# Ethnocomputing

## A Multicultural View on Computer Science

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# Abstract

Despite all the hype around the dream of a global society, the borders of the world have not disappeared. Rather, they have sharpened and changed their form from geographical to digital frontiers. The prevailing westernness of Computer Science is a major problem with the Computer Science education in developing countries. The students not only face a new subject, but also a fundamentally different philosophy and problem solving methods. In this thesis, I shall present a new member to the family of ethnosciences: ethnocomputing. Ethnocomputing challenges the prevailing way of thinking that in order to keep up with the West, other cultures have to adapt to the western ways of thinking. Relying on constructivist theories, I argue that the universal theories of computing take different forms in different cultures, and that the European view on abstract ideas of computing is culturally bound, too. Studying ethnocomputing — i.e. the computational ideas within a culture — may lead to new findings that can be used in both developing the western view of Computer Science, and improving Computer Science education in non-western cultures.

***ACM-classes*** (ACM Computing Classification System, 1998 version): K.3.2, K.4.0, K.4.1

# Foreword

Thanks to Piet Kommers and Erkki Sutinen, the initiators of the idea, without whom this thesis would never have been started, even less completed.

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# Contents

# 1 Introduction

Throughout the history, people have explored other cultures and shared the knowledge often hidden behind traditions, practices and customs. This exchange of cultural capital has enriched and equalized the cultures, including the western culture. For example, the Greek foundations of European civilization are themselves founded upon Black Egyptian civilization (Powell & Frankenstein, 1997). Yet nowadays there exists a widespread consensus of the supremacy of western logic. In Computer Science, like in many other academic disciplines, most of the literature, problem solving methods, and teaching material are based on the traditions of science written by white western males. The examples used in teaching almost without exception derive from North American and European cultures, and the problem solving methods rely on the European view on Mathematics. This causes problems in Computer Science education in non-western cultures. If it can be shown that culture and society considerably affect the way we understand the concepts of Computer Science, it means that we are currently leaving out a significant amount of knowledge in its cultural forms.

The Internet enables the expanding familiarity with the rich diversity of the humanity. Though many people believe that this possibility will yield a pan-human empathy and render the borders and nations into obsolete artifacts of a less-informed age, there is little in human history that supports this (Townsend & Bennett, 2001). Instead of blurring the borders, the march of information society has actually sharpened them (Heikka, 2002). Continents and cities have only been reorganized on the digital basis. Fighting the *digital divide*[1] is for the good of both the developed and developing countries (ibid.). With its limited markets and limited intellectual and material potential, the West will soon come to a dead-end in developing technology (ibid.). The progress of digital development in developing countries could open new economic markets for both sides, benefiting both sides.

In this thesis, I shall present arguments to justify the need for a field of research that studies the phenomena and applications of computing in different cultural settings. This kind of cultural perspective in the problem solving methods, conceptual cate-

[1] In this thesis, I use the term *digital divide* as the division of people to those who create digital technology, and to those who use it. This definition is important, for the users are totally dependent on the creators' decisions on how to govern the technology, and are thus at the mercy of them. In my opinion, the digital divide can be seen also within nations, not only between them.

gories, structures and models used in representing data or other computational practices is from now on referred to as *ethnocomputing*. My interest is not historical by nature — I am not interested in how contemporary science has been established. Rather, I will try to present how my view on understanding the foundations of Computer Science differs from the traditional one that considers those foundations as constant and applicable everywhere as such.

My intention is to make this thesis readable for as many people as possible independently of discipline, so I have tried to elucidate the text with a number of notes and footnotes. Some familiarity with Computer Science as a discipline as well as with the basic paradigms of scientific research is still required from the reader, since I will not have a chance to analyze those matters very deeply. The reader should also sustain criticality towards my attempt to synthesize or move between paradigms. I have chosen this approach due to the fact that none of the basic paradigms are good as such, and so I have decided to use suitable points from a few of them. I shall leave the paradigmatic discussion to be examined later.

This thesis takes three different perspectives in ethnocomputing. First, ethnocomputing is seen from a constructivist angle, second, from a multiculturalist educational point of view, and third, as a member of the family of ethnosciences. The second chapter, *The Social Construction of Reality*, deals with the theoretical framework for this study, and outlines how the constructivist paradigm has been used in this thesis. The works of Peter Berger and Thomas Luckmann ( *The Social Construction of Reality*), Thomas Kuhn (*The Structure of Scientific Revolutions*), and Lev Vygotsky (*Thought and Language*) are emphasized in chapter two.

The third chapter, *Ethnocomputing in Relation to Culturally Sensitive Learning*, introduces some background for multicultural education, followed with an analysis of different views towards it. James A. Banks' views are brought out frequently, but Banks is indeed regularly quoted in many of the studies on multicultural education. In the third chapter I shall try to address the issue of ethnically fair education in Computer Science.

Chapter four, *Ethnosciences*, discusses the background of ethnosciences and criticism towards them, and explains the choices that I have made in defining ethnocomputing. The works of Ubiratan D'Ambrosio and Marcia and Robert Ascher have influenced the fourth chapter the most. Since ultimately my aspiration is to legitimate ethnocomputing as a member of the family of ethnosciences, I will try to set up a framework for my future work on the subject.

The fifth chapter, *Ethnocomputing*, binds the topics of the earlier chapters together with the contemporary view on computing, claiming that there is a need for a cultural view on computational concepts. In chapter five, I also present my view on the relationship between universal and particular computing and define how ethnocomputing can be seen as local variations of a universal theory. Finally, in chapter five, I present a few examples that I regard as ethnocomputing. When justifying the need for a culturally bound view on computing, my sources vary from classics (Kuhn, 1962; Berger & Luckmann, 1966) to popular articles (Heikka, 2002), from theory of computing (Lewis & Papadimitriou, 1998) to multicultural education (Banks, 1999), and from compromises (ACM, 2001) to extreme radicalism (Hodgkin, 1976). I do not think this variety poses a problem, since I see this thesis as a ground survey for my future work, and it would be shortsighted to restrict the view too much at this point.

I shall argue that recognizing cultural differences in Computer Science would reveal new perspectives on the scientific questions. Research of culturally bound computational ideas could address the problem of Computer Science education in non-western countries by bringing the local cultural aspects into teaching. The same local views could be used also in global collaboration, possibly widening other views on Computer Science, too. This kind of a new view is needed in Computer Science, not only because Computer Science is a major factor in broadening the digital divide, and an ethnically fairer view could help to bridge the gap, but also because the new view could help in promoting novel intellectual, innovative ideas in Computer Science, deepening and widening also the western understanding of the theory of computing.

# 2 The Social Construction of Reality

My view on the epistemology of computing owes greatly to Peter Berger and Thomas Luckmann's (1966) work with the sociology of knowledge. Throughout this thesis, I shall try to bring out the dynamics that arises from the *dialectic*[2] nature Berger and Luckmann's theory depicts. According to this theory, society is seen as a human product, and people are correspondingly a product of a society. Though I will try to avoid using ambiguous paradigmatic terminology[3] , in this chapter it cannot fully be avoided. This chapter introduces constructivism, the sociology of knowledge and the theory of the social construction of reality, and their view on how language and culture shape our way of parsing information, understanding the world, comprehending information et cetera. This theoretical framework is used later in this thesis to describe the ways society and culture determines how Computer Science is interpreted.

## 2.1 Constructivism

From the dawn of the history of western philosophy, the nature of knowledge has been debated. According to Esa Saarinen (1985), Plato divided the world into two realities apart from each other: one phenomenal and one absolute and eternal. Plato's idea was that the phenomenal forms are only imperfect reflections of the eternal and absolute ones (ibid.). Aristotle agreed with this, but claimed that the individuals reach the universals in particulars, and thus he concentrated on processes rather than ideas (ibid.). Norman Denzin and Yvonna Lincoln (1994) write that during centuries, the answers to questions such as *"what is real?"*, *"what is the relationship between the inquirer and the known?"*, and *"how do we gain knowledge of the world?"* have developed into differing schools that underlie the research of the scientists. These are called *ontological*, *epistemological*, and *methodological* questions, respectively (ibid.). The choice of what school to follow leads to a choice of a set of values in science also. "There is

[2]Rather than relying on Hegel's idea of dialectics as thesis-antithesis-synthesis, in this thesis dialectic process is understood as a course of change through the conflict of opposing forces, which is closer to the critical-Marxian idea than Hegel's theory (Guba & Lincoln, 1994).

[3]For example, Denzin and Lincoln (1994), Schwandt (1994) and Heiskala (2000) all agree that the terminology in some sociological fields has not yet been fully established. The terrain of constructivist approaches is marked by multiple uses of the term *constructivism* (Schwandt, 1994). Also the term *social constructivism* seems almost to have a life of its own (Heiskala, 2000).

no value-free science", Denzin and Lincoln state. The claim of many natural science researchers that their science is value-free is in itself a value statement — a *positivist*[4] one, to be exact.

Thomas Schwandt (1994) presents the constructivist paradigm explaining that constructivists believe that to understand this "world of meaning" one must interpret it. He continues that constructivists see that an inquirer of the phenomena of the world must elucidate the process of meaning construction. Moreover, the inquirer has to clarify what meanings are embodied in the language and actions of social actors, and how they are embodied. Constructivists, Schwandt claims, are deeply committed to the view according to which what we take to be objective knowledge and truth is a result of perspective. They are principally concerned with matters of knowing and being, not methodology *per se* — in constructivists' opinion, knowledge and truth are created, not discovered by the mind (ibid.). Simplified, the observer actually creates the knowledge.

The constructivist view on the world is *pluralistic* in the sense that reality is expressible with a variety of symbol and language systems, and *plastic* in the sense that reality is stretched and shaped to fit purposeful acts of intentional human agents (ibid.). In other words, constructivists believe that reality manifests to people in different forms that are constructed to meet the human needs.

Schwandt's (1994) notion that in a sense we are all constructivists if we believe that the mind is active in the construction of knowledge is not widely disputed. Most of us would agree that knowing is not passive — a simple imprinting of sensory data on the mind — but active; the mind does something with these impressions, at the very least it forms abstractions and concepts, Schwandt notes. In this sense, Schwandt writes, constructivism means that human beings do not find or discover knowledge so much as they construct or make it. He adds that we invent concepts, models, and schemes to make sense of experiences and, further, we continually test and modify these constructions in the light of new experience. Also Annemarie Sullivan Palincsar (1998) writes that virtually all cognitive science theories entail some form of constructivism to the

[4] Positivism means here a paradigm in which an apprehendable reality is assumed to exist, and the reality is driven by immutable natural laws and mechanisms. In the positivist paradigm, research can converge on the "true" state of affairs. The investigator and the object of investigation are thought to be separate entities, and the investigator is capable of studying the object without influencing it, or being influenced by it (Guba & Lincoln, 1994).

extent that cognitive structures are typically viewed as individually constructed in the process of interpreting experiences in particular contexts.

Guba and Lincoln (1994) state that the constructivist paradigm assumes *relativist ontology*. In relativist ontology, they continue, realities are apprehendable in the form of multiple, intangible mental constructions. The realities are socially and experientally based. That the realities are local and specific by nature does not imply that elements could not be shared among many individuals or even across the cultures (ibid.) — we will come to this in 2.2. Denzin and Lincoln (1994) state that the constructivist epistemology is subjectivist and transactional; i.e. knower and what she or he knows create understandings in the process of the investigation. This notion of constructivist epistemology is used later in the defining of the concept of ethnocomputing as relativist, culturally bound and dialectical by nature.

When presenting critique of constructivism, Schwandt (1994) raises the question of the constructivists' bid to argue from a psychological claim to an epistemological conclusion. That is, the constructivists claim that the process of knowledge does not apply to a real, independent world, but only to our own constructing processes. The difficulty here is how to account for the facts that firstly, knowledge sometimes takes the form of theoretical production; secondly, knowledge is somehow available to individuals; and thirdly, knowledge is often shared and transmitted (ibid.). In other words, how can knowledge that does not exist anywhere else than in the individual's mind be shared or inferred? Without Berger and Luckmann's (1966) work with the social constructivism, the constructivist paradigm would be too impractical for this thesis.

## 2.2 Sociology of Knowledge

Peter Berger and Thomas Luckmann's theory of *social construction of knowledge* responds to Schwandt's (1994) criticism, but the tension between claiming that knowledge is the property of individual minds and the view that knowledge can be publicly shared, is still evident (ibid.). In general, instead of focusing on the matter of individual minds and cognitive processes, social constructivists turn their attention outward to the world of inter-subjectively shared social constructions of meaning and knowledge (Denzin & Lincoln, 1994). In short, social constructivists are interested in language and other social processes that generate meaning and knowledge.

Aittola and Pirttilä (1986) note that it is often thought that it was Max Scheler who solidified sociology of knowledge as an independent discipline. Scheler — Aittola and Pirttilä write — established the search of interest-free ideological knowledge as the main task of sociology of knowledge. Berger and Luckmann (1966), on their part, introduce the problem of sociology of knowledge with allegories to an average person in the street, a philosopher and a sociologist. They state that the average person does not ordinarily become troubled about what is real to her or him or about what he or she knows, but takes her or his reality and knowledge for granted. For example, he or she might think that they possess freedom of will. The philosopher, on the other hand, is professionally obligated not to take anything for granted, and to obtain maximal clarity as to the ultimate status of what the person in the street believes to be "reality" or "knowledge". The philosopher has to ask questions like *"what is freedom?"*, *"is man free?"* or " *"how can one know these things?"* (ibid.). The sociologist, Berger and Luckmann state, is in no position to supply answers for these questions. However, the sociologist has to ask whether the difference between the two "realities" of the common person and the philosopher may not be understood in relation to various differences between their two societies. Hence, the sociologist will need to ask how it is that the notion of "freedom" has come to be taken for granted in one society and not in another, how the "reality" of this notion is maintained in the one society and how, even more interestingly, this "reality" may once again be lost to an individual or to an entire collectivity. What is "real" to a Tibetan monk may not be "real" for an American businessman (ibid.). The sociology of knowledge will have to deal with both the empirical variety of knowledge in human societies, and the processes through which *any* body of knowledge comes to be socially established as "reality" (ibid.).

According to Aittola and Pirttilä (1986), the most central processes in Berger and Luckmann's view on the social construction of reality are *externalization*, *objectivation*, and *internalization*. In externalization, Pirkkoliisa Ahponen (2000) clarifies, an active individual creates the society with her or his contribution. Objectivation is the process where the order of everyday life comes to be understood as ever-existing (ibid.). Ahponen states that the most important elements of objectivation are comprehension and attaching linguistic meaning. Internalization or socialization, she continues, is the process in which individuals adopt the social reality, that they experience, as objective. Finally, *reification* is the process in which the internalized human productions are understood as if they were something other than human product (ibid.) (Figure 1). Ahponen (2000) writes that externalization occurs in the processes where one is confronted with a new social situation and where he or she establishes a personal relationship with the situation. As an example she mentions meeting new friends or starting a new job. She continues that on the other hand, externalization is also a part of those processes that ensure the institutional continuity of social relationships: maintaining friendships, everyday working, or paying income tax.

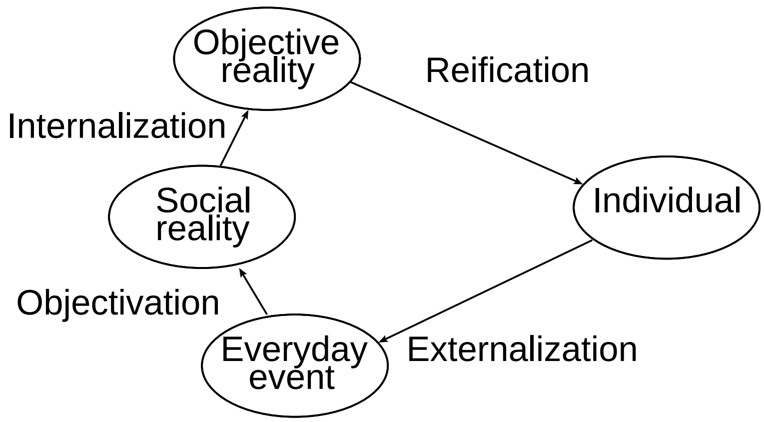


Figure 1: Processes of the social construction of reality.

Berger and Luckmann (1966) specify that it is important to keep in mind that the objectivity of the institutional world, however massive it may appear to the individual, is a humanly produced, constructed objectivity. They emphasize that the relationship between man, the producer, and the social world, his product, is and remains a dialectical one. That is, the collectivities and the social world interact with each other, continuously reshaping each other. Externalization and objectivation are moments in this continuing dialectical process (ibid.). In summary, the externalized experiences[5] attain the character of objectivity through the objectivation process (ibid.). The third process, internalization, fixates the objectivated social world into consciousness in the course of socialization (ibid.). Berger and Luckmann note that here we clearly see a paradox: man is capable of producing a world that he then experiences as something other than a human product! Aittola and Pirttilä (1986) summarize that the society and the whole social reality in Berger and Luckmann's theory can be seen as a dialect between objective and subjective, where people continuously recreate reality with their work and actions.

Risto Heiskala (2000) states that when Berger and Luckmann's theory of social constructivism was published, the term social constructivism was rapidly extended to cover

[5]Externalized experiences are an anthropological necessity; human beings must ongoingly externalize themselves in activity (Berger & Luckmann, 1966).

much more topics than Berger and Luckmann had intended to. Heiskala also claims that even though Berger and Luckmann consider their theory to concentrate on sociology of knowledge, they define sociology of knowledge quite extensively. This study uses only a restricted set of what is thought to belong to the field of research, a set that is defined later in this chapter.

Heiskala (2000) questions Berger and Luckmann's idea of first presuming that individual minds articulate meaning, and only after that examining the structures that have detached from intentional consciences. Heiskala notes that in the same manner, or even more realistically, it could be assumed that the individual consciences are formed by some greater structures. The individual minds would then never have the chance to form a comprehensive conception of the structures that control them (ibid.). Ahponen (2000) writes that in Berger and Luckmann's theory face-to-face interaction is considered the real interaction, and that all the other forms of interaction are derivatives of the face-to-face situation. Heiskala (2000) points out that especially in a mass communication society it is unclear whether it is reasonable to assume face-to-face interaction to be the prototype of meaning interpretation. He also states that the French cultural analysis takes a critical position towards Berger and Luckmann's premise that there exists a dialectical relationship between the objective and subjective cultural realities. The premise might be wrong in that there might not even exist any relationship between the two realities.

## 2.3 Social Constructionism in Educational Psychology

Kenneth Gergen (1985) lists four assumptions of social constructionism in psychology[6]. First, he states that what we take to be experience of the world, does not in itself dictate the terms by which the world is understood. As Bernard Guerin (1992) puts it, our relations with the world do not always correspond to the actual world. Positivist criticism has raised questions such as *"How can theoretical categories be induced or derived from observation, if the process of identifying observational attributes itself relies on one's possessing categories?"* and *"How can theoretical categories map or*

[6]Kenneth Gergen (1985) holds to the term "constructionism", noting that "constructivism" is also used in referring to the Piagetian theory, to a form of perceptual theory, and to a movement of the 20th century art. Gergen's term is used in this chapter, although there would not be a real risk of unclarity with the term "constructivism" either.

*reflect the world if each definition used to link category and observation itself requires a definition?"* (Gergen, 1985). Actually, Gergen states, there are many cases where objective criteria for identifying "behaviors", "events", or "entities" are shown to be either highly circumscribed by culture, history, or social context, or altogether nonexistent.

Gergen's second assumption is that the terms in which the world is understood are social artifacts, products of the historically situated interchanges among people. In other words, the terms we have to explain the world with are also social products (Guerin, 1992). Gergen writes that conceptions of psychological process differ markedly from one culture to another, and they all invite us to consider the social origins of taken-for-granted assumptions about the mind. For example, concepts of "romantic love", "child", and "self" have undergone serious change during history, and have different implications in different cultures. Gergen's first two assumptions invite one to challenge the objective basis of natural sciences.

The third assumption Gergen makes is that the degree to which a given form of understanding prevails or is sustained across time is not fundamentally dependent on the empirical validity of the perspective in question, but on the vicissitudes of social processes (e.g., communication, negotiation, conflict, rhetoric). That is, whether a knowledge is maintained or not can depend as much on social exchanges as on the nonsocial environment (Guerin, 1992). Putting this idea into the context of social interaction, Gergen states that the rules for "what counts as what" are inherently ambiguous and continuously evolving. For example, whether an act is defined as envy, flirtation, or anger floats on a sea of social interchange. As the social relationships change, interpretations change also.

Gergen's fourth assumption is that the forms of negotiated understanding are of critical significance in social life, as they are integrally connected with many other activities in which people engage. Knowledge that is constructed socially cannot be separated from other social life. As an example Gergen mentions that the opening "Hello, how are you?" is typically accompanied by a range of facial expressions, bodily postures, and movements without which the expression would seem artificial. Altering these expressions would cause problems such as misunderstanding the meaning of the situation. Gergen's last two assumptions question the rules within scientific communities that determine what is counted as facts. Gergen states that observation of natural scientists has shown that what is passed as "hard fact" in the natural sciences, typically depends on a potent array of social microprocesses.

Irene Chen (2002) writes that there are two major strands of the constructionist perspective in education: cognitive constructionism and social constructionism. She writes that cognitive constructionism is based on the work of Swiss developmental psychologist Jean Piaget. Piaget's theory has two major parts: an "ages and stages"-part that predicts what children can and cannot understand at different ages, and a theory of development that describes how children develop cognitive abilities (ibid.). Chen writes that another cognitive psychologist, Lev Vygotsky, shared many of Piaget's assumptions of how children[7] learn, but he placed more emphasis on the social context of learning. In Vygotsky's theories both teachers and older or more experienced students play very important roles in learning (ibid.). Chen notes that these two perspectives have a lot in common, but that Vygotsky's theory has much more room for an active, involved teacher. According to Vygotsky, culture gives the student the cognitive tools needed for development. Trish Nicholl (1998) argues in her article on Lev Vygotsky that of the psychological tools that mediate our thoughts, feelings, and behavior, language is the most important. She continues stating that culture provides basic orientations that structure the behavioral environment of the self. It is through language that we construct reality: define, shape and experience it (ibid.). These theories present a psychological angle on constructivism that is well in line with other constructivist ideas I have selected for this thesis.

Lev Vygotsky (1986) distinguishes concepts into two groups: *scientific* concepts and *spontaneous* concepts. The former ones are gained through systematically organized learning in an educational setting, whereas the latter emerge from people's own reflections on everyday experience (ibid.). Vygotsky made this a point in order to argue that scientific concepts, far from being assimilated in a ready-made form, actually undergo substantial development, which essentially depends on the existing level of people's general ability to comprehend concepts.

Spontaneous concepts, Vygotsky states, in working their way "upward" toward greater abstractness, clear a path for scientific concepts in their downward development toward greater concreteness (ibid.). As Harry Daniels (1996) puts it, the everyday (spontaneous) concepts are seen to bring the embedded richness and detailed patterns of signification of everyday thinking into the system and organized structure of scientific

[7] Though Vygotsky writes of children's learning, the ideas are applicable to adult learning also (Tharp & Gallimore, 1992). I assume that Piaget's work is also applicable to adult learning, and I shall hereafter use "person" or "student" instead of "child".

concepts. As they merge with everyday referents, scientific concepts come to life and find a broad range of applications (ibid.). Tharp and Gallimore (1992, 108) claim that in a neo-Vygotskian instructional approach, it is necessary to ensure that an interface between the scientific concepts and everyday concepts is provided. It is on that interface that the highest order of meaning is achieved (ibid.). This theme comes up again later in this thesis in the contexts of multicultural education and problems with the lack of discontinuity between schools and home.

In his influential collection of essays *Mind in Society*, Lev Vygotsky (1978) makes an argument that learning is not development. However, he says that properly organized learning results in mental development, and sets in motion a variety of developmental processes that would be impossible apart from learning (ibid.). Learning is a necessary and universal aspect of the process of developing culturally organized, specifically human, psychological functions (ibid.). Learning awakens a variety of internal developmental processes that are able to operate only when a person is interacting with people in his environment and is in cooperation with his peers (ibid., 90).

From the social constructionist perspective, separating the individual from social influence is not regarded as possible (Palincsar, 1998). The sociocultural contexts in which teaching and learning occur are considered critical to the learning itself, and learning is viewed as culturally and contextually specific (ibid.). Furthermore, cognition is not analyzed as separate from social, motivational, emotional, and identity processes, and the study of generalization is study of processes rather than study of personal or situational attributes (ibid.).

What unifies different postmodern constructionist perspectives is the rejection of the view that the locus of knowledge is in the individual; learning and understanding are regarded as inherently social; and cultural activities and tools (ranging from symbol systems to artifacts and to language) are regarded as integral to conceptual development (Palincsar, 1998). This supports strongly the idea of culturally sensitive learning, which is connected with ethnocomputing later in this thesis. Fully developed constructionism could also furnish a means for understanding the process of science (Gergen, 1985).

## 2.4 Social Construction of Science

Science, if anything, is popularly thought to be some sort of an extreme form of knowledge, yet only a small fraction of people understands the language of science, or is able to express their thoughts in a theoretical form. Quite the contrary to this understanding of knowledge, Berger and Luckmann (1966) state that the sociology of knowledge must concern itself with *everything* that passes for "knowledge" in society. Berger and Luckmann continue specifying that "ideas", theoretical thought, are not *that* important in society. In their view common-sense knowledge rather than ideas must be the central focus for sociology of knowledge. My study emphasizes the importance of understanding the social construction of the theoretical format of scientific representation, and seeing how this understanding has been shaped by a very limited segment of society. Being sketched and elaborated by white, western middle and upper class males, our (western) notion of science is inevitably a biased one (Nieto, 1992, 301). Michael Apple (1993) even states that every definition of knowledge is a site for conflict over the relations between culture and power in class, race, gender and religious terms.

Guba (1990) defines the concept of *paradigm* as a basic set of beliefs that guide the actions of the investigator. A paradigm encompasses three elements: ontology, epistemology and methodology. Denzin and Lincoln (1994) note that the nature of paradigms is that they deal with first principles, or ultimates, and thus must be accepted simply on faith; there is no way to establish their ultimate truthfulness. If there were, Denzin and Lincoln continue, the philosophical debates reflected also here in this thesis would have been resolved millennia ago. Being human creations, paradigms are socially constructed and thus culturally bound. Thomas Kuhn (1962) agrees with this, writing that paradigms are nothing but agreements among a scientific community, and they last for a limited time. Stanley Fish (1989) goes further, claiming that reality *is* the result of the social processes accepted as normal in a specific context, and knowledge claims are intelligible and debatable only within a particular context or community[8]. The process of pushing the location of scientific thought towards a local culture, e.g. holding that both failure and success in science are results of social construction of knowledge, is also called *cultural construction* by some authors (Eglash, 1997a).

My hypothesis is that Berger and Luckmann's (1966) theory of social construction of

[8]Fish's long and abstruse argument is put in this form by Schwandt (1994).

reality holds also in Computer Science. If this is the case, it leads to a claim that man is capable of producing science that he then experiences as something other than human product (cf. Berger and Luckmann's notion of objectivation and internalization processes). In the light of this hypothesis, the process of social construction of science would thus be as follows: first, man produces and publishes a scientific report (externalization); then, the scientific study, when repeated and referred to repeatedly, would attain the character of "objective science" (objectivation). Then, the objectivated scientific studies would, in the course of internalization, be adopted as objective knowledge; and lastly, they would be understood by people as something other than human product (reification).

Since most of the knowledge derives from experiences (Berger & Luckmann, 1966), one of the challenges of ethnocomputing is — to an appropriate extent — to translate this subjective, culturally bound, and usually hidden knowledge into concepts of Computer Science. Supposedly, in many cases, the current paradigms of Computer Science lack the power of expression for the wide variety of different cultural knowledge. Some reasons why the current theory of computing has become dominant are that the western computing is profoundly intertwined with the western Mathematics, and that the current theory has proved useful in the western societies. Of course, this should not be used to justify the supremacy of the western view on Computer Science over other possible views, since this would clearly be circular reasoning: it only shows that a product of western culture works well in western culture. Unfortunately, this argument is rather common.

Lorraine Code (1991) adheres to the claim that along with other characteristics, the gender of the knower is significant, too. She states that academic conversations about knowledge commonly treat "the knower" as a featureless abstraction. In her opinion, science has a putatively self-evident principle that truth, once discerned and knowledge, once established, claim their status *as* truth and knowledge by virtue of a grounding in or coherence within a permanent, objective, ahistorical, and circumstantially neutral framework or set of standards. However, since knowledge is both subjective and objective, Code states, also the gender of the knower is epistemologically significant. However, her opinion is that not only one circumstance, such as sex of the knower, bears the entire epistemological burden, but that different circumstances combine a cluster of subjective factors.

The resistance towards non-positivist[9] study derives from the "ever-present desire to maintain a distinction between hard science and soft scholarship" (Carey, 1989, 99). Positivist sciences (e.g. physics, chemistry, and economics) are often seen as the crowning achievements of western civilization, and in their practices it is assumed that "truth" can transcend opinion and personal bias (ibid.). Objectivity, quite precisely construed, is commonly regarded as a defining feature of knowledge *per se* (Code, 1991). However, in this study the non-positivist arguments are essential. The construction of knowledge is here seen as an inter-subjective process, and a dialectic relationship between the individual and the society, as well as between Computer Science and society, is assumed. Society is to some extent shaped by changes in Computer Science, and Computer Science arises from the society.

[9] Although non-positivist schools differ in their epistemological viewpoints, they are united by their common rejection of the belief that human behavior is governed by general laws and characterized by underlying regularities (Cohen & Manion, 1985). Moreover, they would agree that the social world can only be understood from the standpoint of the individuals who are part of the ongoing action being investigated (ibid.).

# 3 Ethnocomputing in Relation to Culturally Sensitive Learning

Computers and Computer Science are definitely one of the significant factors widening the regional income gap (Heikka, 2002). Like the telecommunication industry contributed to widening the economic gap between the rich and the poor, the Internet may follow a similar pattern (Chon, 2001). The inherent vagueness of the concept "West" (Hall, 1992) that has the privilege to technology, eases the broadening of the digital divide even further. The only way to slow down the separation process between computer-literate and -illiterate people would be to give an equal possibility of computers education to everyone. In the United States, there are already cries for *ethnically fair*[10] education also in science, not only in humanities. Hopefully, the study of the ethnical roots of computing helps in speeding up this process. Ethnocomputing offers a tool for developing a multicultural approach in Computer Science education, recognizing the influence of societal and cultural background on learning Computer Science. This chapter introduces some dimensions of multicultural education, as well as the study of ethnocomputing as a multicultural educational movement.

## 3.1 Multicultural Education

Most of the studies in multicultural education have taken place in the United States, and dealt with the problems of education in the American multicultural society. Even though this narrows the viewpoint down to the American context, these studies reflect the general view on cultural aspects in education, and can thus be used also in the study of ethnocomputing. Still, I see that studying ethnocomputing and using the results gained is easiest in a monocultural society with a coherent culture and value systems. I assume that a coherent culture would help in identifying unique features in a particular ethnocomputing, and that the results could then be used with a greater confidence in that all the members of that particular society are familiar with the concepts.

William Safran (1994) writes about cultural minorities within a dominant culture. He

[10] Banks (1999) uses the term ethnically fair in a multicultural education evaluation checklist. No clear definition for the term has yet been established. Here "ethnically fair" stands for something that is equally available to everybody regardless of race, language, religion, or such, with the same ease or work contribution.

states that rather than *multiculturalism*, *cultural pluralism*[11] may be a force for modernity because it accords a place to ethnic minority cultures that may in certain instances be more advanced than the culture of the majority. He continues claiming that multiculturalism may be anti-modern in some occasions. The viewpoint of this study is that a choice between multiculturalism and cultural pluralism is not needed, since neither of them blocks out the introduction of new perspectives to education. In my opinion, multiculturalist approach in science education has both societal and scientific benefits. First, it meets a social demand, guaranteeing every student an equal chance to excellence, and second, different approaches to scientific problems may also bring along novelties in science in form of new approaches to scientific problems.

Cameron McCarthy (1998) criticizes the American school curriculum for its *Eurocentrism*[12] and westernness. He stresses that the challenge of multiculturalism is the critical challenge of curriculum in postmodern times. He also calls attention to the urgent need to rethink the current privileging of Eurocentric ideas in the contemporary American school curriculum. The rethinking process, he states, must start from the school textbook and the process of textbook production on the whole. In my opinion, seeing computing as subjective knowledge would mean a fundamental change in the whole process of Computer Science education.

Sonia Nieto (1992, 301) notes that one of the hindrances in multicultural education in the United States (as well as in many European countries) is that education has nowadays been canonized[13]. The canon assumes that the most worthy knowledge is already in place in the curriculum. Knowledge in this context is inevitably European, male and upper class in origin and conception. Particularly in the United States, Computer

[11] The policies of multiculturalism clearly constitute a recognition of the sensitivities of ethnic or racial minorities, and stress affirmative action and ascriptive (as opposed to merit-based) recruitment. Cultural pluralism, on the other hand, is premised on that ethnic groups should be maintained as identifiable constituents of a nation, because of the unique contributions they make to the richness and variety of the culture (Safran, 1994).

[12] In this thesis, Eurocentrism means being based on traditions that derive from Europe or from European cultural dependencies. George G. Joseph (1997) defines European cultural dependencies as those countries, which are mainly inhabited by populations having European or similar roots: The United States, Canada, Australia, and New Zealand. Joseph names Eurocentrism as "intellectual racism".

[13] James A. Banks (1999) explains canon as a standard or criterion used to define, select, and evaluate knowledge in the school and university curriculum within a nation. Nieto (1992) writes only about the curriculum in the United States, but in the course of the standardization of the European bachelor degree, the variety in contemporary European curricula will also most probably vanish.

Science educators have gone as far as trying to totally canonize the curriculum. The computing curriculum presented by ACM (ACM, 2001) has a broad view on computing, and it points out many good aspects. Still, it is my opinion that the idea that every institution should have the same courses with the same codes, aims at creating an ultimate canon that defines the only worthy knowledge now and in the future. Only if the educators perceive the report as suggestive rather than determining, will the report succeed in its goals to be "international in scope" and "broadly based". I can not really see anything "broadly based" in defining only one possible path for graduation.

The problems with canonization in studies other than Computer Science are the narrow-minded view on the subject, and the discontinuity between what students experience at home and what they experience at school. For example, Gloria Ladson-Billings (1995, 207) points out that sociolinguistics have suggested that if students' home language is incorporated into the classroom, they are more likely to experience academic success. I would assume that to maximize efficiency, Computer Science education in developing countries should take this into account. Carlos Torres (1998) mentions that the proponents of liberal multiculturalism argue that liberal multiculturalism will increase fairness by representing the range and richness of different ethnicities. In addition, liberal multiculturalism increases tolerance by exposing students to multiple perspectives in the meaning of history (ibid.).

Banks (1999) criticizes the critics of multicultural education movement for oversimplifying the concept. He mentions hearing opinions such as "Math is math, regardless of the color of the students" on the part of science teachers. "An if-then-statement is always the same in all universes, no matter how it is taught"[14] is a computer scientists' comment equivalent to the abovementioned one. Indeed, this criticism unconsciously brings up my point that the learning processes themselves are crucial factors in the concept construction. Relying on the social constructionist theories in education, I believe that effective teaching depends a lot on how familiar the concepts are to the students, and that how concepts are taught shapes the way the information is understood. Banks (1999) names this the *knowledge construction process*. He describes it as the procedures by which social, behavioral, and natural scientists create knowledge and how the implicit cultural assumptions, frames of references, perspectives and biases within a discipline influence the way knowledge is constructed within the discipline (Banks,

[14] The comment of the science editor of a major Finnish newspaper when offered a short article on ethnocomputing.

1993a).

Banks (1993b) claims that multicultural education confronts resistance especially on the part Mathematics and science teachers. Their argument is that multicultural education is not relevant to their disciplines. In his response to this, Banks also mentions the knowledge construction process as one of the dimensions of multicultural education. Multicultural education, he states, needs to be more broadly understood so that teachers from a wide range of disciplines can respond to it in appropriate ways, and so that resistance to it can be minimized (ibid., 20).

In another essay, Banks (1993c) states that a mainstream-centric curriculum is a major way in which racism and ethnocentrism are reinforced and perpetuated in schools and in society at large. In addition, he states that it has negative consequences also for mainstream students, since it reinforces a false sense of superiority, giving them a misleading conception of their relationship with other racial and ethnic groups, and denying them the opportunity to benefit from the knowledge, perspectives, and frames of reference that can be gained from studying and experiencing other cultures and groups. Nothing indicates that Computer Science would be an exception from this; nothing indicates that the pervasive westernness in Computer Science would not impose a sense of superiority of the western culture on the students.

From the multiculturalist educational point of view, systematic study of ethnocomputing aims at developing skills for observing computational phenomena that have their roots in a distinct cultural setting. The results may then lead to new viewpoints into Computer Science which can be used to improve the cultural sensitivity in teaching computing. The new viewpoints clearly benefit western science, but promoting the competence of different social groups with different cultures goes also hand in hand with creating ethnically fair science. As an example of contemporary ethnical inequality, Paula Uimonen (1998) points out that the Internet is far from its claimed true cultural diversity. Only 5-10 percent of the Internet content is of Asian origin while the Asian population represents about half of the world's population (ibid.). She says that the Internet can be seen as a vehicle for marketing western ideas and values. Since the Internet, she continues, differs from traditional broadcasting media in that its users are both consumers and producers of information, Asians will have to be encouraged to use it both ways (cf. the definition of the digital divide used in this thesis). One problem with the encouraging may be the thorough western history and westernness of Computer Science. Because of these roots, almost all the teaching material, problem solving methods and concepts are dominantly western, and as Munir Fasheh (1982) notices, they are usually nonsensical to non-western students. I claim that this causes problems to non-western students who need to start with learning a whole new philosophy when studying Computer Science. The western philosophy may be directly at odds with their perceptions of time and space, society, logic, values, problem solving methods, or even with which questions are considered legitimate. So, on top of a new subject, the non-western students need to learn a whole new way of thinking, whereas the western students are already familiar with the logic that underlies Computer Science.

Ron Miller (2000) writes that there is an ongoing historic shift from schools to learning communities. He claims that modernity as a worldview sees the society as a great machine whose purpose is to turn natural and human resources into commodities and profits. In a culture that values efficiency, competition, and production and consumption of material goods above everything else, what other purposes could schools serve than training young people to fulfill their place in the vast social machine? (ibid.). Miller asks this question, and goes on to criticize that during the past twenty-five years education has become ever more standardized, ever more mechanical, as it serves the political and economic agenda of competition, production, and corporate profit. Young people are not perceived as growing, active human beings but as units of production whose academic achievements contain primarily of economic value (ibid.). William Ellis (2000) argues that the conventional schooling is in no way different from any other aspect of the dominant and domineering Euro-American culture. It is a hierarchical, patriarchal, and authoritarian system of control from the top down (ibid.).

As an antidote to the mechanistic view in schooling, Miller (together with a number of other authors) presents an "attempt to rebuild society's educational system on a post-modern cultural foundation that is democratic and person-centered rather than mechanical, as well as ecological and life-centered rather than driven exclusively by economic forces". His aim is that the places of learning would not be constrained by textbook and curricula established by anonymous bureaucrats; teaching would not be made narrow and petty in the service of "standards" that elite commissions impose on all learners of all persuasions in all communities (Miller, 2000). Ellis (2000) emphasizes that in community learning, there are two aspects in respect to the term "community". One is that which the learners get from the community; the other is that which the learners give to the community — the dialectic composition, again. Community learning would support the idea of Computer Science education that is attached to a local culture.

## 3.2 Different Approaches to Multiculturalism

Multiculturalist movement in education has not been a homogenous social movement. Carlos Torres (1998, 181) points out that multiculturalism cannot be represented by a single theoretical paradigm, or one educational approach or pedagogy. Furthermore, Torres describes different views on multiculturalism, listing four major ways in which the goals of multicultural education vary. First, they vary from developing an ethnic and cultural literacy to developing personal pride of one's ethnic identity. Second, they vary from changing attitudes (stereotypes, racism) to promoting multicultural competence. Third, they vary from developing a proficiency in basic skills to striving to achieve educational equity and excellence simultaneously. Fourth, they vary from pursuing individual empowerment to achieving social reform.

Torres (1998, 181) also mentions four approaches to multicultural education. The approaches are *corporate conservative multiculturalism*, *liberal multicultural approach*, *social democratic approach* and *socialist approach*. Conservative multiculturalism ("contributions approach")[15] emphasizes teaching about the contributions of different social groups and individuals. Liberal multiculturalism ("additive approach") incorporates multicultural lessons as units of study that supplement or become appendixes to the existing curriculum. Social democratic ("transformative") approach attempts to change the basic curriculum and instruction to reflect the perspectives and experiences of diverse ethnic, racial and social groups — each having a culture of their own. Socialist ("social action") approach teaches students that intergroup relations are always an integral part of social and historical conflicts in society.

Computer Science is a young discipline, and still looking for its identity. Lofti A. Zadef noted as early as in 1968 that even among the leading practitioners of Computer Science there are significant disagreements on what Computer Science is (Zadef, 1968). Today, just a glance at the list of the special interest groups of the Association of Computing Machinery is enough to convince one of the diversity of the discipline (ACM, 2002). The interest groups include purely mathematical branches such as the theory of computing, applied studies such as neural computing as well as psychological studies

[15] Originally listed and named by Banks, found e.g. in Banks (1993c) and Banks (1999).

such as human-computer interaction. The field is rapidly evolving to directions that are changing and difficult to anticipate (Zadef, 1968)[16]. The boundaries of Computer Science are not strictly defined, and change and reform are actually a part of the nature of the discipline. I believe that probably because of these properties, many companies have adopted information technology as a tool for change, whereas accounting, for example, might be described as a preserving element.

That most of special interest groups of the Association of Computing Machinery are interdisciplinary by nature leads to the conclusion that the value and use of Computer Science is mostly instrumental. This multidisciplinarity also problematizes the philosophy of Computer Science. The roots of Computer Science are in mathematics, and thus positivist by nature. Still, falsification — a postpositivist method — is widely used in several areas. For example, proving a program correct is often impossible in the real world, and thus the program is supposed to be "correct enough" if extensive testing does not reveal more errors — but certainty is never achieved. Constructivism, on the other hand, can be found, for example, in the area of human-computer interaction. This variety of paradigms causes uncertainty among students — and probably among researchers, too. Yet I believe that the same diversity also holds strength in it. Because the discipline is intrinsically open to many differing paradigms, certain openness and adaptability is preserved. Encouraging interdisciplinary studies rather than eliminating them could help solve a problem that is widely acknowledged in information industry — the lack of understanding between the programmer and the client.

The educational goal of the study of ethnocomputing, if seen as a multiculturalist movement, does not unambiguously fit in any of Banks' (1999) four classes. The closest of the four classes is the socialist democratic approach, but it fails to bring out the internal dynamics of Computer Science. Another approach is needed in order to emphasize the radical reformative nature of ethnocomputing; I shall name this approach *reformative multiculturalism*.

Reformative multiculturalism emphasizes the diversity and constant change of the society (and consequent change in knowledge and science), and underlines the role of the students in this change. Especially in a science that is in constant fluctuation it is imperative to incorporate the cultural knowledge and the idea of a continuous change into the teaching. On one hand, ethnocomputing should be seen as an active force of

[16]Lofti A. Zadef's comment that was made in 1968 is still valid in 2002 — after over thirty years of change in Computer Science.

societal change; on the other hand as a dynamic subject of change. Ethnocomputing arises from the culture and adapts to the changes in the culture.

# 4 Ethnosciences

In the past decades, ethnosciences have evoked worldwide discussion, raising fervent arguments for and against them. Especially large in scale and spirited this debate has been over ethnomathematics. The conversation clearly shows the uncertainty (on the side of the proponents as well as the opponents) of what the goals of ethnosciences are, and even more clearly brings forward the misconceptions and fears about ethnosciences. I am intentionally leaving out the discussion of different paradigms or perspectives of ethnosciences, because that debate is not essential for this study. Therefore, instead of comparing paradigms and perspectives, I shall discuss the background of ethnosciences and the criticism towards them, and briefly present two perspectives into ethnocomputing.

## 4.1 Theory of Ethnosciences

In the famous article "Ethnomathematics and its Place in the History and Pedagogy of Mathematics", in which Ubiratan D'Ambrosio (1985) defines *ethnomathematics*[17], he uses the term *ethnoscience* as "the study of scientific and, by extension, technological phenomena in direct relation to their social, economic and cultural backgrounds". For example, ethnomathematics is thus defined as the study of mathematical ideas of non-literate[18] people (Ascher & Ascher, 1986). If described in terms of the development of the science in general, ethnosciences are a corpora of knowledge established as systems of explanations and "ways of doing", which have been accumulated through generations in distinct cultural environments (D'Ambrosio 1998). Nowadays, there have been studies in ethnoastronomy, ethnobiology, ethnochemistry, and ethnogeography, to mention a few (Bernard 1995, 528). Quite contrary to John Glenn's (2001) goal of using scientific progress for sustaining the advantage of developed countries, especially the U.S., over developing countries in the name of economy, the American

[17]It is unclear (and unimportant to this study) who used the term ethnomathematics first. At least Wilbur Mellerna (1990) claims to have invented the term in 1967, and to have used it in a talk in 1971.

[18]Terms primitive and illiterate are used in different, inconsistent ways. Here I use "non-literate" instead of "primitive", "illiterate" or "uneducated" for a few reasons. First, I use it to emphasize the idea of Sheik Jamani (Negroponte, 1995) that primitive people are not uneducated, but that they use different ways of transferring knowledge from generation to generation. Second, I use it to disassociate from the evolutionary-biased term "primitive" (Ascher & Ascher, 1986).

way of life, and its national defense, ethnosciences generally aim for equal distribution of the benefits of progress.

The presumption about the abilities of non-literate people — or people whose thinking doesn't follow the logical rules of western science — is usually that they are simpleminded, childlike, illogical, of lesser intelligence, or incapable of analytic thought (Ascher & Ascher 1986; Cooper, 1975). Ethnosciences discard this belief, and rely on the idea that each community has developed its own ways, styles and techniques of doing certain tasks, and responses to the search of explanations, understanding and learning (D'Ambrosio, 1998). D'Ambrosio names these the *systems of knowledge*. All these different systems use inference, quantification, comparison, classification, representation and measuring. Western science is a such system of knowledge, but other systems of knowledge with the same aims have also developed. The other systems use other ways of inferring, quantifying, comparing, classifying, representing and measuring, but are not simpleminded or childlike (ibid.). However, Code (1991) suggested that from the claim that no single scheme has absolute explanatory power, it does not follow that *all* schemes are equally valid. Contrary to her opinion, according to which some knowledge is *better* than other knowledge, it is my view that comparison between different systems of knowledge is groundless due to the fact that they have arisen in different environments to meet different demands. Of course, as Fasheh (1982) admits, not all logics and assumptions are equally effective in understanding and dealing with a certain situation, but this does not imply that western logic or assumptions would be useful in all situations.

Thomas Kuhn (1962) states that apparently arbitrary elements, compounded of personal and historical accidents, are always forming the beliefs of scientific communities. Normal science[19], he states, owes its success to the ability of scientists to regularly select problems that can be solved with conceptual and instrumental techniques close to those already existing. Normal science does not aim at novelties of fact or theory and, when successful, finds none (ibid.). Clearly, when a paradigm denies the validity of a large class of problems, it leaves out a number of socially and scientifically important problems and solutions. This nature of normal science considerably limits the possibilities of multicultural research and education, since the rules of other cultures

[19]Thomas Kuhn, who took in use e.g. the terms "paradigm", "normal science" and "scientific revolution", defines "normal science" as research that is based on past scientific achievements, and acknowledged as a foundation for further practice of that particular science (Kuhn, 1962).

may not fit into our currently legitimate paradigm, and thus the problems and results are rejected, no matter how valid they are in the surroundings where they emerge. The reluctance to adopt a new paradigm might be due to the fact that a new paradigm often enforces the scientists to redefine or even discard their earlier work. Kuhn notes that in adopting a new paradigm, some old problems may be declared entirely "unscientific", whereas others that were previously nonexistent or trivial may become the very archetypes of significant scientific achievement.

As Kuhn (ibid.) recognizes, normal research does not aim to produce major novelties, conceptual or phenomenal. Even those projects, whose goal is paradigm articulation, aim not at the *unexpected* novelty. Moreover, Kuhn states that the paradigm procedures, applications, laws and theories restrict the phenomenological field accessible to scientific investigation at any given time. I see ethnosciences possibly speeding up the process of paradigm re-evaluation and finding unexpected novelties in science in general. Ethnosciences may work as a catalyst, introducing and encouraging new paradigms to challenge the prevailing ones.

Kuhn suggests that there are two alternatives in a scientific crisis: either no scientific theory ever confronts a counterinstance, or all such theories confront counterinstances at all times. It is my view that concurrently, there exist several culturally bound paradigms within a discipline, and that none of these are better or worse than the others — they just have arisen to meet the different needs of different cultures. One reason why ethnosciences have emerged this late may be because of the fact that these different culturally bound paradigms have not really confronted each other before, and thus have not been able to interact. Now, in a global scientific community where all the new publications are available on-line, paradigms from different cultures meet continuously, and crises are inevitable. It is only the all-extensive western influence that prevents new viewpoints from emerging if they are not fully-fledged and totally revolutionary. It seems to me that questioning the supremacy and omnipotence of western science is considered heresy in the West.

The value of local traditions has been highly noted in the field of statistics (Desrosières, 1996). After mid-nineteenth century, the attempts to find a common language and to unify the methodology lead to a universal professional language of statistics (ibid.). However, it was soon noticed that the differences between national traditions, which were earlier presented as obstacles to research, actually brought useful information to the underlying structures (ibid.). Differences in classification systems and changes over time are now seen as phenomena that deserve to be examined in their own right (ibid.). The debate in the field of statistics portrays a question: should local traditions in science be viewed as an essential source of information and knowledge, or should a universal language be sought instead?

One important by-product of ethnosciences is that they can serve in softening the inevitable clash of civilizations in the near future. Actually, in the light of recent development of global politics, many people definitely see this as an aim rather than a by-product. Samuel Huntington (1993) points out that the growth of civilization-consciousness and fundamentalism are enhanced by the dual role of the West[20]. The West at the peak of its power confronts non-Wests that increasingly have the desire, the will and the resources to shape the world in non-western ways. The quest of the non-western civilizations is to modernize, but not to westernize (ibid.). Since science does not, in my opinion, belong only to Europeans and Americans, it has to be adapted to the different cultures of different people. Huntington states that deep-rooted cultural characteristics and differences are less easily compromised and resolved than politics or economics (or, in my opinion, the teaching of Computer Science). The concept of a global world is intimately related to the emergence of religions of conversion, essentially the Christian and Islamic faiths (D'Ambrosio, 1997). The very notion that there could be a "universal civilization" is a western idea, and directly at odds with the *particularism*[21] of e.g. most Asian societies and their emphasis on what distinguishes one people from another (Huntington, 1993).

## 4.2 Criticism of Ethnosciences

In the United States, current ethnomathematics has been criticized for several reasons. Eglash (1997b)[22] states that the currently existing trend of primitivist romanticism and orientalism can be as damaging as racism. When mean-spirited talk of "savages" changes to well-intentioned romanticism of "children of the forest", the portrait of

[20]On one hand, the West embodies a triumph of economic success and globalization, but on the other hand, it represents unfavorable values that encourage sometimes even hostile back-to-roots phenomena in non-western civilizations.

[21]Particularism is exclusive adherence to, dedication to, or interest in one's own group, party, sect or nation (American Heritage Dictionary of English Language, 2000).

[22]Eglash's text can also be found in `www.rpi.edu/~eglash/isgem.dir/texts.dir/multcrit.htm` (May 5th, 2002). The text on the web page (also by Ron Eglash) is a summary of the original.

indigenous people as unconscious, animal-like extensions of the ecosystem does not change (ibid.). Eglash continues claiming that the present multicultural Mathematics education fails in applying real examples of intentional indigenous Mathematics in curriculum. What he criticizes is that what goes under the name of multicultural Mathematics is too often a cheap shortcut that merely replaces "Dick and Jane counting marbles" with "Tatuk and Esteban counting coconuts". That multiculturalism is used only in basic contexts unintentionally implies primitivism, e.g. that mathematical concepts from African cultures are only child-like (ibid.). Eglash's third remark is that the essentialist approach leans too heavily on the crutch of "self-esteem", as if all cultural barriers could be reduced to a self-imposed shame. Also, a child from Puerto Rico may find himself or herself confronted with a situation in school where he or she is expected to automatically be familiar with artifacts from the universe of Latin American societies, e.g. the Incan llamas, simply because he or she is "Latina".

The comment that Sirkku Hellsten (2001) makes about African philosophy should also be mentioned here. It should be noted that since the theory of computing is universal, a certain approach or interpretation is considered non-western primarily because of its non-western problem field and application area, or because of the ethnic background of the author. Hellsten also makes a point that it is often hard to outline what is meant by "African philosophy". If the mythological worldview represents the philosophy of a certain culture, then Finnish philosophy would be represented by the mythical worldview of the Finnish national epic Kalevala — a statement that most Finns discard as ridiculous. When a foreign researcher investigates a culture, they may be able to find distinctive characteristics that they then might label as ethnocomputing. In my opinion, an outsider's understanding of objectivated cultural traits is always an interpretation that may emphasize inessential features, or even misinterpret concepts. The problem that arises from this is how to extract the culturally bound computational ideas without letting the culture of the investigator interfere with them.

Marianne M. Jennings (1996) criticizes multicultural Mathematics education as being "MTV math"[23]. She claims the new Mathematics textbook "Secondary Math: An Integrated Approach: Focus on Algebra" concentrates on insubstantial things such as essays on the Dogon tribe of Africa, questions such as "what role should zoos play in

[23]Jennings apparently refers to Music Television, which broadcasts mainly superficial images of a perfect "party-society". The programs keep continuously flashing "fact boxes" that bring out the names of the pets of the stars and other such information.

today's society" et cetera. Jennings' view is that the educators have "taken math out of math", thus stripping the discipline of the beauty of Mathematics. MTV Math, she states, offers only brief, superficial glimpses of numbers, disguised in inane problems even children find laughable. In her article, Jennings demands that the teaching of the conceptual understanding of math should be replaced with problems and practice. Another text of Jennings on the same subject was quoted by senator Robert Byrd (1997) in his speech for the Senate, although Byrd's uppermost concern seems to be that the U.S. is falling behind Japanese in Mathematics. However, what Byrd does not take into account, is that the tests used to compare children from different countries emphasize some aspects of Mathematics (e.g. rote learning), but not necessarily understanding of the concepts.

Bill Barton (1998) states that if science (Mathematics in his case) is seen as a cultural approximation of the truth, its merits can be measured in terms of closeness to the ideal. He continues that this allows colonial, ethnocentric categorizations of primitive Mathematics or sophisticated Mathematics etc. Where I think Barton falls short in his analysis is that he limits his view to the Platonic view of ideas, where phenomenal world, or the world that we derive through our senses rather than our mind, is secondary to the ideal world. Plato actually rejects the study of the phenomenal world as unimportant (Saarinen, 1985). Instead, if the ideas are understood in the Kantian sense, we are unable to reach the noumenal[24]reality. According to Kant, knowledge and understanding relate only to the phenomenal world, and cannot even in theory reach the thing as itself; *das Ding an sich* (ibid.).

Now, measuring closeness to the ideal loses its meaning, since there is no standard for comparison. If we see the ideas in the above-mentioned way, we are able to measure out only how well the culturally bound computing works in where it is applied, but this would be self-justifying, as mentioned earlier. The comparison would be based on a subjective scale, since the applications are also culturally bound. Then again, Kuhn (1962) points out that it is inevitable and natural that paradigms are evaluated by the criteria they dictate for themselves. Since no paradigm ever solves all the problems it defines, and since no two paradigms leave all the same problems unsolved, paradigm problems always include the question " *which problems is it more significant to have*

[24]In the philosophy of Kant, an object as it is in itself independent of the mind, as opposed to a phenomenon; also called thing-in-itself — *das Ding an sich* (American Heritage Dictionary of English Language, 2000).

*solved?*". This question of values can be answered only in terms of criteria that lie outside of normal science altogether (ibid.).

Another model where Barton (1998) shows pitfalls is seeing science as if the science within each culture would be a shadow of the "real" science. According to this view, as cultures interact, the science which is more developed will subsume the other, and an illusion of one science developing towards a universal perfection is maintained. This view would allow us to say that some cultures are "seeing" science more truly than others, and the hegemony would continue (ibid.). This is where the study of ethnocomputing faces a choice.

In respect to Barton's (1998) notion and the question of universal language in statistics referred to above (Desrosières, 1996), different approaches for the study of ethnocomputing could be set. First, the aim of the study of ethnocomputing could be to totally differentiate computing between different cultures, so that all the differing cultures would be equally important as such, and that concepts foreign to a culture should not be introduced in it. Second, the aim of the study of ethnocomputing could be to seek the ultimate synthesis of culturally bound views on computing, and claim it to be all-inclusive and ethnically fair.

Clearly the first approach concentrates on how computing is best taught among different cultural groups, and the second one focuses on developing the Computer Science towards a common goal. Thus, I shall name the approaches *differentiating study of ethnocomputing* and *integrating study of ethnocomputing*, respectively. Both approaches have apparent flaws. The first one could be criticized for excessive insularism, but it is supported by the claims that human nature seems to require borders to distinguish *us* from *them*, and that nations will continue to serve the purpose of power elites that will preserve sovereignty and distort the information infrastructure to serve this end (Townsend & Bennett, 2001; Hall, 1992). The second approach could be criticized for lack of consideration towards particularism in many cultures, and claimed to be building up a "McDonaldization" of science, but it is supported by the arguments that all civilizations, though they differ and develop at different pace, have always been bound together inextricably (Anderson, 1990), and it is also supported by my conjecture that a common set of concepts could ease the co-operation in education and science across cultures. Since neither of these approaches is clearly better than the other, but actually support the other, they are both equally important in developing ethnically fair computing. Ethnically fairer Computer Science supports the teaching of computing in different cultural settings, and teaching that takes into account the cultural origin of the students produces fresh, creative views on Computer Science on the whole.

The goals of the study of ethnocomputing should not be tied too strictly to any of the Torres' (1998) variations of multiculturalist movements (see paragraph 3.2). Still, I find developing an ethnic and cultural literacy more important than developing a pride of one's ethnic identity. Both changing attitudes and promoting multicultural competence are equally important goals, as are developing proficiency in basic skills and educational equity. Pursuing individual empowerment and achieving social reform are easily labeled as political issues, but if those connotations are dropped, both can be harnessed to bridge the digital divide.

# 5 Ethnocomputing

My definition of ethnocomputing is a *postpositivist*[25] one in a sense that the noumenal world is thought to exist, but its objects are unapproachable. Still, the heavy emphasis on the social construction of concepts leans the idea towards constructivism. The culture and society are thought to be in constant interaction with the concepts of computing, all changing in the process. My view is still apart from radical constructivism, which starts from the assumption that there is no way of knowing about the reality of other people (Glasersfeld, 1995). Although there are certain dangers in moving between paradigms, methodologically (but also theoretically) *triangulation*, for example, is sometimes used when a multimethod approach is needed (see, e.g., Cohen & Manion, 1985, pp.254-). In this chapter, I shall briefly discuss the current debate, define the term *ethnocomputing*, and finally propose a few examples that I reckon to be among ethnocomputing.

## 5.1 Computing and Society

According to Barton (1998), Computer Science as a tool has evolved in response to its surroundings. Thus, starting from its birth, Computer Science has been culturally dependent. It could be said that the value of Computer Science is merely instrumental. For example, Dan Bricklin (2001) acknowledges that we use information technology because of what it can do for us, not for its inherent qualities. Its benefit to society is that today's people can use it to fulfill today's needs (ibid.). Karen Holtzblatt (2001) notes that since technology is fundamentally just an extension of the stick when the arm cannot reach, any discussion of the future of computing has to consider its use in human practice. The lack of adaptability in software products is already a problem among the major segments of society, Cherri Pancake (2001) writes. She argues that the only solution for the problem is that the software products become more responsive to humans in all their diversity.

Luke Hodgkin (1976) and Brian Martin (1988) claim that a large sector of scientific work, especially Computer Science, is organized directly around and for capital and

[25]In postpositivist paradigm, the reality is assumed to exist, but to be only imperfectly apprehendable because of the basically flawed human intellectual mechanisms and the fundamentally intractable nature of phenomena (Guba & Lincoln, 1994).

actual or potential military applications. Anita Borg (2001) chooses a softer approach, stating that as a field, computing has been driven by technical or scientific goals. The great challenges, she writes, have been framed in terms of the technology we want to create — the fastest, smallest, hottest, biggest or coolest. Instead, the research and the creation of technology should be driven by what people need and want (ibid.). Technology, Borg envisions, should be based on the degree to which it successfully addresses a societal challenge instead of being one of those "—ests" mentioned earlier; technology should be directed to improving human life (ibid.).

Still, in the field of Computer Science the discussion of the social and ethical concerns of technology (e.g. Mason, 1995; Laudon, 1995; Collins et al, 1994; Huff & Martin, 1995) has been one of the few social topics concerned. Friedman and Kahn (1994) state in their article that the social and ethical concerns are definitely an integral part of designing computer systems, but that they were at that time, 1994, absent in Computer Science education — although they actually are already mentioned in the curricula proposition in 1991 (Tucker et al, 1991). In 1996 the Project ImpactCS (Martin et al, 1996) proposed how teaching ethics and the social impact of Computer Science should be embedded in the curriculum. As late as in the proposition for curricula at the end of 2001, the "Joint Task Force for Computing Curricula" included "social and professional issues" in the new report (ACM, 2001). In other fields plenty of research on the information age and information technology can be found. Philosophers, for example, are debating the meaning and effect of artificial intelligence and computing for their discipline (Graubard, 1988; Floridi, 1999).

Sociologist Manuel Castells (1998) claims that contrary to the common belief, information technology is not the cause of the changes we are living amidst. Without new information and communication technologies, though, none of the things that are changing our lives would have been possible (ibid.). In Castells' opinion, information and communication technology *per se* do not solve any problems, but are the functional equivalent of electricity in the industrial era. He sees information and communication technology as the essential tool for economic development and material well-being. Castells characterizes the conditions of development so that cultural and educational development conditions technological development, which conditions economic development, which conditions social development; and this stimulates cultural and educational development once more (Figure 2)[26]. Castells notes that this can be a

[26]Castells did not present the picture, but it is added to clarify the idea.

virtuous circle of development or a downward spiral of underdevelopment — and the course of this process is not decided by technology, but by society (ibid.).

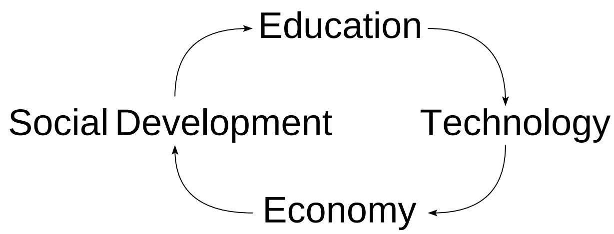


Figure 2: Conditions of development.

Up to now, the studies seem to have centered only on the social and ethical impact of computing on society, and not the other way round. Although Castells (1998) mentions the circle, he focuses on the social consequences of the information age. In my opinion, the impact of society on the development of Computer Science is an equally important and interesting question. Indeed, Keith Miller (1988) writes that technical issues are best understood — and most effectively taught — in their social context, and the societal aspects of computing are best understood in the context of the underlying technical detail. He claims that including societal aspects in the Computer Science curriculum can enhance students' learning, increase their motivation, and deepen their understanding. The goal of recognizing ethnocomputing is not to give the computational methods of other cultures a western stamp of approval, but to recognize that they are, and always have been, important as such.

## 5.2 Definition of the Term

The etymology of the prefix *ethno*-traces back to the Greek word *ethnos* meaning "people", "nation" or "foreign people" (American Heritage Dictionary of English Language, 2000). In the context of ethnocomputing, though, *ethno* does not refer to race or people only, but also to differences in culture. Of course, these cultural differences may include differences based on racial oppression or nationality, but they are mainly based on language, history, religion, customs, institutions, and on the subjective self-identification of the people — these are the social, economic and cultural backgrounds that Huntington (1993) mentions when he defines civilization as a "cultural entity".

Moreover, Huntington states that people of different cultures have different views on the relationships between god and man, the individual and the group, the citizen and the state, parents and children, husband and wife; as well as differing views on the relative importance of rights and responsibilities, liberty and authority, and equality and hierarchy. These differences between cultures are a product of centuries, and they will not disappear rapidly (ibid.). They are far more fundamental than differences among political ideologies and political regimes (ibid.). In addition to these categories, culture is here expanded to include also the cultures of differing professional groups and age classes (D'Ambrosio, 1985) as well as social classes, gender, and so on.

Definitely, as Brian M. Bullivant (1993) stresses out, the term *culture* is often used in several confusing ways. He points out that people belong to, or live in, or are members of social groups; they are not members of "culture". Along with this notion, he defines culture as a social group's design for surviving in and adapting to its environment (ibid.). However, culture is here defined as the ideations, symbols, behaviors, values, knowledge and beliefs that are shared by a community (Banks & Banks, 1993). The essence of a culture is not its artifacts, tools or other tangible cultural elements, but the way(s) the members of the group interpret, use, and perceive them (ibid.). An artifact may be used in different cultures in very different ways and for very different purposes — computers are a good example of this.

There is certainly a need for this broad a definition of culture to ensure that none of the cultural groups that might have privileged knowledge are excluded from the study. Nel Noddings (1995) writes that from the view of "standpoint" epistemologists, women have privileged knowledge with respect to issues of their gender, the poor with respect to poverty and so on. He adds that standpoint theorists do not believe that we come closer to truth by confessing the biases and rooting them out. On the contrary, they claim that such standpoint-laden claims and reports are epistemically richer and more accurate than those generated through traditional objective methods (ibid.).

As Dennis Tsichritzis (2001) points out, after Church's thesis in 1936, computing has been understood as something that Turing machines or similar models can compute. However, he reminds that this definition of computing is rather limited. Most of the interesting problems are thought to be insolvable, though they are practically solved using different kinds of heuristics (ibid.). Differently from the traditional constrained view, using Gibbs and Tucker's (1986) definition of Computer Science as a basis, *computing* is here defined as a combination of

1. the organized structures and models used to represent information (data struc-

tures),

2. the ways of manipulating the organized information (algorithms),
3. the mechanical and linguistic realizations of the above, and
4. the applications of all of the above.

Rather than changing the science itself (the content), the goal of the study of ethnocomputing is to concentrate on the form (the outward appearance) of computing. In other words, the aim is not to question the very foundations of computing. It is the way in which the computational concepts are presented that ethnocomputing has particular interest in. Instead of being another paradigm itself, the study of ethnocomputing aims at encouraging the search for novel ideas, and their examination and adoption. There is no reason to believe that the idea behind the universal Turing machine[27], for example, would not belong to the foundations of Computer Science in any culture. Instead, there is reason to believe that the form that the concept of the universal Turing machine takes, or how it is taught best, may differ from one cultural setting to another. As shown before, Berger and Luckmann (1966) and Banks (1993a), among others, suggest that reality is a social construct, and that knowledge reflects the social, cultural, and power positions of people within a society.

## 5.3 Relationship Between the Universal and The Particular

The internal tension in the term ethnocomputing is intentional. *Ethno* represents particularity and *computing* universality, and a combination of the particular and the universal leads to computing activity that takes its place within a culture. The concepts of ethnocomputing can manifest as direct applications in real-life situations, or as objects among cultural groups (such as the quipu, which we shall discuss later), and they reflect the traditional practices of a culture. It should also be noted that the study of ethnocomputing is not the study of ideas of non-literate people, like Ascher & Ascher's (1986) ethnomathematics is. It is rather a study of the ideas of culturally different groups —

[27] The idea of the universal Turing Machine is one of a "generic" Turing machine that can — for any problem that can be solved by Turing machines — produce a Turing machine that solves the problem in question (see, e.g. Lewis & Papadimitriou, 1998).

whether or not technically advanced. It is necessary to understand how computational concepts are born, conceptualized and adapted into the practices of a society.

As I see it, the apparent development of Computer Science within a culture is actually a process of change in that particular culture's ethnocomputing. The process should be seen as development within one culture, and not in absolute terms, since the concepts that form the ethnocomputing of a particular culture may not fit in other cultures that use different constructions of ethnocomputing, or in other cultures that have different priorities for Computer Science. Kuhn (1962) states that different eras of normal science may raise new questions that were earlier thought to be insignificant, and may also render some of the as far essential questions pointless. Similarly, I see that apparently significant findings in science relate to preferences of one culture, and they must be dealt with as such.

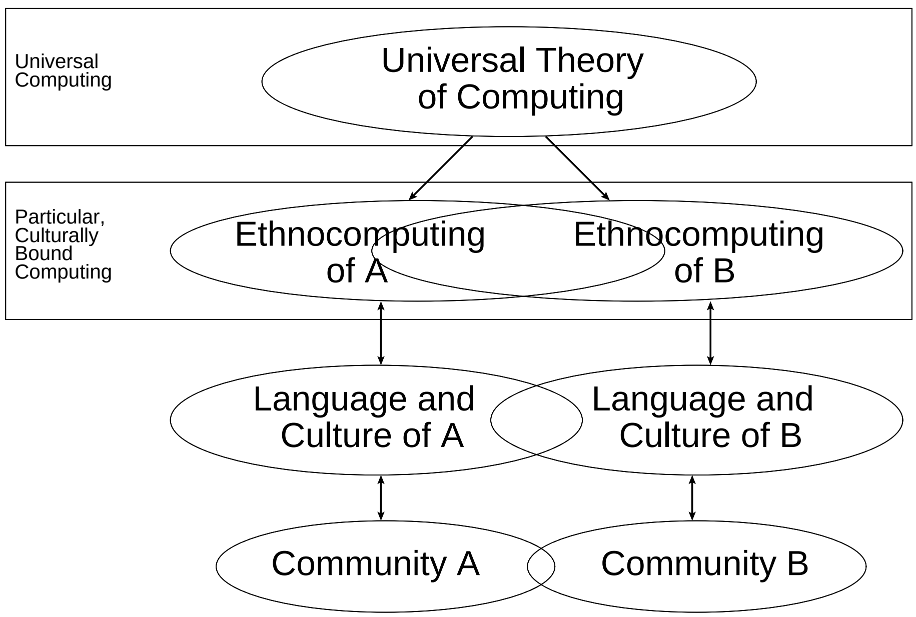


Figure 3: The relationship between particular and universal computing.

Figure 3 represents my idea of the layers of knowledge. Community A could represent, for example, the IT users at Finnish countryside, whereas community B could be the programming elite of the Seoul National University. Thus, a community is a group of people forming a distinct segment of society, or even a segment of the humankind as a whole that shares some cultural characteristics. A person may, of course, belong to many communities. Distinct communities may have their own language and culture, but the languages and cultures of different communities may also overlap. The relationship works both ways; language and culture also change (and sometimes define) the community. The universal theory of computing includes computational ideas in the Kantian sense. We can only acquire knowledge confined to the appearance of the ideas, but we cannot reach the noumenal reality, *das Ding an sich*. The layer of ethnocomputing represents the appearance of the concepts to us. Different cultures may have different abstractions of the concepts, and these abstractions can overlap. It must be noted that all the knowledge attached to the universal phenomena is culturally bound and thus inter-subjective.

Since my idea of the social construction of concepts in Computer Science has a claim of the existence of a universal theory that is static and objective, and also a claim that this theory is filtered to us through culture, it can be criticized for various reasons. Due to the great number of different theories that criticize each other (positivist, constructivist, or critical-Marxist theories, for example), I will here leave out the debate over different paradigms. Especially susceptible to criticism my view is in its attempt to take influences from two very different paradigms (Denzin & Lincoln, 1994). However, since I am not trying to present a paradigm, but a perspective or interpretation — a less developed system than paradigm — this moving-between should be allowed (ibid.).

## 5.4 Examples of Ethnocomputing

According to Denning et al. (1989), Computer Science and engineering is the systematic study of algorithmic processes — their theory, analysis, design, efficiency, implementation, and application — that describes and transforms information. This definition of the western Computer Science includes all of the four items in the above-mentioned definition of computing. The first item (data structures) is a part of both "theory" and "design"; the second item (algorithms) is dealt in "analysis" and "efficiency"; the third item (mechanical and linguistic realizations) in "implementation"; and the last item (application) naturally in "application". Thus, western Computer Science can be regarded as "computing" by this definition — and, due to its cultural roots in the western society, as ethnocomputing in the western settings.

### Artificial Intelligence

The importance of a non-traditional view on Computer Science is emphasized with the emergence of the new types of problems related to artificial intelligence. Characteristic of these new problems is that they cannot be solved using syllogistic (classical Aristotelian) logic, but need multivalued logic, often called *fuzzy logic* — that is, the logic that underlies inexact or approximate reasoning, Lofti Zadef (1984) says. In his opinion, multivalued logic was taken into Computer Science to serve the needs of real-life situations. Zadef states that in classical two-valued systems, all classes have sharply defined boundaries (dead-alive, inside-outside), and each object is either a member of a class or not a member of a class. However, most classes in real world do not have sharp boundaries (how are the boundaries of beauty, kindness, or tallness defined?). The classes with blurred boundaries are the cases where multivalued logic comes in handy (ibid.).

Another example, John McCarthy's (1980) circumscription logic, if used in a heuristic program, has to include domain dependent heuristics for what circumscriptions to make and when to take them back. Circumscription will allow us to conjecture that no relevant objects exist in the categories of a problem except those whose existence follows from the statement of the problem and common sense knowledge (ibid.). For example, when solving *Missionaries and Cannibals* puzzle[28], circumscription disallows the solutions where missionaries can fly, or where a bridge is found upstream, and other unrelated solutions (ibid.). Circumscription, heuristics and multivalued logic are used in attempts to formalize human-like processes (Ascher & Ascher, 1986) that are culturally bound. For example, the Hindu, Chinese and Japanese cultures have contributed to the development of fuzzy logic more than western science (Zadef, 1984). In these cultures, there is a greater acceptance of a truth-value that is neither perfect truth nor perfect falsehood (ibid.).

## Inca Quipu

The Inca *quipu* that Marcia and Robert Ascher's work (1981) illustrates is a good example of ethnocomputing. Instead of writing, Incas used quipus to record and transmit information throughout the vast Inca Empire (ibid.). A quipu is a collection of dyed cotton cords with knots tied in them, where the number of cords can range from three to several thousands (ibid.). Ascher & Ascher state that quipus have three important properties. First, they can be assigned horizontal or vertical direction, thus giving the cords and knots properties *before*, *after*, *above* and *below*. Second, they have multiple

[28]"Three missionaries and three cannibals come to a river. A rowboat that seats two is available. If the cannibals ever outnumber the missionaries on either bank of the river, the missionaries will be eaten. How shall they cross the river?"

levels, and a hierarchical structure. Third, they consist of cords and spaces between cords. The cords can thus be associated with different meanings depending on their color, their vertical direction, their level, their relative positions along the main cord, and, if they are subsidiaries (on lower hierarchical structure), on their relative positions within the same level (ibid.) (Figure 4).

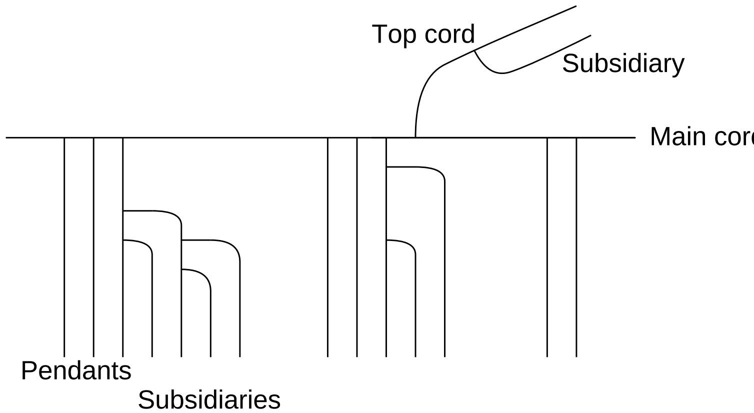


Figure 4: A blank quipu.

As Ascher & Ascher (1981) note, using color-coding is also familiar to western culture. For example, in the field of electronics, the resistance and accuracy of resistors is represented with a certain color code, where colors and their positions are associated with the properties of the component (ibid.). Similarly, in the Inca quipus, the number of colors represents the number of distinctions being made, and the overall patterning (combining different colors to one, multicolored cord) exhibits the relationships that are being represented (ibid.). The features whose meanings for color and meanings for positions used in combination with each other are shared by the resistor color system and the quipu (ibid.). In quipu, the knots tied to the cords represent numbers.

Table 1: Inca quipu as ethnocomputing.

| *Requirement* | *Inca quipu* |
|---|---|
| Data structures | Semantics coded in colors, knots, and hierarcy of the cords |
| Algorithms | Summation, categorical summation, charts etc. |
| Mechanical and linguistic realizations | Some quipus exist, language has disappeared |
| Applications | Hints of their use e.g. in accounting |

Since, according to Ascher & Ascher (1981), quipu did not serve merely in recording numbers in the form of knots, but had also semantics for different colors and these semantics were relative to context, quipu meets the first requirement of my definition of *computing* (Table 1). Quipu is a structure that represents organized information, and can be considered as a data structure. Ascher & Ascher present a number of algorithms for quipu, including summation, categorical summation, charts and sub charts et cetera. Thus, the second requirement is met. Requirements three and four; mechanical and linguistic realizations and the applications are presumable, but since the Spanish destroyed almost all the quipus along with the Inca civilization (ibid.), there is no evidence of what the use of the quipu has been. Even though the four hundred remaining quipus have been taken out of their context, and their origin is unknown (ibid.), it can be assumed that the quipu has served a sophisticated computational function in the Inca society.

## Bamana Sand Writing and African Fractals

Ron Eglash presents a few interesting points of view to recursion in ethnomathematics. These could be applied directly into Computer Science education in certain African cultures, and it might be possible to take this idea of recursion into other teaching contexts as well. Eglash (1999, 223) states that in addition to the apparent benefits of utilizing indigenous knowledge for development and education in Africa, African fractals can also serve in education in the United States. It is his opinion that fractal design tools should be applied in the curriculum of especially African American students, since the African connection can spark the interest to the study of recursion among them. The Bamana sand divination (Eglash, 1997a) works as an indigenous example of recursion. The Bamana diviners pass the outputs of an operation back to it as the new input, and iterate the process until certain criteria are met (ibid.).

Eglash (1999) also suggests developing the African continent by interconnecting African fractals (indigenous design) and modern computing. He mentions a few existing applications such as a Ghanaian national television broadcast test pattern and projects in Burkina Faso that combine traditional fractal architecture with modern techniques. Eglash's vision is further still in the future. He sees "grass roots" rather than top-down approach as the tool for putting African fractals to work for sustainable development. As examples of promising targets for development, Eglash mentions organizing production and vending, decentralized electronic voting (decision making in many African cultures is traditionally decentralized) and neural-net style decision-making. Eglash admits that neither the African fractals framework nor dissemination of information technologies offers panaceas. Rather, he suggests, the shift in perspective does not need to be a conservative return to the past, nor the epistemological equivalent of an alien invasion. African fractals offer a framework that is both rooted in indigenous cultures, and cross-pollinates with new hybrids (ibid.).

Ethnocomputing seems to be important especially in the new fields of research such as artificial intelligence and fuzzy logic. In my opinion, though, ethnocomputing has been given a chance only in the new research — or ethnocomputing has lead to new fields of research. Current normal science does not give ethnocomputing of non-western cultures much chance to introduce new views into old themes. My opinion is that different cultures can contribute to the development of concepts and ideas and enrich them — also in the traditional fields of Computer Science.

In addition to the development of Computer Science and education, ethnocomputing holds another equally important objective. As Ubiratan D'Ambrosio (1997) recognizes, ethnoscience (ethnomathematics in his case) means going back to basics with the common goal of equity and dignity. In his opinion, the Eurocentric conception of science has been imposed globally as the pattern of "rational" human behavior. The results of this intended globalization under the control of western powers are far from being acceptable (ibid.). The study of ethnocomputing could encourage the ethics of respect, solidarity and co-operation across cultures. Eventually, if science were equally available to all, ethnically fair by nature, and local cultural bindings were admitted, the ultimate goal of getting rid of the *ethno*-prefix could be accomplished.

# 6 Summary

The purpose of this study was to justify the research of cultural perspectives in Computer Science. The claim was that the contemporary Computer Science is dominantly Eurocentric, and that this Eurocentrism facilitates the digital divide and hinders the prospects of Computer Science education in non-western cultures. The motivation to a cultural approach was the assumption that adopting cultural perspectives into Computer Science would bring local issues into global discussion, and thus help in meeting the local needs.

I have proposed a social constructivist theory into Computer Science, suggesting that Computer Science is a social product, and that there exists a dialectic relationship between computing and society. This claim is supported by the social constructivist theories in sociology and educational psychology as well as the idea of how scientific revolutions are structured. Moreover, I have presented that Computer Science is dominated by the preferences of the West, and that this Eurocentrism can pose a problem in Computer Science education in non-western cultures.

From these grounds, I have presented definitions for ethnocomputing and for the study of ethnocomputing as follows: *ethnocomputing* stands for computational ideas that have their roots within a culture. The *study of ethnocomputing* is defined as the study of computational phenomena within a culture. Ethnocomputing differs from the traditional definition of computing in that whereas the traditional view considers the foundations of Computer Science as constant and applicable everywhere as such, the study of ethnocomputing takes the position that Computer Science is a social construction, and thus culturally bound.

All the local variations of ethnocomputing have developed to meet the needs of a certain culture, which has the following consequences: first, the impact that Computer Science has on the culture reflects back to Computer Science, changing it — and this leads to a dialectic process where Computer Science and the culture in which it originates are constantly reshaping one another. Second, together with the definition of layers between particular and universal computing, comparisons between computational ideas of different cultures become groundless. There does not exist a standard for comparison, since every measure is subjective, and would only measure how well computing works in a culture where it is applied. For example, western standards such as efficiency and exactness are useful only in a very limited set of problems, and they may become insignificant if the legitimate problem field changes. Third, Computer Science education can no longer ignore cultural considerations. The educators have to take into account the cultural and philosophical background of a society. Different cultures may have different perceptions of time and space, logic, problem solving methods, society, values, or which questions are considered legitimate.

Adopting ethnocomputing could serve several purposes. First of all, recognizing the importance of local cultures as such would help in Computer Science education in non-western cultures. This would definitely produce first students, then researchers that have fresh, novel views on the problems of Computer Science. These researchers, in turn, would contribute to the development of Computer Science on the whole towards an ethnically fairer goal. Ethnically fairer Computer Science would in its part give developing countries better prospects to narrow the digital divide.

The hardest part of the adoption of ethnocomputing is the pervasive view of the western philosophy as the crowning jewel of scientific evolution. Current normal science is seen as good and final as such, which, in the light of history of science, is clearly a daring conclusion. Much more probable is that the future scientific revolutions will turn the direction of Computer Science to directions that are unexpected, and so far even unheard of.

Ethnocomputing is a hypothesis. There are absolutely no empirical studies whatsoever, on whether any differences between cultures actually exist. None of the theoretical background presented in this study deals with Computer Science. Thus, the next challenge of the study of ethnocomputing is to test the hypothesis by comparing the views of different cultures on Computer Science. To accomplish this, researchers from different cultures should come together to find out whether ethnocomputing is just an idea, or whether it actually has something to contribute to Computer Science.

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