Appreciating the Knowledge of Students in Computer Science Education in Developing Countries

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Abstract **Computer Science education in developing countries should take the cultural background of students into account. Not only classroom work or teaching practices, but also the science itself should be adapted into the cultural settings. Instead of trying to find problems in developing countries that Western Computer Science could solve, the goal should be to use the science creatively to solve the problems currently at hand. This kind of cultural contextualization has to start from the educational level. If Western philosophy is emphasized as the single right worldview, it definitely alienates the science from the culture it should help. We believe that appreciating the knowledge that students have about their world is invaluable when addressing the problems in their own countries. Fostering culturally bound ways of inferring, quantifying, classifying, representing, and measuring, will definitely lead to a better understanding of science because it supports the students' mental images. Also, this esoteric knowledge may well produce new ideas and fresh views on Computer Science itself.**

Index Terms— **Computer Science Education, Ethnocomputing, Social Factors, Philosophical Considerations.**

I. Introduction

Computer Science is a Western cultural product. Its foundations were laid in Europe and America, and the development of computers, computer networks, and information and communication technology (ICT) are all Western products. Being Western products, the teaching material, literature, and problem solving methods of Computer Science are dominantly Western. This inevitably causes problems in Computer Science education (CSE) in non-Western cultures, for a considerable amount of understanding about Western system of knowledge (e.g. inference, quantification, comparison, classification, representation, and measuring is assumed [1]).

"Computers are cultural products". This claim infuriates a number of technicians and engineers, who have failed to grasp the social and cultural significance of computers, and would rather see the development of computers as a part of an inevitable continuum of logical scientific progress, the triumph of the West. However, in the light of the history of computers, it is obvious that the interests of military and intelligence (from Colossus[1] to the Cold War to Carnivore[2] to nuclear reaction simulations), economics, and other sciences have guided the directions of the development of computers from the beginning.

In some projects that have involved Tanzanian Computer Science (CS) students, we have noticed difficulties in learning CS: students have had problems in programming independently (when not just copy-pasting code); theoretical, especially mathematically oriented concepts have been hard to grasp; there has emerged a fragmented learning style (rote learning and memorization); and then there are problems with the English language. But interestingly, we have also noted that the students have also created novel, culturally bound representations of concepts (e.g. for representations of data structures).

This has lead us to propose that instead of taking Western Computer Science into any non-Western culture as such, more emphasis should be put on adapting the science into the thinking of students in non-Western countries. Mental representations are hard to change: as soon as certain patterns of thinking, feeling, and behaving have been established in a person's mind, he or she must unlearn these before being able to learn something different, and unlearning is more difficult than learning for the first time [2]. The need to unlearn is unnecessary cognitive overhead, something that we could get rid of if we would concentrate more on the cultural contextualization of Computer Science education in non-Western countries.

Firstly, we would like to present Computer Science as a cultural product; secondly we will discuss the problem of the current Eurocentric CS education, and how it should be adapted in non-Western countries.

II. Science and Culture: An Impossible Equation?

Obviously, the dominating paradigm in Computer Science today is positivism. According to the positivist paradigm, an

[1] The computer that broke the German secret code in the Second World War, changing the course of the war.
[2] The computer system used by FBI to wiretap Internet traffic.

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apprehendable reality is assumed to exist, and this reality is driven by immutable natural laws and mechanisms. In the positivist paradigm, research can approach the "true" state of affairs [3]. A positivist worldview makes it possible to divide knowledge, or thinking, into "better" and "worse", according to which is closer to the "truth". Any person whose behavior, or thinking, is not predictable to the positivist, or is peculiar in any way, is slightly out of his or her mind, improperly brought up, irresponsible, psychopathic, politically motivated to a point beyond all redemption, or just plain inferior [4]. According to positivists, science can help us get closer to the true knowledge.

Unfortunately, this is also the view that the public seems to have on technology. Technology is often seen as something that is given from outside, *deus ex machina*, rather than as a product of the society. Societies embrace new technologies that the enclosed technological circles produce. However, in reality the class of experts, or technocrats, is too remote from common interests as to become a class of private interests and private knowledge [5]. The knowledge of computer scientists is inevitably detached from societal context, and their interests may rather be those of big corporations or pure science, than those of common people.

The Internet is a Western product, and its first users and developers have already shaped the Internet for latecomers, both in terms of content and technology [6]. To empower everyone to participate in shaping this international network, we feel that not mere increase in the use of technology, but a cultural contextualization of education and educational tools is necessary. Technology itself is not the reason for changes; it only makes change possible [6].

CS students occupy a special place in the development of the Internet and ICT in general. Compared to the citizens who are or become consumers of the Internet and preferably even its producers [6], Computer Science students that graduate are already producers of the ICT (not only the Internet) by definition. System designers, programmers, and computer engineers are automatically change agents in the communities that aspire to assimilate ICT.

In science, Western science is usually seen as the crowning jewel of scientific evolution. Among science and mathematics teachers, multicultural ideas are seen as irrelevant to science [7]. Since the students in developing countries may have quite differing views on the very premises of logic, perceptions of time and space, society, values, problem solving methods, or even which problems are considered legitimate, we believe that the Eurocentric view on science greatly hinders the possibilities of effective Computer Science education in developing countries [12].

If information and communication technologies are to reach their full potential in developing countries, it is imperative that the needs of the local societies work as the starting point of CSE. Our opinion is that instead of looking for problems that the Western Computer Science could solve, the focus of science has to be changed, adjusted to solve the real problems at hand in developing countries. Those problems and needs may be very different from the needs of Western countries, and adjusting education to address those needs may require us to view CS in an untraditional manner. Even though the technology would be foreign to the cultures of developing countries, the uses of technology are what matters.

When addressing the immediate needs of developing countries, we should consider how information and communication technology could be changed to help with those needs. If the problem is lack of democracy, ICT can address it. In a country with an inadequate telephone and communication system, the Internet can fulfill both needs at the same time. Illiteracy, distance education, lack of software in the native language of the people, lack of domestic technology, localization of software[3] – these are issues that Computer Science can help to solve.

Hunger, civil wars, and lack of natural resources are issues to which Computer Science does not have much to contribute – at least, not without serious cultural contextualization. Indirectly, though, ICT-based logistics technology can become useful in fighting these problems. However, more equal distribution of food or natural resources are not in the hands of scientists, but rather a political issue. It should be born in mind that having access to the Internet does not provide the basic levels of Maslow's hierarchy of needs, especially bodily needs or security needs [8]. A starving person will not be motivated by anything except the quest for food [2].

People, institutions, and society at large transform technology – any technology – by appropriating it, by modifying it, and by experimenting with it [6]. Technological systems are socially produced, and social production is culturally informed. This leads us away from positivism, toward the theory of the social construction of reality. Repetitive patterns of behavior generate customs that are first enforced by institutions and organizations, and finally adopted as something non-human [9]. In a sense we are all constructivists if we believe that learning and knowing are not just passive storing of data in a high-capacity device, the brain – but that mind processes the information somehow, at least forming abstractions and concepts of the data [10]. Science is no exception. Throughout time, people have felt their current view on science is something greater than human.

Scientific paradigms, how ever solid and eternal they seem, are nothing else than social constructs, since they are essentially the result of an agreement among a scientific community [11]. If we agree that a paradigm is the result of a consensus among scientists, we can argue that debates on knowledge claims are valid only within a restricted community in a certain era. If we can agree with this, we should leave room for other epistemologies than ours, and

[3] In here, we use the term "localization of software" to denote adapting software to a locale. The language, norms, values, and conventions of the culture need to be met, as well as the needs of the cultural group that the software is meant to fulfill.

essentially, we should give culturally bound knowledge the chance to support the students' mental imagery in learning.

Our claim of ethnocomputing [12] suggests that the conceptual understanding of Computer Science differs between cultures as well. We defined computing as a combination of four levels: the organized structures and models used to represent information (data structures); the ways of manipulating the organized information (algorithms); the mechanical and linguistic realizations of the former; and the applications of all the three former levels. Different cultures have different views on the concepts on each level, and this should be taken into account in CSE.

We think that the Western notion of the Turing Machine also represents a subjective view on numeral computing. It is necessary to understand how computational concepts are born, conceptualized and adapted into the practices in a society [13]. The dominance of only one legitimate, objective view - and the resulting rejection of practical issues - is the very reason why science fails in establishing a dialectic relationship[4] with society. A dialectic relationship with society is exactly what is needed in developing countries. Science needs to be able to adapt to the needs of the society, and likewise, the society must be able to respond to the new technologies and their uses. Otherwise science will only create new needs to those societies, and not solve anything.

III. Recognizing Culture in Education

A. *The Clustered Net*

Everyone knows something that nobody else knows, and nobody knows everything [14]. Even though the utopian future would be the appreciation of every single person individually, so that everybody would be treated as an owner of a unique combination of knowledge, human qualities, capacities, and talent, we feel that this future is not yet achievable. It is already imaginable, which means that in one point in the future we might see it happen, but the structure of the Internet, its bureaucracy and technology, and the users' imbalanced knowledge drive the utopia out of reach today.

The rules of the Internet, the technological protocols used (e.g. character sets), the uses of Internet – all these were originally defined by quite small circles. Nowadays, as the Internet has gained a good foothold also in other cultures, the Internet culture cannot anymore be reduced to Western culture.

Quite a few authors make a mistake by defining "an Internet culture" without considering local, sometimes esoteric embodiments of the culture. The Korean Internet scene, for example, is rich in nuances, and it has developed its very own ways and uses, which differ sometimes greatly from their Western counterparts – if any counterparts always even exist. The Korean use of Internet cafés is extensive; for a cheap price they offer a doorway to nation-wide entertainment, online-dating, communications, etc. For example, millions of Koreans are living another life in an interactive virtual city "lineage", where a new society has been born. It has spawned a new economy and forms of interaction.

A total of 78% of websites are in English only, which creates a substantial barrier for most people in the world. Having experience with Internet users in different countries, we claim that there is no global village, and such village will not emerge before there exists a true *lingua franca* for everybody in the world. Rather, we believe that the Internet has already clustered into fractions, that the hyperlink structure of the Internet has e.g. English, Chinese, and Korean clusters that are not strongly interconnected.

The consequences of the inevitable changes that ICT will bring can be unpredictable. Does taking ICT into feudal economies allow them to skip certain phases, going straight into postmodern, knowledge economies? These economies are extremely volatile to changes in global economy. It seems that the village economies will have to step from eroding village communities (young people leaving to the big cities once they finish school) into self-sustained communities with one access point (now in African countries usually the post office) where farms and souvenir industry may orient to addressing new markets and finding knowledge on how to optimize production methods.

B. *Education for Masses*

The structures of society still handle people in bulk, even in decision-making [14]. For example, a vote is just a statistical tool, giving no real information about the individuals. All the individuals who cast the same ballot are interchangeable, even though their concerns, needs, hopes, or motives differ greatly [14]. However, distinctively different patterns of media use among different cultural groups have been shown [15].

We think that current education also handles students as bulk on different levels. First of all, the national standards for education state what the average student will need to learn. Secondly, the books used are made to suit "a mainstream" of students. Thirdly, large class sizes cannot take individual qualities into account. Of course, these vary between countries and cultures. These broad categorizations of students are made even broader when our standards of education, scientific and philosophical foundations, and ways of teaching are taken into other cultures.

Geert Hofstede has illustrated human mental programming[5] as a three-level pyramid (see Fig.1), where *personality* is the unique set of mental programs that an individual does not share with other individuals; *human nature* is what all human beings have in common; and *culture* is the collective

[4] By dialectic relationship, we do not mean the Hegelian idea of thesis-antithesis-synthesis, but a course of change through the conflict of two forces: the society on the other side and the technology on the other side. Both constantly reshape each other in the process of change.

[5] Certain patterns of thinking, feeling, and acting that have been established in people's mind [2]. Much of the software of the mind has been acquired in early childhood, but the programming goes on throughout one's life. However, a person's behavior is not thoroughly determined by the mental programs; a person has a basic ability to deviate from them [2].

programming of the mind that derives from one's social environment [2]. We are interested in the influence of culture on Computer Science education. We see that cultural understanding works as a key to understanding how Computer Science should be taught in non-Western countries. However, rather than focusing on the level of individual differences, we still concentrate on the mass level.

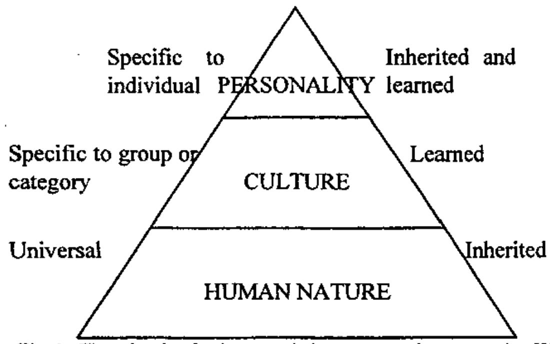

Fig. 1. Three levels of uniqueness in human mental programming [2].

Concepts of Computer Science are not inherited; they are *not* embedded in the universal human nature. They have been developed within a culture, and are learned in a community. Thus, they are specific to a group or category, e.g. Western scientific community, to some degree. Even though conceptual understanding of Computer Science shares more features *between* cultures than some other cultural aspects do, it is still a societal product.

We see culture as a powerful tool that may offer valuable instruments in Computer Science education. Instead of taking our categorizations and ideas to the developing countries, we would like to see CSE originating from the cultures, using the cultures' concepts, artifacts, and knowledge to contextualize the science.

The students of Computer Science in, for example Finland, undergo 12 years of all-round education before even beginning their Computer Science studies. This level will not be achieved for a long time in developing countries. Because of this deficiency in basic education, a wide conceptual understanding of CS is quite hard to achieve.

IV. Appreciating the Cultural Knowledge

Effective teaching depends a lot on how familiar the concepts are to the students, and how concepts are taught shapes the way the information is understood. This is named the knowledge construction process [16]. Knowledge construction process is 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 [17].

What kind of measures should we take in order to take the cultural context and cultural knowledge into account in developing countries? First of all, we agree that just teaching how to use tools is short-sighted. Some fundamentals of Computer Science have to be taught. This could be achieved if the philosophical approach of CS could be adapted into the cultures. For example, Inca Quipu [18], Bamana sand divination [19], and the origin of fuzzy logic are good examples of ethnocomputing. Especially fuzzy logic is a good example of non-Western cultural knowledge contributing to Computer Science on global level. Hindu, Chinese and Japanese cultures have contributed to the development of fuzzy logic more than Western science [20]. In these cultures, there is a greater acceptance of a truth-value that is neither perfect truth nor perfect falsehood [20].

The ideal way for students and educators to become aware of the various cultural dimensions of CS might not be studying books, but undertaking *projects* in these fields. Individuals with their unique personality and common human nature would learn about different middle-levels of culture – different epistemologies (see Fig.1). For example, ACM might add to its CS curriculum some courses that would take CS students into a new setting, with a new problem set, and a need for creative problem solving. In the ideal case, even the idea of a WWW page as a document could be challenged, for it is a highly biased shape. It is quite probable that other cultures will need different metaphors to build a relation between creators and visitors.

Because the urgent problem fields are quite different between countries, the question of what kinds of professionals are needed has to be solved. In the software industry of e.g. Finland, the majority of the people do not hold higher university degrees, and much of the work is done with visual tools (e.g. Visual Basic) and databases – which does not require profound conceptual understanding of Computer Science. Localization of existing programs needs even less education, but incorporates a lower level of cultural cognizance than programs made in developing countries from the beginning.

On the university level Computer Science education, more effort should be put on finding cultural parallels in the concepts. For example, the use of fractals in indigenous design can be used in teaching recursion [21]. Also, the emphasis should be put in creative problem solving rather than the mathematical background of CS (in which the basic education of students is often insufficient). Even though a mathematical definition of a problem and its solution has its intrinsic beauty, it is still a theoretical construction.

Admittedly, for a person to be able to collaborate in developing science, he or she has to be aware of the underlying constructions and the Western theory – if only to be able to understand and write scientific articles. But from the practical perspective, we believe that problem solving is still the most necessary skill for a computer scientist or software engineer. And the practical perspective is the foremost issue right now in developing countries. We do not want to set priorities for science and practice; we think of them as equally important.

In Western countries education and life-long learning have become essential resources for work achievement and personal development [6]. The critical matter in the Western individualist countries is less to know how to do, than to know *how to learn* [2]. As most information is online, what is really required is the skill to decide what to look for, how to retrieve it, how to process it, and how to use it for the specific task that prompted the search for information [6].

However, in collectivist societies education stresses adaptation to the skills and virtues necessary for an individual to be an acceptable group member, rather than the individualist societies' "modern man"–thinking [2].

Even though every human being is an individual, his or her thinking has developed within a culture, and follows that cultural framework at least to some extent [4]. If Computer Science education is taken into a non-Western cultural context as such, it may not take the students' cultural knowledge into account, and that being the case, is not ethnically fair[6].

In Lévy's utopian view on collective intelligence of the future, he sees that knowledge will depend on the social goals and objectives of the individual at a given moment [14]. Only a contextually vital interpretation gives meaning and value to knowledge [14]. 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 [22].

We do not believe that we come closer to "truth" by confessing cultural biases and rooting them out. On the contrary, such standpoint-laden claims and reports are epistemically richer than those generated through traditional objective methods [23]. Moreover, if Western values, philosophy, logic, and worldview are emphasized also in other cultures, does it not carry a message to the students that Western thinking is superior to the systems of knowledge of their own cultures? If students were encouraged to use the systems of knowledge of their own cultures where applicable, their interpretations would be more accurate, having tangible counterparts in the students' world.

The issue of culturally meaningful entry points to learning Computer Science should also be more evident in the philosophical approach of Western Computer Science education. Western games, society, and infrastructure are currently clearly visible in the examples of CS literature. Deck of cards or chess, family structures, and traffic arrangements, just to mention a few, are used to clarify computational concepts. They work very well in the West, and should be developed even further, but the current education system and literature are not ethnically fair.

We claim that encouraging cultural perspectives in Computer Science education would turn out to be a benefit both locally and globally. Computer Science education would gain more pragmatic factors that support the use of information and communication technology, and more authentic interpretations for computational concepts, especially in non-Western cultures. Education should supply mental support in terms of reducing cognitive overhead and allowing visual imagination through displays [12].

[6] 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. The term has been used, for example, in [15], but not with a clear definition.

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