many Western and non-Western students.

The purpose of this chapter is to discuss cultural aspects of learning science by sketching a cultural perspective for science education, by illustrating empirically how a student's culture can affect his/her learning science, and by identifying issues for research and teaching. Accordingly, the chapter is organized into several main sections: culture and science education, subcultures and students, views of nature and learning science, issues for research, and issues for teaching.

Culture and Science Education

In cultural anthropology, teaching science is viewed as cultural transmission (Spindler, 1987) and learning science as culture acquisition (Wolcott, 1991), where culture means "an ordered system of meaning and symbols, in terms of which social interaction takes place" (Geertz, 1973, p. 5). We talk about, for example, a Western culture or an Oriental culture because members of these groups share, in general, a system of meaning and symbols for the purpose of social interaction. We use Geertz's definition of culture in our chapter.

Other definitions of culture have guided research in science education; for example, Banks (1988), Bullivant (1981), Ingle and Turner (1981), Jordan (1985), Leavitt (1995), Phelan, Davidson and Cao (1991), Samovar, Porter and Jain (1981), and Tharp (1989). From these sources one could compose the following list of attributes of culture: communication (psycho and sociolinguistic), social structures (authority, participant interactions, etc.), skills (psycho-motor and cognitive), customs, norms, attitudes, values, beliefs, expectations, cognition, conventional actions, material artifacts, technological know-how, and worldview. In various studies reported in the literature, different attributes of culture have been selected to focus on a particular interest in multicultural or cross-cultural science education (Baker and Taylor, 1995; Barba, 1993; George, 1992; Jegede, 1995; Lee, Fradd and Sutman, 1995; MacIvor, 1995; McKinley et al., 1992; Rakow and Bermudez, 1993; Wilson, 1981). For instance, Maddock (1981, p. 20) listed "beliefs, attitudes, technologies, languages, leadership and authority structures;" Ogawa (1986) addressed a culture's view of humans, its view of nature, and its way of thinking; while Aikenhead (1996) conceptualized culture according to anthropologists Phelan et al. (1991) as the norms, values, beliefs, expectations, and conventional actions of a group.

Within every culture there exist subgroups that are commonly identified by race, language, ethnicity, gender, social class, occupation, religion, etc. A person can belong to several subgroups at the same time; for example, a Native American female middle-class research scientist or a Euro-American male working-class technician. Large numbers and many combinations of subgroups exist due to the associations that naturally form among people in society. In the context of science education, Furnham (1992) identified several powerful subgroups that influence the learning of science: the family, peers, the school, the mass media, and the physical, social, and economic environment. Each identifiable subgroup is composed of people who generally embrace a defining system of meaning and symbols, in terms of which social interaction takes place. In short, each subgroup shares a culture, which we designate as "subculture" to convey its identity with a subgroup. One can talk about, for example, the subculture of females, the subculture of our peers, the subculture of a particular science classroom, and the subculture of science.

Science itself is a subculture of Western or Euro-American culture (Dart, 1972; Horton, 1994; Ogunniyi, 1986; Pickering, 1992), and so "Western science" can also be called "subculture science." Scientists share a well defined system of meaning and symbols, in terms of which social interaction takes place. Because science tends to be a Western cultural icon of prestige, power, and progress (Adas, 1989), Western science can often permeate the culture of those who engage it with remarkable ease. Assimilation or acculturation can threaten non-Western cultures, thereby causing Western science to be seen as a hegemonic icon of cultural imperialism (Ermine, 1995; Maddock, 1981; Simonelli, 1994). Similarly but much more subtly, attempts to assimilate Western students—who identify with C. P. Snow's (1964) non-science culture—into the subculture of science can create alienation and an anti-science element in Western countries (Appleyard,1992; Holton, 1993).

Closely aligned with Western science is school science, whose main goal has been cultural transmission of the subculture of science (Cobern, 1991, ch. 5; Layton, Jenkins, Macgill and Davey, 1993; Maddock, 1981) and cultural transmission of the country's dominant culture (Krugly-Smolska, 1995; Stanley and Brickhouse, 1994).

Thus, the subculture of school science is comprised of a dynamic integration of at least two major cultural influences (Aikenhead, 1996; Apple, 1979; Fensham, 1992). Transmitting a scientific subculture to students can either be supportive or disruptive. If the subculture of science generally harmonizes with a student's everyday culture, science instruction will tend to support the student's view of the world, and the result is enculturation (Hawkins and Pea, 1987). When enculturation occurs, scientific thinking enhances a person's everyday thinking.

But if the subculture of science is generally at odds with a student's everyday world, as it is with most students (Costa, 1995; Ogawa, 1995), then science instruction will tend to disrupt the student's view of the world by forcing that student to abandon or marginalize his/her indigenous way of knowing and reconstruct in its place a new (scientific) way of knowing. The result is assimilation (Jegede, 1995; MacIvor, 1995) which has highly negative connotations as evidenced by such epitaphs as "educational hegemony" (Baker and Koolmatrie, 1994, p. 4), "cultural imperialism" (Battiste, 1986, p. 23), the "arrogance of ethnocentricity" (Maddock, 1981, p. 13), and "racist" (Hodson, 1993, p. 687). Students struggle to negotiate the cultural borders between their indigenous subcultures and the subculture of science. But in doing so students often come to reject important aspects of their own natal culture. For example, in a series of studies between 1972 and 1980, Maddock (1983) found that science education in Papua New Guinea had a significant alienating effect that separated students from their traditional culture, "the more formal schooling a person had received, the greater the alienation" (p. 32). When assimilation occurs, scientific thinking dominates a person's everyday thinking. Assimilation has caused oppression throughout the world and has disempowered whole groups of people (Ermine, 1995; Gallard, 1993; Hodson, 1993; Urevbu, 1987).

Although the cultural function of school science has traditionally been to enculturate or assimilate students into the subculture of science (AAAS, 1989; Aikenhead, 1996; Cobern, 1991, ch. 5), many students persistently and creatively resist assimilation (Driver, 1989; Hills, 1989; West and Pines, 1985), some by playing a type of school game that allows them to pass their science course without learning the content assumed by the teacher and community. The game can have explicit rules which Larson (1995) discovered as "Fatima's Rules," named after an articulate student in a high school chemistry class. Latour (1987) anticipated the phenomenon when he noted one of the cultural expectations of school science: "Most schooling is based on the ability to answer questions unrelated to any context outside of the school room" (p. 197). Fatima's Rules tell us how to do just that without understanding the subject matter meaningfully.

Conventional science education has produced three avenues for "learning" science: enculturation, assimilation, and Fatima's Rules. When we extend our cultural analysis of learning science to include cross-cultural learning, new avenues emerge: autonomous acculturation and "anthropological" learning (Aikenhead, 1996). Autonomous acculturation is a process of intercultural borrowing or adaptation in which one borrows or adapts attractive content or aspects of another culture and incorporates (assimilates) that content into one's indigenous (everyday) culture. Clear examples are documented in Haden’s (1973) use of traditional Ugandan iron smelting procedures as a basis for secondary school chemistry lessons and George's (1995) case study of a Trinidadian woman who combined aspects of Western medicine with her indigenous folk medicine. A paradigm of educational practice is found in Snively's (1990) case study of a First Nations (Native American) boy in grade 6 studying the seashore. The phrase "autonomous acculturation" attempts to avoid the negative connotations associated with acculturation and assimilation (described above).

But autonomous acculturation is not the only process that nurtures learning. Students do not need to modify features of their indigenous culture to understand the subculture of science (Solomon, 1987). In other words, the conceptual modification associated with autonomous acculturation is set aside in favour of conceptual proliferation dictated by specific social or practical contexts (Dart and Pradham, 1967; Driver, Asoko, Leach, Mortimer, and Scott, 1994). By analogy, cultural anthropologists do not need to accept the cultural ways of their "subjects" in order to learn and engage in some of those ways (Medvitz, 1985; Traweek, 1992). A different type of learning, one called "anthropological" learning of science (Aikenhead, 1996), puts students in a position not unlike an anthropologist. "Anthropological" learning is associated with students who enjoy and are capable of constructing meaning out of the "foreign" subculture of science, but who do not assimilate or acculturate science's cultural baggage. Somehow they easily negotiate the transitions between their everyday worlds and the subculture of science.

Cultural transitions are endemic to cross-cultural learning. Inspired by Giroux's (1992) Border Crossings, Pomeroy (1994, p. 50) suggested that Western teachers and their non-Western students should become "cultural border crossers." Aikenhead (1996) applied this idea to Western students studying science, and described students' classroom experiences in terms of students crossing cultural borders from the subcultures of their peers and family into the subcultures of science and school science. Border crossing, therefore, becomes a crucial cultural aspect of learning science.

Subcultures and Students

Only a few researchers have studied the phenomenon of individuals moving back and forth from their indigenous subcultures to the subculture of science. Medvitz (1985) documented cases of Nigerian scientists who moved effortlessly between the subcultures of a scientific laboratory and their tribal village, even when the scientists recognized the contradictions between the two. Similar results were found for some high school graduates in a rural Melanesian culture in the South Pacific (Waldrip and Taylor, 1994). Jegede's (1995) collateral learning theory explains how students might benefit from being guided through a progression of types of collateral learning, a progression that appears to move from "anthropological" learning to autonomous acculturation. Peat (1994) provides a personal account of his transitions from a theoretical physics worldview into a Native American worldview. The capacity and motivation to participate in diverse subcultures are well known human phenomena.

Capacities and motivations to participate in other subcultures are not shared equally among all humans, as American anthropologists Phelan et al. (1991) discovered when they investigated students' movement (cultural border crossings) between the worlds of students' families, peers, schools, and classrooms. School success largely depends on how well a student learns to negotiate the boundaries separating these cultural worlds. Phelan et al. identified four patterns to the cultural border crossings between these multiple worlds: congruent worlds support smooth transitions, different worlds require transitions to be managed, diverse worlds lead to hazardous transitions, and highly discordant worlds cause students to resist transitions which therefore become virtually impossible.

Costa (1995) provides a link between Phelan et al.'s anthropological study of schools and the specific issues faced by science educators. Based on the words and actions of 43 high school science students enrolled in two Californian schools with diverse student populations, Costa concluded:

> Although there was great variety in students' descriptions of their worlds and the world of science, there were also distinctive patterns among the relationships between students' worlds of family and friends and their success in school and in science classrooms. (p. 316)

These patterns in the ease with which students move into the subculture of science were described in terms of familiar student characteristics and were clustered into five categories (summarized here in a context of border crossing): (1) "Potential Scientists" cross borders into school science so smoothly and naturally that the borders appear invisible; (2) "Other Smart Kids" manage their border crossing so well that few express any sense of science being a foreign subculture; (3) " I Don't Know' Students" confront hazardous border crossings but learn to cope and survive; (4) "Outsiders" tend to be alienated from school itself and so border crossing into school science is virtually impossible; and (5) "Inside Outsiders" find border crossing into the subculture of school to be almost impossible because of overt discrimination at the school level, even though the students possessed an intense curiosity about the natural world.

We have summarized several theoretical frameworks that provide a coherent cultural perspective on learning science. The perspective is illustrated in the next section by research investigating one attribute of culture, one's view of nature.

Views of Nature and Learning Science

Based on a decade of research, Jegede (1995) described five major cultural inhibitions to learning science in Africa (authoritarianism, goal structure, traditional worldview, societal expectations, and sacredness of science). A traditional worldview "holds the notion that supernatural forces have significant roles to play in daily occurrences" (p. 114). Such a view of nature makes it difficult for African students to cross the cultural border into the mechanistic reductionistic rationalism of Western science to construct meaning of natural phenomena. Native Americans traditionally analyze nature rationally and empirically, but their rationalism and empiricism are guided by spirituality, holism, mystery, survival, etc. (Ermine, 1995; Knudtson and Suzuki, 1992; Peat, 1994; Pomeroy, 1994; Simonelli, 1994). This disparity between Native American cultures and Western science creates "hazardous" or "impossible" (Phelan et al., 1991) border crossings for Native American students (MacIvor, 1995).

A Japanese cultural perspective illustrates potential difficulties for Japanese students who also hold a view of nature at odds with the Western scientific view (Kawasaki, 1990; Ogawa, 1986). Their sense of harmony with nature contrasts with Western scientific images of power and dominion over nature. The crassness of our scientific conceptualization of nature can be significantly offensive to Japanese students, and can inhibit border crossings.

Only recently has interpretive research focused on American students' conceptualizations of nature. If one grants the important tenet of a cultural perspective that all ideas including scientific ones are expressed within a cultural milieu, then one must ask questions such as how do the cultural ideas of the science teacher compare with the ideas of students in the classroom. Cobern et al. (1995) examined this question by analyzing the transcripts of interviews with students and their science teacher. The interviews simulated naturalistic conversation on the topic of <u>nature</u> by inviting informants to respond at will to a series of elicitation devices. Specifically, the research addressed the questions:

> To what extent do students enjoin scientific knowledge vis-à-vis other domains of knowledge in a discussion about nature? 1) Given, that science is unarguably relevant to the topic of nature and ought easily to be brought to bear. 2) Yet, nature is a topic that most people do not explicitly associate with science. Moreover, what are the concepts that appear to have scope and force in the students' thinking about this topic? (Cobern et al., 1995, p. 3)

The rationale here is that it is one thing to be able to give (or not give) correct answers on a science exam; it is quite another thing to use appropriate scientific knowledge in the absence of any kind of science prompt or cue. For instance, we would expect (as was found in the study described below) that science will hold meaning for a science teacher so strongly that science knowledge will come readily to mind (without prompting) when the teacher talks about nature. Similar expectations are reasonable for Costa's (1995) Potential Scientists. But, what about the students who are not potential scientists? The following sub sections introduce a science teacher and four students from the Cobern et al. (1995) and Costa (1995) research to illustrate the different patterns for border crossings.

<u>The View of a Science Teacher</u>

Mr. Hess is a science teacher and without prompting he immediately began to discuss nature in terms of scientific processes and concepts. Note the emphasized words.

> <u>Nature is orderly and understandable</u>. The tides and the rotation of the earth... That the planets and the stars are <u>governed by physical forces</u> and any deviations are simply because we have not yet discovered the other part of nature's orderliness... As a science teacher I feel that <u>with enough scientific knowledge all things are understandable</u>... I think that the more we understand about matter itself, and the more we know about how to make things,

the more predictable nature will be. Scientific or reductionistic thinking is very powerful. I feel that once we know enough about the minutia of the world, breaking it down by using the scientific method, scientists tearing it apart and analyzing the parts of nature and seeing how they interact, that we will be able to predict just about anything about nature. (Mr. Hess: WWC.n3, Narrative in Cobern, 1994, p. 18, emphasis added)

Mr. Hess' conceptualization of nature is essentially monothematic. His comments about nature are focused and have an explicitly scientific emphasis.

The Views of a Potential Scientist

Now compare Mr. Hess with a student, Howard, who considers himself to be very scientific. Figure 1 shows Howard' conceptualization of nature. Note the dark encircling line that graphically illustrates how central and dominant scientific knowledge is to his thinking about nature.

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Insert Figure 1 about here.
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As with Mr. Hess, a significant portion of Howard's thought about nature is scientific. Moreover, his other thoughts about curiosity about nature and resources in nature are both connected to his scientific thoughts about nature. As with Mr. Hess, Howard's comments are focused and explicit, and very much about science. Note the emphasized words.

> I think that nature is understandable. We don't understand all that there is to nature at this moment but we will understand more and more as time goes on. Most things about nature are somewhat orderly and/or have a pattern to them. Because of this the study of science allows us to explain what is going on in nature. The orderliness also lets us predict many things that are going to happen in nature, like the weather, for example. Sometimes nature seems chaotic but that is mostly because our knowledge is incomplete and therefore our understanding is limited... I think that most things in nature can be explained by science. Matter, both living and non living, and what it does follows basic laws. Things like the law of conservation of mass, reproductive cycles of plants and animals, convection currents and ecosystems can be understood if the laws of science are studied. (Howard: ATG.n3, Narrative in Cobern et al., 1995, p. 17, emphasis added)

The point of these examples is that they show a science teacher and student who are quite similar in thought. Though this represents only a small window into the lives of these two people, the indication is that the cultural border crossing for this student in this teacher's science class will likely be smooth.

Other Smart Kids

Consider a second pattern for border crossings. This is the pattern followed by students who manage the border crossings between cultural worlds of family, peers or community, and school, even though the world of science is primarily irrelevant to the students' personal worlds. Ann was such a student in Mr. Hess' science class. She is bright and also has been a good science student.

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Insert Figure 2 about here.

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Figure 2 is an interpretive view of Ann's conceptualization of nature. Note that the encircled science and knowledge area is a much smaller fraction of her total map than this area was for Howard. At the center of the map, one can see that Ann conceives of nature as something enduring and inclusive. Her sense of inclusiveness draws together knowledge of nature, the natural beauty and purity of nature, nature as God's creation, and the conservation of nature. Ann clearly speaks about nature as something one can know about through science.

> Nature is knowable... We can learn to understand many things about nature through personal experience, school and science. Science itself provides us with technology which in turn increases our scientific knowledge. Technology helps provide us with many wants which, of course, increases our pleasure. It also uses resources. (Ann: ATG.n6, Narrative in Cobern et al., 1995, p. 24)

This appreciation of science, however, is not where her narrative begins. Note the emphasized words.

> To me, nature is beautiful and pure because it is God's creation. Nature provides both aesthetic and emotional pleasure and I need it for self renewal. I like to go where you can't see any influence by man. When I'm out in nature I feel calm and peaceful. It is a spiritual feeling and it helps me understand myself... This leads me to ask questions that I'd like to find answers to. The pleasure I get from nature is enhanced by the mysteries I see in it. (Ann: ATG.n6, Narrative in Cobern et al., 1995, p. 24, emphasis added)

Ann's conceptualization of the natural world has significant aesthetic and religious elements. Moreover, when Ann was asked about Mr. Hess' science class, she made it quite clear that the class was not about nature. Nature in her view is something friendly that you can joyously be part of. What impressed her about the physical science class was the teacher's warning about the dangerous chemicals they would be handling during the course. It was no surprise then to hear from Ann that she was not particularly fond of the class and would prefer to be taking something else. One might be tempted to dismiss this young lady's aversion to dangerous chemicals as temporary and solely a result of insufficient conceptual understanding. She does not yet understand that there is danger in nature, but with proper understanding and technique this danger need not be viewed as a threat. From a cultural perspective, however, Ann's aversion can be seen as rooted in an aesthetic sense of nature that has more scope and force than the science teacher's assurances and explanations. Thus, for example, conceptual change research might well lead to instructional approaches that would help this young lady do better in her physical science course; but it is difficult to see how the improvement could be anything like what science education aspires to achieve (AAAS, 1989), given the student's distaste for the context given to the concepts being taught.

It is critical that one note that Ann's problem is not with science but with the context her science teacher chose to give science. Figure 2 is not a map dominated by canonical scientific thinking as is the map of Howard. Her map represents a synoptic view of nature where several themes (not one) or large concepts have scope and force. Ann has a sense of wonder about nature that is grounded in her fundamental view of nature as beautiful and pure. This sense of wonder leads her to ask questions about nature and thus adds to her understanding of nature, including scientific and technological understanding. During the interview Ann volunteered accurate information from science and technology as part of her discussion of what one can know about nature. She is interested in scientific concepts but her foundation, the cultural frame that gives meaning to that interest, is in conflict with the classroom frame provided by the teacher.

"I Don't Know" Students

The third border crossing pattern is followed by students whose cultural worlds show even greater disparity making border crossings hazardous at best. A student from Costa’s (1992, 1995) research provides a good example. Rattuang attends an American high school. He “spends his free time singing and playing rhythm guitar for a heavy metal band, ‘Rattfinks,’ often writing his own music... [Rattuang is] a Hawaiian with long, thick black hair, neatly groomed, usually wears black leather pants and jacket, with boots and a dark t-shirt” (Costa, 1992, p. 26). When Rattuang graduates he aspires to be a professional recording artist with his band. About science he says:

> If you want to learn science, you should be in a class. Society doesn’t really need it. Really, its up to you. But, its kind of good, ‘cause you learn things. At least you know some knowledge about science. You don’t want to be a dummy in school” (Costa 1995, p. 322, emphasis added).

Rattuang is clearly ambiguous about science. He says science is good to know about but it is something society does not really need. It is as if he were saying science is fine if you like it but as for me I have other interests like my music. One would not expect to find Rattuang in science classes beyond the school’s minimum requirements. His world is oriented to the culture of his peers.

Students Who are Outsiders

The fourth type of cultural border crossing identified by Phelan et al. (1991) and Costa (1995) is impenetrable or insurmountable, due to the fact that students are alienated from school and science. Art, a ninth grader from Cobern et al. (1995), is a good example. Art has been in and out of high school largely depending on his own whims. He is a nice person but one very much opposed to the organized structures of society. He has strong inclinations for the aesthetic and mystical aspects of life. Figure 3 shows his conceptualization of nature.

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Insert Figure 3 about here.

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One immediately sees that the fraction of Art's map given to science is very small. His concept of knowing about nature has little to do with canonical scientific views. He sees some value in science related knowledge such as the study of origins but he also links scientific study with pollution and exploitation. Moreover, he strongly links knowledge of nature with his mystical, religious views of nature. Again, compare Art's comments below with the comments of Mr. Hess, paying particular attention to the emphasized words:

> No matter what we humans do we're still natural and we're part of the natural world." I believe that <u>man does not stand separate from nature but is part of it</u>, including space, planets, oceans, living organisms and non-living things... <u>Man has changed the natural world by exploiting its resources and polluting the environment</u>... Nature is a source of knowledge... At the present time our knowledge of the natural world is limited. Many things that we perceive to be complex and confusing because we don't understand them are actually quite simple and orderly. The construction of a spider web, for example, is quite a complicated operation to us but <u>to the spider building the web it is a simple procedure</u>. As we gain in understanding of the diversity and power of nature, we will understand the perfect balance of everything in nature. We will also begin to understand our place within nature. <u>It is more important to have a spiritual understanding of nature than just scientific knowledge. That understanding can't be gained from school. You have to spend time in nature and learn to feel it</u>. Then you will understand it. There is a spiritual aspect to nature to many people... Animals are very important to me, <u>I can feel things through animals. The American Indian culture has the kind of understanding for nature that encourages preservation rather than destruction</u>. Scientists, also, are people that understand the need to preserve and protect... <u>Unfortunately scientists and scientific knowledge are also increasing our tendency to pollute, destroy and clutter up the earth and space. They are trying to destroy it and study it at the same time</u>. (Art: ATG.n4, Narrative in Cobern et al., 1995, p. 19-20, emphasis added)

This is a lengthy paragraph but it is an important one because it clearly shows the student's alienation from science. It is all the more interesting because the student is an American who grew up in what is considered a highly Western scientific and technological society. Yet, there is still the alienation at the root of which is a serious cultural mismatch, not unlike the mismatch experienced by cultural minorities. Art is a true modern day heretic who resolutely refuses to accept the meaningfulness of canonical science.

Cultural Research in Science Education

The preceding cases exemplify four patterns of cultural border crossings experienced by students studying school science. The crossings are easiest when the cultures of family, peer or community, school and school science are congruent. The greater the disparities, the greater the border crossing hazards; and the chances for successful student achievement in science are reduced. When struggling students do succeed, the chances of natal cultural alienation are increased.

Cultural border crossing implies multicultural or cross-cultural science education, for which there is a rich literature. Based on a review of this literature, Pomeroy (1994) abstracted nine distinct research agendas: (1) science and engineering career support projects, (2) an indigenous social issues context for science content, (3) culturally sensitive instruction strategies, (4) historical non-Western role models, (5) demystifying stereotype images of science, (6) science communication for language minorities, (7) indigenous content for science to explain, (8) compare and bridge students' worldviews and the worldview of science, and (9) explore the content and epistemology of Western and non-Western knowledge of the physical world. Pomeroy (1994, p. 68) pointed out:

> The nine agendas... generally move from a more static multicultural view, which maintains the structure of the institutions of science and culture as they are, to a more dynamic inter, or cross-cultural view which requires deconstruction of the view of Western science as universal with a new construction of and, most important, access to alternative views and methods.

Agendas one to seven lead to the assimilation of students into Western science, while agendas eight and nine challenge us to conceive of alternatives to assimilation (and to Fatima's rules). Two were described earlier in the chapter, autonomous acculturation and "anthropological" instruction.

Obviously more research is needed to understand the diverse experiences of students managing, coping with, or being repelled by, their border crossings into the subculture of science or school science. Pomeroy's (1994) nine research agendas provide a framework for defining many research programs. She gives high priority to item nine because she believes that cross-cultural science education has the greatest potential to engage students in a way that has scope and force for them. For example, how can teachers recognize cultural aspects to their students learning science? How can we train science teachers to be cultural brokers? What happens when student cultures, a teacher's culture, and the culture of science, meet face to face in the classroom? What are the political ramifications to a cross-cultural science curriculum characterized by Pomeroy's ninth research agenda? A plethora of new and highly significant research ideas emerge, a phenomenon associated with any new paradigm of research; in this case a paradigm called cultural aspects of learning science.

Implications for Science Teaching

Science is a system of meaning and symbols, with which social interaction takes place. Because science has great explanatory power for natural phenomena, it is invasive of other systems of meaning. The question to educators is: To what extent is science's system of meaning compatible with, or attractive to, students' culturally based systems of meanings? Though there is good evidence that cultural compatibility improves education (Tharp, 1989), the honest and unfortunate response is that all to often the extent of compatibility is limited. How can we deal with students who traditionally have been the target of scientific assimilation? Students need a contextualized approach to teaching science that draws upon the cultural worlds of students and makes sense in those worlds. We need to develop teaching methods that engender autonomous acculturation and/or "anthropological" instruction.

O'Loughlin (1992, p. 791) proposed an ideal goal that students "master and critique scientific ways of knowing without, in the process, sacrificing their own personally and culturally constructed ways of knowing." The capacity and motivation to master and critique scientific ways of knowing seem to depend on the ease with which students cross the cultural borders between their everyday worlds and the world of science. One implication for teaching, therefore, is to develop instructional methods and materials that: (1) make border crossings explicit for students; (2) facilitate these border crossings; (3) promote discourse so that students, not just the teacher, are talking science; (4) substantiate and build on the validity of students' personally and culturally constructed ways of knowing; and (5) teach the knowledge, skills, and values of Western science in the context of its societal roles (social, political, economic, etc.). This implication for teaching strengthens item nine in Pomeroy's (1994) review of cross-cultural research agendas, and harmonizes with curriculum proposals for Native Americans (Nelson-Barber and Estrin, 1995) and for students in developing countries (Jegede, 1995; Medvitz, 1985; Yoong, 1986).

Aikenhead (1996) proposed a cross-cultural STS science and technology curriculum for Western students, based on the idea of border crossings between students' indigenous cultures and the subculture of science. This cultural perspective for science education requires different roles for teachers and students. The metaphor "teacher as culture broker" was used by Stairs (1995) to analyze the teacher's role in resolving cultural conflicts that arise in cross-cultural education. In Aikenhead's proposal, students are "tourists" in a foreign culture and depend on teachers to be "tour guides" or "travel agents" who take (or send) students across cultural borders into Western science and direct the use of science and technology in the context of the students' everyday worlds. Some students need more help (or more independence) than others when they cross into the subculture of science. Snively (1990) describes how a teacher became such a travel agent for both Aboriginal and non-Aboriginal students in her classroom.

Border crossings within a cross-cultural STS science curriculum may be facilitated by studying the subcultures of students' everyday worlds (peers or communities, family, etc.), by contrasting those subcultures with a critical analysis of the subculture of science, and by consciously moving back and forth between the everyday world and the science world, switching language conventions explicitly, switching conceptualizations explicitly, switching values explicitly, switching epistemologies explicitly, but never requiring students to adopt a scientific way of knowing as their personal way (Aikenhead, 1996). This "no assimilation" rule, however, does not preclude teachers from capturing a student's interest and curiosity in science and then doing a good job at a rite of passage into the subculture of science.

Cultural aspects of learning science means that learning results from the organic interaction among: (1) the personal orientations of a student; (2) the subcultures of a student's family, peers, community, tribe, school, media, etc; (3) the culture of his or her country or nation; and (4) the subcultures of science and school science. Much more research and development is needed to understand this organic interaction more clearly and to provide appropriate learning experiences for all students.

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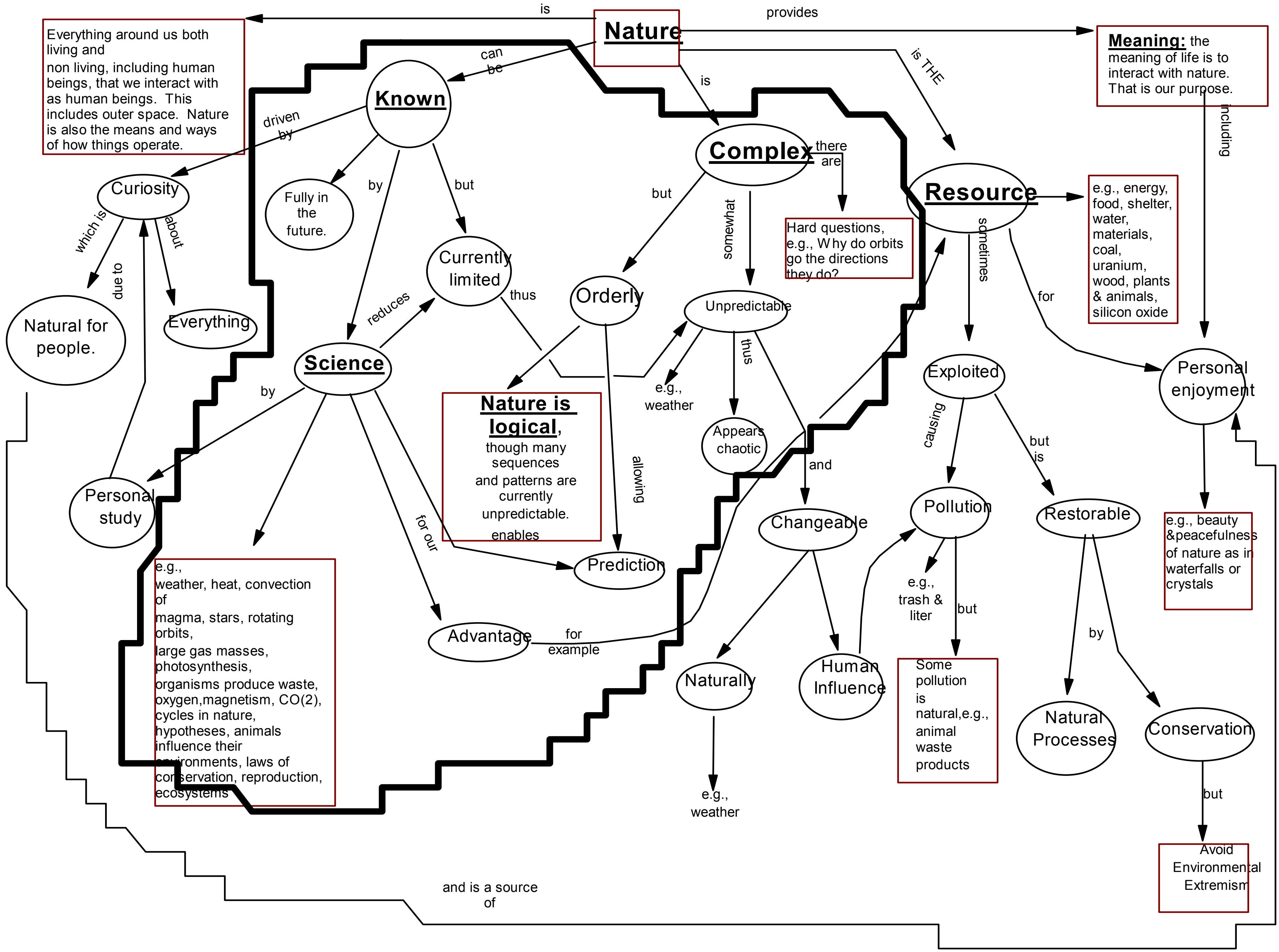
Nature
is
Everything around us both living and non living, including human beings, that we interact with as human beings. This includes outer space. Nature is also the means and ways of how things operate.
provides
Meaning: the meaning of life is to interact with nature. That is our purpose.
including
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Curiosity
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Natural for people.
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by
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Currently limited
reduces
Science
by
Personal study
e.g., weather, heat, convection of magma, stars, rotating orbits, large gas masses, photosynthesis, organisms produce waste, oxygen,magnetism, CO(2), cycles in nature, hypotheses, animals influence their environments, laws of conservation, reproduction, ecosystems
for our
Advantage
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enables
Prediction
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Complex
there are
Hard questions, e.g., Why do orbits go the directions they do?
but
Orderly
Nature is logical, though many sequences and patterns are currently unpredictable.
allowing
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Unpredictable
e.g., weather
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Appears chaotic
and
Changeable
Naturally
e.g., weather
Human Influence
is THE
Resource
e.g., energy, food, shelter, water, materials, coal, uranium, wood, plants & animals, silicon oxide
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Exploited
causing
Pollution
e.g., trash & liter
but
Some pollution is natural,e.g., animal waste products
but is
Restorable
by
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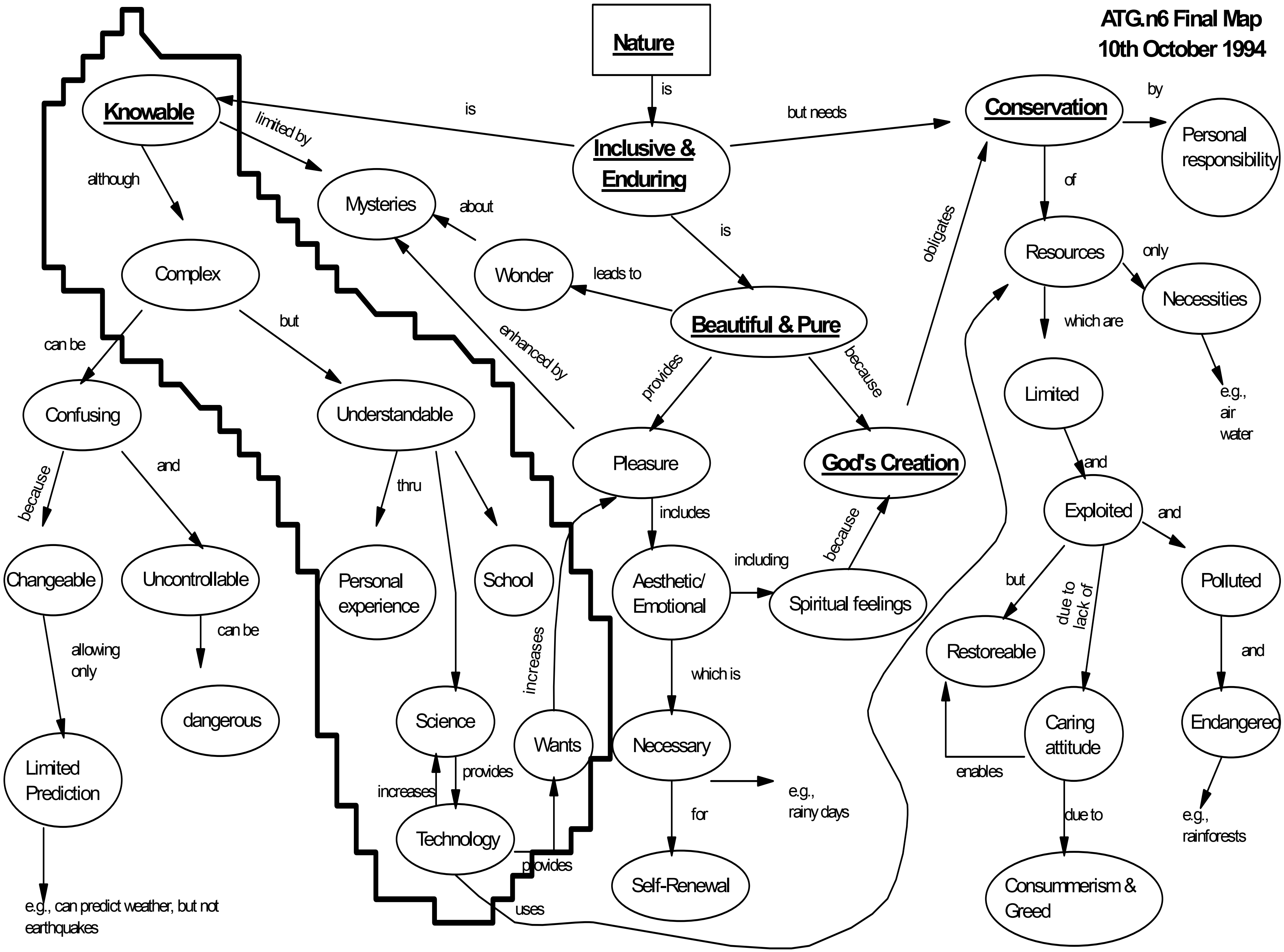
Conservation
but
Avoid Environmental Extremism
for
Personal enjoyment
e.g., beauty &peacefulness of nature as in waterfalls or crystals
and is a source of


ATG.n6 Final Map
10th October 1994
Nature
is
Inclusive & Enduring
is
Knowable
limited by
Mysteries
although
Complex
can be
Confusing
but
Understandable
because
Changeable
and
Uncontrollable
allowing only
Limited Prediction
e.g., can predict weather, but not earthquakes
can be
dangerous
thru
Personal experience
School
Science
provides
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increases
provides
Wants
increases
uses
about
Wonder
leads to
Beautiful & Pure
enhanced by
provides
Pleasure
includes
Aesthetic/ Emotional
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Spiritual feelings
because
God's Creation
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Necessary
e.g., rainy days
for
Self-Renewal
but needs
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Limited
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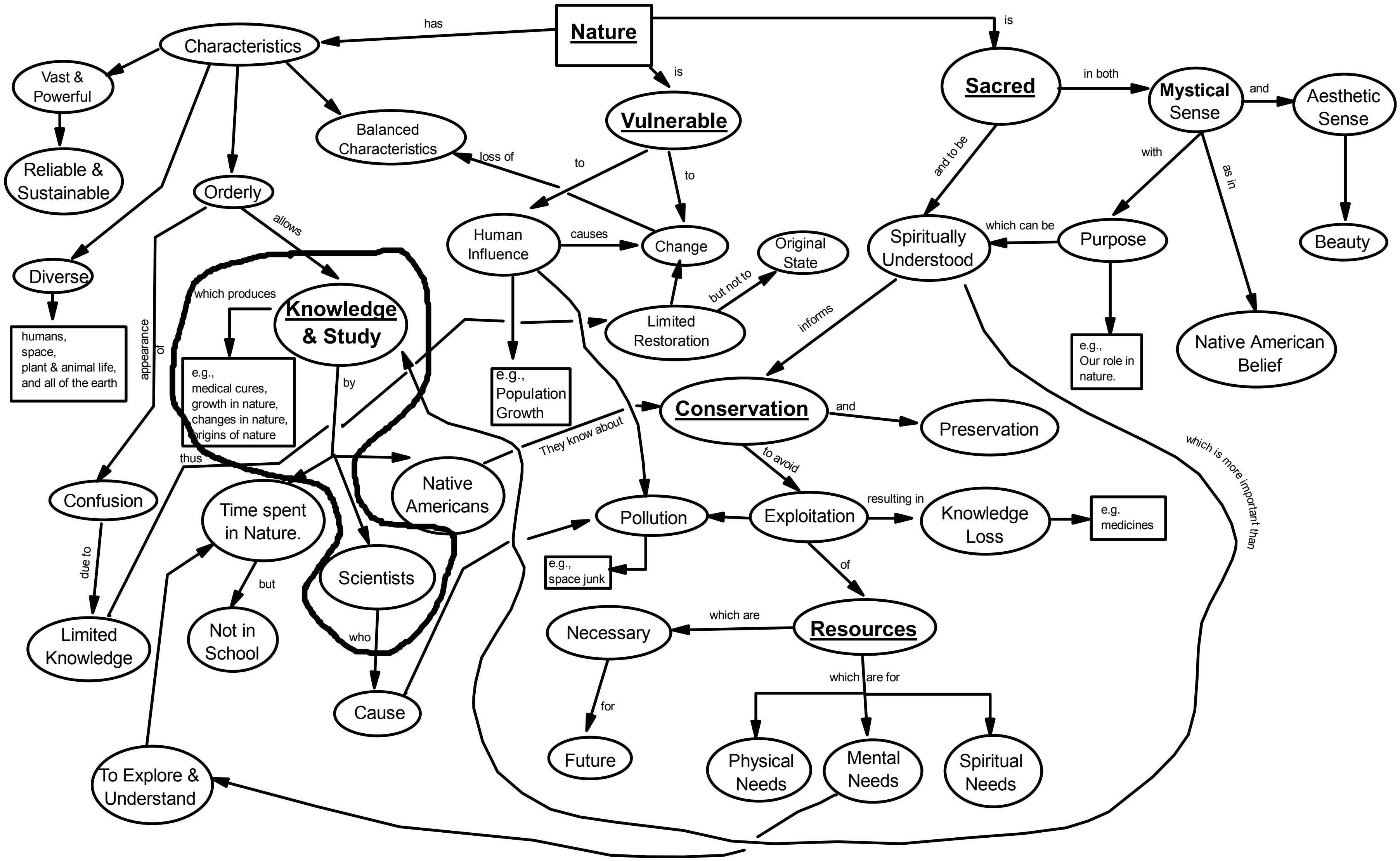
Consummerism & Greed


Nature
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Characteristics
Vast & Powerful
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Diverse
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Limited Restoration
e.g., Population Growth
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and
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to avoid
Pollution
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Exploitation
resulting in
Knowledge Loss
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and
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