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CULTURAL FACTORS IN THE ORIGIN AND REMEDIATION OF ALTERNATIVE CONCEPTIONS

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Abstract

Cultural Factors in the Origin and Remediation of Alternative Conceptions

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Cultural factors in the origin and remediation of alternative conceptions

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1 INTRODUCTION

In constructivism the concept attainment of students depends on their success in changing their alternative conceptions. This process of conceptual change is expected to be culturally determined. Cultural factors determine the science performance of secondary school students as follows from a number of science education publications. To what extent, however, are the alternative conceptions themselves culturally determined? This question will be the subject of this paper.

The paper starts off with a discussion of some general aspects of alternative conceptions. Then follows a brief over-view of (historical and cross-cultural) data that point to the universality of some physics conceptions. Next we discuss some methodological issues in drawing conclusions from cross-cultural studies. Then we give a brief summary of a number of articles from the science education literature that emphasize the relevance and influence of a number of cultural factors, such as language, world-view, reasoning patterns, teaching and learning style, and traditional beliefs. After overviewing the cultural factors, we then try to discuss alternative conceptions in the light of nature and nurture. We suggest a distinction between common and deeply rooted conceptions which are quite universal, and some other alternative conceptions which might be more dependent on language and culture. The paper ends with some tentative conclusions.

2 GENERAL ASPECTS OF ALTERNATIVE CONCEPTIONS

2.1 Terminology

In our paper we will use the following definitions as regards the terms: concept, conception, alternative conception, and preconception.

Concept is the scientific notion underlying a class of things or events, as currently intended by the community of scientists and documented by leading textbooks. A concept acquires its meaning through its network of relationships with other concepts.

Conception refers to an individual's interpretation of the meaning of a concept. Such an interpretation would usually have some idiosyncratic features, even if the individual is a scientist.

Alternative conception, also called misconception, refers to a conception which in some aspects is contradictory to, or inconsistent with, the concept. Such inconsistency usually shows in one or more relations of the conception with other conceptions. It thus often involves more than one concept. We only talk of alternative conceptions if alternative beliefs have some robustness and persistency across ages and levels of schooling.

Preconception refers to a conception which has been formed without exposure to formal instruction in school, also called: intuitive or pre-instructional conception, spontaneous knowledge, children's science, folk-knowledge. Preconceptions are especially interesting in cross-cultural studies as supposedly school influence has been weaker than with conceptions where school instruction in relevant concepts has occurred. Frequently however, preconceptions are taken to be the conceptions before the teaching of a new topic. Such conceptions may have been influenced by previous schooling in related topics. The term alternative conceptions include preconceptions, i.e. preconceived ideas, as well as misconceptions which arise in the student's mind because of incorrect teaching or incorrectly assimilated formal instruction.

2.2 **Features**

A number of research studies have shown that students harbour persistent alternative conceptions over a wide range of subject areas in physics (mechanics, electricity, heat, light, the particulate nature of matter), chemistry (mole concept, concept of equilibrium), biology (growth, health, photosynthesis, heredity). For an over-view, see for example: Gilbert and Watts (1983), Driver and Erickson (1983), Driver et al. (1985), and Novak (1988). Driver et al. (1985) list the following general features of children's conceptions:

D1 perceptually dominated thinking:
pupils' tendency to base their reasoning on observable features in a problem situation

D2 limited focus:
attention appears to depend on the saliency of particular perpetual features.

D3 focus on change rather than steady-state situations

D4 linear causal reasoning

D5 undifferentiated concepts

D6 context dependency.

Most student ideas are fragmented and not logically integrated (Solomon, 1983). However, if students have a lack of articulation of their alternative conceptions, it might mean that either the conceptions are rather weak, or that the conceptions are there, but students are not yet fully aware and do not yet have the terminology to express them. For example, a post-test typically has a higher reliability: either vague preconceptions have become more consistent or students now have the terminology to express their preconceptions more clearly. In other words, schooling may make alternative conceptions more clearly visible.

There are some alternative conceptions which have a cluster character. By this we mean that, in a test with qualitative questions, students answer a cluster of test-items, which refer to scientifically (closely) related problem situations, from the very same points of view. These alternative conceptions do not necessarily lack the articulation and consistency of the correct student conceptions. For example, Licht and Thijs (1990) have researched the reliability of alternative conceptions for the subject area of electricity and mechanics for the lower Forms (Grade 7-9) and higher Forms (Grade 10-12) of secondary education in a Netherlands test sample. The results are shown in table 1. This cross-sectional study indicates that reliability generally increases throughout years of schooling, both for the physical and the alternative conceptions. Also the alternative conceptions, though opted for by fewer students in higher grades, are also gradually used more coherently throughout years of schooling. In other words, coherency, be it in an alternative way, seems to be a result of instruction.

Table 1.
Reliability of students answering correct options and options relating to alternative
conceptions in multiple choice tests on electricity and mechanics.

		Electricity	*Mechanics*	
Cronbach alpha	correct	altern	correct	altern
Lower Grades		.57		.76
		.48		.42
Higher Grades	.86		.83	
	.66		.51	
All Grades		.86		.85
		.77		.54

However, it is doubtful whether alternative conceptions really deserve the status of 'conceptual frameworks' (Driver and Erickson, 1983). An *alternative framework* may be defined as a (set of) alternative conception(s) which is consistently used across a variety of contexts.
According to Kuiper (1993), secondary school students do not use alternative conceptions in a consistent way that would justify the term 'framework', they rather incoherently mix alternative conceptions and school knowledge. However, as Kuiper found, at the time students enter secondary school they make use of their intuitive preconception in a more or less coherent way, not yet being confused by contrary school knowledge which has still to be provided.

2.3 **Parallels in history**

Many authors have drawn attention to the similarity of students' conceptions at different levels of education and historical conceptions of Aristotle, Galileï, Buridan and other pre-Newtonian scientists. Nussbaum (1983, 1989) writes that such parallels had been noticed much earlier, amongst others by Piaget in 1962. Nussbaum then cautiously extends the parallel to conceptual change. He contrasts conceptual change in history according to various philosophies of science and suggests the equivalent alternatives for conceptual change in students. It should be pointed out that one of the major differences between preconceptions of students and the historical conceptions is, that the conceptions of scientists like Aristotle, Euclid, and Buridan, must have been much more articulate and consistent than those of students.

2.4 Relevance of cross-cultural comparisons

Cross-cultural comparison of alternative conceptions may provide important information on which variables do and which do not influence the formation of conceptions about nature and natural phenomena. For example, does the natural environment influence peoples basic conceptions of physical phenomena or not? Do people in the tropics develop different conceptions about light and seeing than Eskimos in the arctic or people in the moderate zones? Does culture affect formation of school physics concepts? Do linguistic factors affect concept formation?

Cross-cultural comparisons usually concern contemporary comparisons between cultures and peoples. However, comparisons of beliefs and conceptions of people in the past with beliefs and conceptions of people at present can also be called cross-cultural. In spite of the fact that present day western culture may have roots in the ancient Greek world, Aristotle and Euclid lived in a very different culture and technological environment, so did Al-Hazen and other Arab scientists. Even Galileo, Copernicus, and Newton lived in a different socio-cultural and technological environment compared to today's world. Therefore a comparison of science conceptions today with those of scientists in the past could be called cross-cultural.

3 UNIVERSALITY OF SOME PHYSICS CONCEPTIONS

In this section we discuss data supporting the universality of alternative conceptions in a few subject areas in physics, i.e., mechanics, heat and temperature, light and electricity. For each area we summarize the main alternative conceptions found among students in western countries; then we indicate historical parallels in that area; and finally we briefly report on similar findings in non-western countries.

3.1 Mechanics

In mechanics the subject area of 'force and motion' evokes particularly strong alternative conceptions. It has been well established by research (Champagne et al., 1980; Minstrell, 1982; Watts, 1983; Clement, 1983; McDermott, 1984; Halloun and Hestenes, 1985; Gunstone and Watts, 1985; Licht and Thijs, 1990) that many secondary school students in western countries harbour the following alternative conceptions:

(a) *Associating force and motion*

In a rest situation no forces are present; an object moving at a constant velocity requires a force in the direction of the motion; a force exerted on an object is imparted as an acquired 'impetus'; the impetus of a moving body is gradually weakened, resulting in a decreasing velocity (in the absence of a force); an increasing velocity requires an increasing force in the direction of the motion.

(b) *Associating a force with a single agent*
Events are not described in terms of a symmetric interaction between objects. In collision of balls, a force is attributed either to the ball which is perceived to initiate the collision, or to the ball which is perceived to be dominant in terms of innate properties (size or mass). In particular the second alternative conception is resistant to change.

(c) *Not differentiating various aspects of a motion*
No clear distinction between velocity and position, velocity and acceleration, velocity and force. Students have a tendency to define motion with respect to an absolute frame of reference, such as the ground.

Some remediation studies on western students (e.g. Minstrell, 1982; Champagne et al., 1985; Clement, 1987; Thijs, 1992; Thijs and Bosch, 1993) have been published; they report on some successful approaches to promote student conceptual change in the area of force and motion.

Saltiel and Viennot (1985) observe that students' reasoning in mechanics is often reminiscent of historical stages of the corresponding theories. Impetus theories go back as far as the 6th century (Philipon) and were developed mainly around the 14th century; they were still at the background of Galileï's thought. Steinberg, Brown and Clement (1990) state that even Newton's development of his system of mechanics was hampered by a persistent belief in 'the force of a (moving) body', force as a property, and transfer of force. Halloun and Hestenes (1985) remark that Buridan's formulation of the impetus concept is a clear articulation of the more or less vague student intuitions. The impetus concept is a historical precursor of the concepts of momentum and kinetic energy. Whitaker (1983) exclaims 'Aristotle is not dead' and quotes Dijksterhuis (1961, p.30): *To this day every student of elementary physics has to struggle with the same errors and misconceptions which then had to be overcome, and on a reduced scale, in the teaching of this branch of knowledge in schools, history repeats itself every year. The reason is obvious: Aristotle merely formulated the most commonplace experiences in the matter of motion as universal scientific propositions.*

Cross-cultural research in mechanics includes the following. Thijs (1987, 1988) studied conceptions of 195 Dutch and 428 Zimbabwean high school students as a function of instruction. Wolff et al. (1988) assessed mechanics conceptions of 77 teacher education students in Indonesia using a mixture of multiple choice and essay items. They also compared with the results obtained with the same instrument (but in English or Dutch) in Lesotho and the Netherlands. Boeha (1990) interviewed 21 grade 12 students in Papua New Guinea on the forces acting on a softball during its flight after being hit and found "Aristotle alive and well in Papua New Guinea science classrooms" as is the case in other countries. Arum and van den Berg (1990) studied

Indonesian student ideas on forces in rest situations, testing 450 and interviewing 20 high school students. Alternative conceptions of force and friction were similar to those found elsewhere and conceptions were quite consistent across test formats. Lee et al. (1992) conducted a study among 485 Grade 10 students in Malaysia. More than half of the students did not see the need for a force in a rest situation; the impetus idea surfaced in more than half of the sample. Kuiper (1991) tested 512 urban and 364 rural students of different grade levels (Form 2-6, or Grade 8-12) in Zimbabwe and interviewed 25 students on ideas about force. With the same instrument he also investigated small samples of students from Botswana, Lesotho, and Swaziland, and a larger sample (266 students) from the Netherlands. Results included most of the alternative conceptions reported by the research studies carried out in western countries. Thijs et al.(1993) report on some remediation studies among students in Botswana. These studies have results as expected on the basis of the western remediation studies.

3.2 Heat and temperature

Studies regarding conceptions of heat and temperature (Erickson, 1979 and 1980; Stavy and Berkovitz, 1980; Shayer and Wylam, 1981; Wiser and Carey, 1983; Erickson and Tiberghien, 1985) have indicated a number of alternative conceptions. The ones which would most likely be preconceptions and thus not a result of schooling are the following:

(a) Temperature is taken to be an extensive variable (thus dependent on amount of material) rather than an intensive one.
(b) Lack of distinction between temperature and heat.
(c) Perception of heat as material (caloric fluid like Lavoisier).

Especially (a) might be a preconception as independence of temperature of amount of matter is not explicitly taught in school science and this particular conception was found (amongst others) with Grade 4 students (Stavy and Berkovitz, 1980).

Carey (1992) reports a historical study of the 17th century Academy of Florence, the first group to systematically study thermal phenomena. The Academy's concept of heat *had both causal strength (the greater the degree of heat, the more ice would be melted, for example) and qualitative intensity (the greater the degree of heat, the hotter an entity would feel) - that is, aspects of both modern heat and modern temperature*. (p.97). The Academy members (who called themselves the 'Experimenters') did not separately quantify heat and temperature and did not seek to study relations between the two. It was Joseph Black in the 18th century who first distinguished heat and temperature.

In Indonesia, Kristyanto and Berg (1991) and Berg (1992) interviewed thirty students from Grades 7, 9, 10, and 11 and administered a test to 251 students from 7 junior and senior high schools representing middle to high ranked schools. The test focussed on temperature as intensive variable, the difference of heat and temperature, and specific heat as intensive property. The Cronbach alpha reliability coefficient of the test was 0.83. Results closely resembled those of researchers in France, United Kingdom, USA, and Israel, i.e. many students did not distinguish between heat and temperature, and interpreted heat as an extensive variable. Similar lack of distinction was found with the concepts of specific heat and heat capacity.

3.3 **Light**

Stead and Osborne (1980) investigated conceptions of propagation of light among 144 Form 2 (not yet studied light) and 235 Form 3 (already studied light) students in New Zealand. Test items were constructed after interviews. For example, a candle was shown and the student was asked whether : (a) the light stays on the candle, by night (about 10% of the students) and by day (about 50%); (b) comes out halfway towards you; (c) comes out as far as you but no further; (d) comes out until it hits something. Their conclusion: for students it depends on the environment whether and how far light propagates. An example of another study into alternative conceptions on light is the study of Goldberg and McDermott (1987) who investigated student conceptions in the area of optical image forming. A comparative study of Fetherstonhaugh et al. (1987) indicates how secondary students in many countries (Australia, New Zealand, France, Sweden, USA) hold similar alternative conceptions of how light travels and interacts with mirrors and lenses and how we are able to see objects. These alternative conceptions do not vary much with age and grade level. Some alternative ideas (Ramadas and Driver, 1989) can be listed as follows:

(a) Light is conceived as a source e.g. an electric bulb, an effect e.g. patch of light, or a state e.g. brightness.
(b) Light is not recognized as a physical entity existing in space between its source and the effect it produces.
(c) For luminous objects, vision is explained as light coming to the eye; for non-luminous objects however an 'eye is active' model is used.

According to Andersson and Karrqvist (1981, 1983) the ancient Greeks advanced three different models for light and vision. Empedocles thought that objects emitted an 'external elementary fire' which reached the eye bringing with it the shape and the colour of the object. From inside the eye came an 'internal elementary fire', a kind of internal flux which met the external flux of the external elementary fire and then produced vision. So the basic idea was the link between object and eye through combining two fluxes moving in opposite directions. Leucippus (one of the atomists) thought that objects emit a kind of image which conveyed the objects properties to the soul. On the other hand Archytas (a Pythagorean) thought only in terms of internal flux, an invisible fire emitted from the eye. Euclid supported this idea that vision is explained by something going outward from the eye. Euclid thought in terms of rays, but going out from the eye rather than going into it. He wrote a book about geometrical optics which was used as a textbook for 1500 years. Thanks to the reversibility of optic rays his theory described reality quite well in spite of wrong ideas about the direction of visual rays and the process of seeing.

In Indonesia, Berg and Sundaru (1990) used the same test items as Stead and Osborne (1980) in a sample of 78 elementary school teachers who were teaching about light and 112 biology education students. Follow-up interviews were conducted with 15 biology education students and produced a high consistency with the written test. Percentages were different in this older population, however, the trends in the data were very similar regarding the effects of night and day and the effects of different light sources. The Cronbach alpha reliability of the sub-test with 8 items was 0.80. Unpublished results of Berg in a junior high school population reproduced the trends found by Stead and Osborne even stronger. In the same study, Berg and Sundaru (1990) also investigated conceptions of the velocity of light, inspired by some experiences during a laboratory lesson in Indonesia. Respondents (30-50% on different questions) turned out to have a very strong and consistent (Cronbach alpha = 0,80 for 10 items) conception that brighter light travels faster and that obstacles like lenses, filters, and mirrors slow down the light. To our knowledge no similar items have been administered in other countries, however, results may well be the same.

3.4 **Electricity**

In the subject area of electric circuits, the following alternative conceptions have been identified in a number of research studies (Osborne, 1983; Cohen et al., 1983; Shipstone, 1984; Mc Dermott and Zee, 1985; Joshua and Dupin, 1987; Shipstone et al., 1988; Licht and Thijs, 1990; McDermott and Shaffer, 1992):

(a) Many students seem to believe that the same amount of current is supplied by a battery independent of the circuit connected ('constant supply of current'), and that the current is 'used up' as it flows through the bulbs ('current consumption').

(b) Instead of a way of reasoning where all parts of a circuit are interrelated and influence one another, many pupils think that a change in a circuit has only local or sequential ('downstream') consequences.

(c) Clashing currents: in a circuit there are two opposing currents which clash in an appliance or lamp.
(d) Most of the students discriminate insufficiently between related concepts, such as current, energy, power or voltage.

In particular the alternative conception of 'constant supply of current' (instead of constant voltage) appears to be used persistently across years of schooling (Licht and Thijs, 1990). These alternative conceptions surface very early in electricity education. Some, such as (a), are even with students at the elementary school level (Osborne, 1983) thus could be called preconceptions. One would not expect electricity conceptions to be 'hard-wired' into the brains of babies, however, the consistency and tenacity of alternative conceptions in the field of electricity makes one wonder whether some underlying general schemata are operating which are either hard-wired (genotype) or develop very early. We will continue the discussion on origins of alternative conceptions in section 6.

In the 18th century, electricity was thought to be an imponderable liquid, like heat, light and magnetism. Following the one-fluid theory there was one electric fluid. The two-fluid theory claimed both a positive and a negative fluid.

Research studies on electric circuits have revealed similar alternative conceptions in non-western countries, such as: Lesotho, Swaziland, Indonesia, as compared to the Netherlands (Kuiper et al, 1985), several East Asian countries (Talisayon, 1991), and Indonesia (Berg et al, 1992). Remediation studies have been conducted in western countries, but have met with only partial success. Remediation studies in non-western countries have been conducted in Indonesia (Berg et al., 1992, Katu et al., 1993) and have met with similar results as in other countries. Especially Katu's study (Katu, 1992; Katu et al., 1992, 1993) is interesting as it was an in-depth remediation study using teaching experiment methodology. As others elsewhere, he found that cognitive conflict needs to be followed up by models and analogies in order to be effective. One could object that this study has been looking for western misconceptions only and may be blind for indigenous alternative conceptions. However, Katu et al. (1992) followed up a written test with in-depth interviews in which about three times one hour per student was spent on further diagnosis of alternative conceptions of students. Katu was able to look more at a fine structure of alternative conceptions and their interrelations. He found little that could be classified as typical for Indonesian students. One of the interesting findings was that students who in simple situations do not subscribe to the 'clashing currents' model, may start using proton and electron currents in wires when questioning goes deeper, arguing that something has to go from the + to the - pole.

3.5 General observations

The similarities over history and across countries do suggest that human beings in a completely different culture and a different environment (without electricity etc.) develop conceptions similar to us. So culture and differences in man-made aspects of the environment might have only a limited influence on the formation or construction of certain science conceptions. The question which would fall fastest, a small light stone or a big heavy one would have drawn similar answers from the ancient Greeks shopping in the market and Americans, Dutch, and Indonesians in the shopping malls today (see also Champagne et al., 1985).

Students generally have difficulties in differentiating between concepts in the four domains of physics discussed above. As to this lack of differentiation, we refer to some interesting remarks of Carey (1992). She discusses (p.106) the evidence that six-to-twelve-year-old children do not conceptually differentiate between weight and density. She raises the question as to how such a concept could function in any conceptual system, given the contradiction it leads the child into. Her short answer is that the contexts in which the child deploys his or her *weight/density* concept do not, in general, elicit these contradictions. She suggests that this is the same answer as for the 17th century Experimenters' *degree of heat* -which is undifferentiated between heat and temperature, or for Aristotle's *speed* -which is undifferentiated between average and instantaneous velocity.

To summarize, in all countries students harbour similar alternative conceptions (see table 2). In-depth studies do show all kinds of subtleties within these generally known categories, however, major patterns are similar to results with students from other countries. In mechanics the impetus concept is very common, as are lack of differentiation between velocity and acceleration, between force and momentum, and problems with forces like the normal force and the force of friction. On heat and temperature students have a lack of distinction. In optics, the environment is very influential on whether and how far light is thought to propagate. And for electric circuits, everywhere a teacher will find current consumers, sequential reasoners, and fixed-current source rather than fixed-voltage source thinkers.

4 METHODOLOGICAL ISSUES

Most diagnostic studies on alternative conceptions in non-western countries used questionnaires with essay or multiple choice items, or a combination of essay and multiple choice items. Some studies used interviews, or a combination of written tests plus interviews. Sometimes such interviews were done before developing written tests as in many of the well known New Zealand studies (Osborne and Freyberg, 1985), while in other studies a sub-sample of written answers were followed up by interviews. Few studies involved extensive anthropological interviews (Hewson and Hamlyn, 1984). One study used teacher experiment methodology (Katu et al. 1992 and 1993), a relatively new methodology (Steffe, 1991) in which the researcher interacts

Table 2. Summary of some studies reporting the same alternative conceptions in western and
in non-western countries and their historic parallels in four domains of physics.

MECHANICS

Western research

Champagne et al. 1980, Minstrell 1982, Watts 1983, Clement 1983, McDermott 1984, Halloun and Hestenes 1985, Gunstone and Watts 1985, Licht and Thijs 1990. Remediation studies: Minstrell 1982, Champagne et al. 1985, Clement 1987, Thijs 1992, Thijs and Bosch 1993.

Non-western research

Thijs 1987 and 1988, Wolff et al. 1988, Boeha 1990, Arum and van den Berg 1990, Kuiper 1991 and 1993, Lee et al. 1992. Remediation studies: Thijs et al.1993.

Historic parallels

Saltiel and Viennot 1985, Halloun and Hestenes 1985, Whitaker 1983, Steinberg et al. 1990.

HEAT & TEMPERATURE

Western research

Erickson 1979 and 1980, Stavy and Berkovitz 1980, Shayer and Wylam 1981, Wiser and Carey 1983, Erickson and Tiberghien 1985.

Non-western research

Hewson and Hamlyn 1984, Kristyanto and Berg 1991, Berg 1992.

Historic parallels

Carey 1992.

LIGHT

Western research

Stead and Osborne 1980, Goldberg and Dermott 1987, Fetherstonhaugh et al.1987, Ramadas and Driver 1989.

Non-western research

Berg and Sundaru 1990.

Historic parallels

Karrqvist 1981 and 1983

ELECTRICITY

Western research

Osborne 1983, Cohen et al. 1983, Shipstone 1984, Mc Dermott and Zee 1985, Joshua and Dupin, 1987, Shipstone et al. 1988, Licht and Thijs 1990, McDermott and Shaffer 1992.

Non-western research

Kuiper et al. 1985, Talisayon 1991, Berg et al. 1992.

Remediation studies: Berg et al., 1992, Katu 1992; Katu et al. 1992 and 1993.

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with the subject in a clinical setting and attempts to construct the concept *development* of the student during a teaching experiment. Remediation studies have been done as well and they followed methodologies used in western countries such as conceptual conflict experiments, bridging analogies, and extensive class discussions (Berg et al., 1992; Thijs et al., 1993).

The reported cross-cultural results indicate the similarity of *types* of alternative conceptions, not so much the relative *frequencies* with which they are used. Frequencies might be different for a particular level of education, or age, of the students. However, it would not be easy to compare frequencies, unless it can be made sure that the student samples to be compared are matched in educational terms. Between countries such matching is next to impossible. Cross-cultural Piagetian studies have shown that concentration on percentages of children at different stages is quite task and context dependent, while the nature and sequence of stages in quite stable (Laboratory of Comparative Human Cognition, 1982). In analogy with this, we prefer to concentrate on general trends rather than percentages.

The use of multiple choice tests might be criticized for 'projecting known alternative conceptions onto students from other cultures', as the item-alternatives already presented alternative conceptions found elsewhere. In our opinion, results of multiple choice tests cannot be discounted as reliabilities have been reasonable (so something was being measured), and reasonable consistency was obtained with preceding or following interviews and essay tests. One might also object, that the studies quoted used test items which were limited to typical physics answers. However, those are the ones that matter in school physics. There is no point providing anthropological alternatives in test items if students do not use them in school context anyway (as seen in interviews and essays).

Yet, even essay tests and interviews might be criticized for 'looking for known or school-physics types of alternative conceptions', thus finding similarities with other cultures rather than differences. Studies using methods which go deeper and probe all kinds of connotations of concepts including religious, linguistic and cultural connotations, probably will find differences in free associations with concepts. However, we think that many such associations do not play a role in much of school physics types of tests, where problem solving behaviour in concrete situations are tested. Students seem to know how to distinguish between the world of school physics and most possible cultural and religious connotations of science concepts. School physics is sufficiently different in students' eyes from every-day life. In biology, the link between language and beliefs with school science might be stronger than in physics, as we will discuss in section 6.

However, one has to be very cautious for over-interpretation of culture related differences (if found). Culture is a complex phenomenon, with many variables interacting and no clear separation between dependent and independent variables. The history of cross-cultural cognitive psychology (including Piagetian comparisons) shows many pitfalls (Laboratory of Comparative Human Cognition, 1982). Furthermore, in cross-cultural comparison of students one deals with subjects who have studied or are studying science in school from books and with methods, which are very similar to those encountered in most other countries (including western countries). In the next section we will focus our discussion on cultural factors.

5 CULTURAL FACTORS

We define *culture* as 'the whole complex of distinctive spiritual, material, intellectual and emotional features that characterize a society or a societal group' (UNESCO, 1982). Cultural factors in relation to alternative conceptions include all kinds of aspects of culture, such as: language, environment, social structure characteristics, traditional values and beliefs, modes of thought and epistemology. There is much research evidence that cultural factors are most important in the science learning and teaching process (Wilson, 1981).

Below we give a brief summary of the importance of cultural factors under the headings of language, world-view, reasoning patterns, teaching and learning style. Then we discuss the general impact of culture, the importance of traditional beliefs, and the difference between the domains of science/physics and metaphysics.

5.1 Language

Language clearly does interfere with science learning as shown in Case (1971) and Gardner (1976) for science teaching in English to students with an African respectively Asian mother tongue. In particular the use of logical connectives in science seems to be difficult for students. Misconceptions are reinforced by colloquial expressions. To give just one example in the subject area of heat: 'Please shut the door to keep the cold out of the room'. Language certainly is a factor in learning and teaching, but does it affect the formation of preconceptions?

A few articles discuss the language dependence of science concepts attainment. Ross and Sutton (1982) report on secondary school pupils in England and Nigeria writing free definitions of common scientific words (such as light, growth, heat and temperature, electricity) and indicate that cultural differences stand out as more significant than language (English or Tiv language). Rutherford and Nkopodi (1990) on the other hand report in their study of Nothern Sotho speaking students (Grades 7-10) that the use of English enhances the recognition of science concept definitions. Rollnick (1990) however reports, that the use of the mother tongue (SiSwati, instead of English) facilitated the learning and expression of science concepts.

The use of metaphors, which are certainly language dependent, is an important element in the teaching of concepts. Hewson and Hamlyn (1984) suggest that the Basotho student's linguistic-metaphorical conception of being 'hot' has consequences for the individual's understanding of physical heat. Thijs (1987) reports on the way some teachers in Zimbabwe compare 'exerting of a force' with 'casting of a spell over somebody'. It is quite clear that the use of such a metaphor is not conducive to the reduction of the 'impetus' conception.

The relationship between language and thought could be between two extremes (McNaught, 1992). On the one hand are those who state that language shapes thought, that individuals who speak different languages actually differ in how they think (Whorf, 1956). On the other hand there are those who state that there are universal roots in human cognition and capacity for language, for example, that there are universal ideas and concepts that precede language (Chomsky, 1968). There is also a universal capacity of children to pick up grammar. The reality of the relationship between language and thought is probably a mixture of both. Applying this to science conceptual development, one might suspect on the one hand that there are a number of concepts and notions which precede language or are represented in all languages. On the other hand there will be concepts and notions which are language dependent, where speakers of different languages might tend to have different conceptions. The strong physics alternative conceptions as discussed in section 3, seem to belong to the first category.

5.2 **World-view**

Odhiambo (1972) states that the African world-view is monistic and does not distinguish the material world from the spiritual world. He suggest that the African must modify his monistic world-view in order to embrace more science. Horton (1971) however argues that there are striking similarities in the structure and functions of theoretical thinking in African traditional thought and western science. As a key difference he identifies the (lack of) critical approach to established principles, and the willingness to put them to experimental test. Ogunniyi (1988) argues that science is largely a product of western culture. Scientific (openness, self-criticism and persistence, mechanistic explanatory) views of the world and traditional (anthropomorphic explanatory) views of the world, conflict with each other.

Also Thijs (1984) emphasizes that science is a cultural enterprise. He argues that a culture should have certain traits if the scientific enterprise is to flourish. He suggests implications for teaching which refer to: nature of science (cf. Masakata Ogawa, 1986), contents of teaching (cf. Maddock, 1981; Ingle and Turner, 1981; Knamiller, 1984; Swift,1992), and teaching style and learning mode. In other words, world-view and culture are seen as have an important bearing on modes of science teaching and learning in general. They however do not seem to be responsible for the formation of strong physic conceptions as such.

5.3 **Reasoning patterns**

By the term reasoning we indicate the process of reaching conclusions by using arguments. Differences in reasoning may arise as regards the following questions: what type of process? (consistent and coherent?) and what type of arguments? (based on empirical observations, or some other authority?). There are a few articles which refer to the specificity of reasoning patterns in non-western countries. However, as Valerie Curran (1980) summarizes cross-cultural perspectives on cognition: *There is no evidence to date that cultural groups vary in their repertoires of cognitive processes. Rather, cultural differences have been shown to reside in the contexts in which particular process are combined into functional systems. Questions about whether different cultural groups 'have' certain ways of thinking and reasoning have now been replaced by questions about the contexts in which those processes are applied.* (p.328).

Along this line of focussing on contexts, Lewin (1993) argues that there is a need to undertake research that can provide more operationally useful insights into the cultural contexts within which science education is learned and taught. *The reasoning processes that lead to misconceptions and different attitudes to constructs like causality need to be understood and used as a basis for curriculum development which reflects learners' existing understanding, rather than rejected as simply 'unscientific*. (p.9)

George and Glasgow (1988) have done such a job by focussing on street science and conventional science in the West Indies. They have studied patterns of reasoning in street science and local cultural beliefs (as regards nutrition, health, reproduction and child care, and food production), such as ready generalizations. They wonder whether these patterns are not quite different from the patterns of conventional western-style science in which interaction of variables, tentativeness and a questioning attitude are points to stress.

So we may certainly expect cultural differences in reasoning patterns of students. In the *remediation* of alternative conceptions these differences will certainly play a role. However it is doubtful whether these differences come to the fore in the *formation* of the strong physics preconceptions.

5.4 **Teaching and learning style**

A characteristic difference between the teaching as observed in western and African classrooms, is the lack of students' participation in the African lessons which consist mainly of teacher talk. Prophet (1988) reports that Botswana pupils' learning is unreflective and by rote, the teachers setting themselves up as authority figures whose word is not questioned, and most pupils simply wanting clear instructions of what is expected of them.

Using the Science Teaching Observation Schedule (STOS), developed by Eggleston et al. (1976), the intellectual interactions in a classroom can be grouped into several categories of which teacher-initiated and student-initiated activities are the main ones. The STOS instrument has been used in a number of studies in western countries, e.g. Eggleston et al. (1976) and Hacker et al. (1979), and African countries, e.g. Ajeyalemi (1986), McDonald and Rogan (1988) and Kuiper (1991). The African teacher gives information of facts and principles, and the student listens. The amount of time that is spent on application of principles and problem solving, is generally less than in a western classroom. Buseri (1987) argues that in Nigeria the students do not ask questions because the teacher is seen as a person in authority, and according to the rules of polite conduct a person in authority is never questioned.

In discussing the emphasis on theory and the lack of experiment of school science in India, King (1986) points out that it is easy to assume that the differences in styles of learning (as compared to western schools) are the result of poverty and examination orientation (the diploma disease). However, as he suggests, *the differences may have as much to do with different traditions of organising knowledge, as they do with the lack of chemicals or laboratories*. (p.66).

Phillips and Owens (1986) report on a project aimed at making Indonesian children more active in classrooms where variability and interaction would be typical rather than exceptional. As they observe, questioning in Indonesia was widely regarded as a testing, or a disciplinary device rather than a teaching technique. They however still question, whether these were the right skills to be promoted for this education system in this culture. On the other hand, the personal experiences of the authors suggest that Indonesian upper secondary and tertiary students could adjust well to a highly interactive classroom. The main obstacles for achieving interaction in Indonesia might be the low confidence of poorly trained teachers and the attitudes of the teacher toward students (quite a few teachers dislike students who ask critical questions).

To summarize, it is widely reported that in non-western classrooms students accept phenomena without the desire to question them or seek explanations. The perception of the role of the teacher results in a rather authoritarian teaching style.

5.5 **Importance of traditional beliefs**

Ogunniyi (1987) raises the question whether there are genuine conflicts in the minds of students between the traditional cosmological viewpoints in their homes and the scientific world-view they encounter at school? As he suggests (p.109), *faulty conceptions about the external world could create learning difficulties in science. For instance, the rainbow cannot be explained as a sign of good omen on the one hand and as the refractive dispersion of sunlight in rain droplets or mist on the other. The two viewpoints are certainly inconsistent with each other.*

In contrast to the traditional hindrance as suggested by Ogunniyi, Kuiper(1991) could not trace immediate effects of traditional beliefs on Zimbabwe students. Besides administering a test on conceptual understanding in mechanics, he also held interviews with a number of students about the relationship between the traditional beliefs and what they learn at school. He found that students from the rural areas in particular meet with some suspicion when they talk with their parents, and especially grandparents, about what they have learned at school. Explanations of physics for rainfall and lightning are viewed with scepticism, because of the rich collection of traditional beliefs on these phenomena. Traditional beliefs seem not to be totally rejected by the interviewed students, but used in specific circumstances only. A student explained that, when he was nine years old, he wondered why a stone which was catapulted into the air would fall back to the earth. In those years he thought that the 'Mudzimo' (ancestral spirits) on the ground would pull the stone back. He said he abandoned that idea quickly when he learnt about gravity at secondary school. However, other questions such as to why a certain person is struck by lightning, could not be answered on the basis of his school knowledge. He then would resort to traditional beliefs. Kuiper concludes from the results of the test as administered in the Netherlands, Zimbabwe, Botswana, Lesotho and Swaziland, that all test samples show similar student ideas on force. The additional interviews he administered did not reveal traditional beliefs of force that would change this picture of similarity.

5.6 **General impact of culture**

As to the importance of cultural factors in concept attainment of students, Okebukola and Jegede (1990) have used the so-called socio-cultural environment scale of the following dimensions: (1) general environment of the community (automated, or manual), (2) reasoning pattern (empirical, or magical/superstitious), (3) goal structure (cooperative, competitive, or individualistic), and (4) nature of home (authoritarian, or permissive). The article reports on the administration of a science concept test and the use of above scale in the analysis. The following results are found. Students who live in a predominantly automated environment, who are empirical in reasoning, who expressed preference for cooperative learning and who are from permissive homes, do better in the concept test. The authors contend that science teachers need to recognize that learning of science concepts can be greatly influenced by cultural factors. As they suggest, the non-scientific explanations that students within rural communities are used to, could exert hindering influences on the acceptance of scientific explanations. See also Jegede and Okebukola (1991a and 1991b).

As to the possible hindering effects of traditional beliefs on science understanding, we would suggest that domains of science/physics and metaphysics do no overlap. We refer to Ladrière (1977) who states that *The direct impact of science on culture does seem to exist in setting the cognitive system apart from other systems, particularly the axio-logical system, and* *hence introduce into a culture a dualism or pluralism which runs counter to its integrating ability.*

In other words, we do not belief that there is a serious interference between traditional and superstitious beliefs and scientific understanding. The two domains are separated in terms of the types of questions considered. There is a difference between 'how' questions which belong to the science domain, and the 'what purpose' questions on values pertaining to the metaphysical realm. As Heisenberg (1973) states: *The thinkers of the Enlightenment abandoned the earlier concern of philosophers of why (and the search for a final cause) and moved to the question of how (and the method of causation).*

We agree with the remarks of Dart and Pradhan (1967), who studied science teaching in a non-western cultural environment, i.e. in lower-secondary schools in Nepal. They suggest that science should be taught as a 'second language', complementing that already present rather than seeking to replace it. They would not consider it harmful, if a student uses an explanation of lightning in terms of physics in a school context, while using on other occasions, folk-oriented beliefs such as 'lightning comes from the bangles of Indra's dancers'.

There are many articles that emphasize the importance of traditional beliefs for science learning. We briefly discuss two of them. Stahl (1992) reports on the pervasive influence of folk-religious concepts on the science learning of Oriental Jews. Most of the examples he mentions of traditional lore in science classes refer to biology : diseases caused by evil spirits, menstrual blood being dangerous, frogs cursing people, etc., at the level of primary education. There are hardly any examples referring to physics concepts at secondary level. It is also doubtful whether the examples mentioned are real obstacles for science teaching that has an orientation which differs from the traditional beliefs. The same comments apply to the study of Rice (1991) who reports on traditional ideas of Thai children on concepts of health and illness.

As we would suggest, the real problem for students learning science is, to realise that the two domains, science and life-world, are different. Also in the west, the subject of science appears to represent an alien way of thinking and reasoning for students. To give a telling example, we refer to a transcript included in the article of Lin (1983), who takes a 'cultural look' at physics classes in the USA. The transcript reports a students saying: *My intuition for physics and the way things work isn't always the way I 'm told they are supposed to work...It's like learning to play chess by watching people play, and nobody tells you the knight moves in an L.* (p.198).

In other words, science seems to represent a strange world in all cultures. Science itself is a foreign culture for all students, also for students from western countries.

To summarize, language and other cultural factors (in particular reasoning patterns, and teaching and learning style) strongly influence the science learning process. For the remediation of alternative conceptions and the choice of appropriate remediation strategies, these factors play an important role. For the alternative conceptions themselves we may expect cultural influences in the formation of some conceptions. However, we do not expect a cultural influence in the formation of some other alternative conceptions such as the strong physics preconceptions discussed in section 3. This distinction will be elaborated in the next section.

6 INTERPRETATIONS OF ALTERNATIVE CONCEPTIONS

6.1 Models in literature

In this section we will give a brief summary of some articles in the literature on the organising principles of alternative conceptions.

In 1984 Preece wrote an article entitled 'Intuitive science: learned or triggered?' He wondered whether various preconceptions are hard-wired into the brain and triggered by instruction or whether preconceptions develop: nature or nurture! The fact that we have not seen any reactions to this provocative statement might mean that most researchers do not seriously entertain the nature alternative. Most authors seem to implicitly assume that preconceptions are a result of development (nurture). Some papers explicitly addressing the origin of alternative conceptions are clearly on the nurture side and constructivism seems to be nurture anyway.

However, neuro-biologists responding to the apparent universality of many alternative conceptions right away answer 'of course', all humans have the same brain. Preece proposes that preconceptions are wired into the brain waiting to be triggered. This is not as strange as it seems. Changeux (1985, p.243) describes the great variation of sounds/syllables of the young swamp sparrow compared to the mature one. As if a large vocabulary is available (nature) and nurture triggers/selects a very limited sub-sample. The linguist Jakobson held similar views regarding the development from babbling to speech in children. Chomsky's view of universal grammar templates in humans goes into the same direction.

Osborne and Wittrock (1983, 1985) suggest that the brain actively constructs its own interpretations of information and draws inferences from them: it ignores some information and selectively attends to other information. The generative learning model incorporates aspects of both the constructivist and the information processing traditions of cognitive psychology.

People retrieve information from long-term memory and use their information processing strategies to generate meaning from the incoming information, to organize it, to code it, and to store it in long-term memory. (Osborne and Wittrock 1983, p.493).

The model is described in universal language. The model does not specify which of the information processing elements (filtering, organizing, coding, and storing) would be culture dependent. It also does not give any clue as to a possible difference between various alternative conceptions.

The Piagetians concentrated their studies on universal mental processes and structures which were assumed to be rather 'content' independent. The alternative conceptions researchers took issue with that and and have focussed on 'content'. However, within this 'content' some patterns appear. There may be some more general schemes operating behind the well known alternative conceptions. Such schemes may help in explaining origins of preconceptions as well. In the next we give a brief account of two articles that attempt to work out a model of common sense reasoning.

(1) Andersson (1986) states that there is a common core to alternative conceptions on widely differing areas such as temperature and heat, electricity, optics and mechanics, and that is the 'experiential gestalt of causation'. Its parts are agent (gives energy), instrument (energy flow) and object (receives energy). The greater the effort the bigger the effect; the nearer, the greater the effect. Andersson shows how this model can be used to describe the students' reasoning in a variety of physics problem situations.

(2) Gutierrez and Ogborn (1992) developed a model to provide a language to describe common-sense causal thinking. The model has the following elements: locality (cause near effect), asymmetry (cause precedes effect), productivity (an effect is produced by a cause), constancy (if there is a cause it is always followed by an effect), and uniqueness (same cause, same effect). This model refers to the logical structure of alternative conceptions, it describes the form, not the content of causal reasoning.

The two above models of common sense reasoning are not phrased in terms that are culture dependent. On the contrary, most important elements are cause - effect considerations, which as such are not necessarily culture dependent. On the contrary, as argued by Horton (1971), one of the *similarities* between African traditional thought and western science is the general proposition on the nature of theoretical thinking, specified by Horton in relation to causality as follows: *theory places things in a causal context wider than that provided by common sense*. (p.135) . So we would certainly not expect students in an African setting to follow patterns of common sense causal thinking which can not be described by above models. The models discussed so far are universal and not culture specific.

Head (1986) suggests at least five possibilities can be suggested for the origin of pupils' ideas: (1) Every day experience and observation; (2) Confusion about analogies; (3) Use of metaphors; (4) Peer culture; (5) Innate origin of some ideas: children may be genetically programmed to cope with manipulation of the immediate environment, and in that event ideas contrary to conventional science could arise. In order to illustrate the confusion introduced by every day experience and observation (1), we could give the following example. The coldness or hotness of an object as experienced by an person does not indicate the object's temperature but the temperature difference between object and the person and the object's heat conductivity. In other words, since our senses do no register temperature, we can not intuitively answer questions on temperature correctly. If there would even be an innate origin of this misconception (5), the every day experience might be even more deeply rooted and harder to modify. We would therefore suggest that the strong physics alternative conceptions have to be explained in terms of the categories (1) and (5) as mentioned by Head (1986).

We finally briefly discuss an article of Chi (1992) that specifies the character of the strong and innate physics preconceptions. Chi refers to research evidence and argues that the fundamental conception that underlies most of the students' conception of physical science concepts (heat, light, forces, current) is to treat them as a kind of *substance*. As Chi remarks, students' naive conceptions are similar to medieval scientists' conceptions which were substance-based as well. In history, the so-called 'mechanization of the world picture', which took place in the 17th century in the west, has been a radical process. According to the historian of science Dijksterhuis, this process had indeed the character of replacing substance-based thinking: *substantial thinking which inquired about the true nature of things, was exchanged for 'functional' thinking, which wants to ascertain the behaviour of things in their interdependence, with an essentially mathematical mode of expression.* (Dijksterhuis 1961, p.501).

To illustrate the substantial character of physics preconceptions, we could give an example taken from mechanics. We take the example from Saltiel and Malgrange (1980), who describe 'spontaneous' ways of reasoning in elementary kinematics by a 'natural model'. In this model, motion and velocity are considered as physical properties of the moving body alone, independent of observers, and defined through reference to the driving forces which cause them, and not to frames.

To summarize, strong student alternative conceptions in physics, which have immediate historic parallels and are found cross-culturally, can be characterized by thinking in terms of substance, treating physical concepts as substance-based entities. We would suggest that these conceptions are sensory based and are constructed on the basis of innate schemata. The educational starting position of students entering schools in various cultures are very similar as far as their preconceptions in physics are concerned. Culture may come in when it concerns the remediation strategies for reducing existing preconceptions. In the next section we will see whether we could find such a picture in a cross-cultural study.

6.2 **Cross-cultural study**

We have performed cross-sectional studies throughout consecutive school years in secondary schools both in Zimbabwe and the Netherlands (Thijs and Kuiper, 1990). A test on problems of 'force and movement' was administered in two secondary schools in the Netherlands (270 students, 12-20 years old) and eight secondary schools in Zimbabwe (870 students, 13-22 years old). The results reported here refer to three questions on objects which were set in motion, i.e. a ball thrown by a man, fired by a cannon, and kicked by a person. The students were asked to draw the forces acting just after the release of the object. Many students indicate a force in the direction of the motion (similar to the medieval 'impetus') which they think needs to be there to maintain the motion after release. The development of the alternative conception of 'impetus' in shown in figure 1. The co-ordinate 'amount of instruction' corresponds to the number of school years as far as Forms 1-4 (Grades 7-10) are concerned. Since the amount of physics instruction in higher grades is about twice as intensive, Forms 5 and 6 (Grades 11 and 12) correspond with units 6 and 8 respectively.

In interpreting figure 1 we have to be somewhat cautious. It has to be acknowledged that the test populations in both countries are not matched in terms of age of students, gender ratio, and quality of instruction. The results are however most interesting in that the starting position of the alternative conception of 'impetus' is about the same for both countries. The diagram starts at a percentage score of around 87% in Grade 8. In the preceding school years (Grades 1-7) it is not to be expected that the students' conception of force has been articulated much, and that almost all students keep harbouring the alternative conception of 'impetus' which apparently has the character of a preconception. In secondary school the process of changing this preconception takes place gradually and more effectively in the Netherlands than in Zimbabwe. The Zimbabwe schools in the rural areas did worse as compared to the urban schools. A variety of factors could be responsible for the different reduction of the preconception by instruction in both countries. The attention paid in class to the concept of 'force' may be different, teachers may have different mastery of the physics concepts themselves, teaching styles may be different, and the language used in class and in textbooks may be more or less different from language used by students in their own life-world. A number of these factors have a cultural character (teaching style, student-teacher interaction, language).

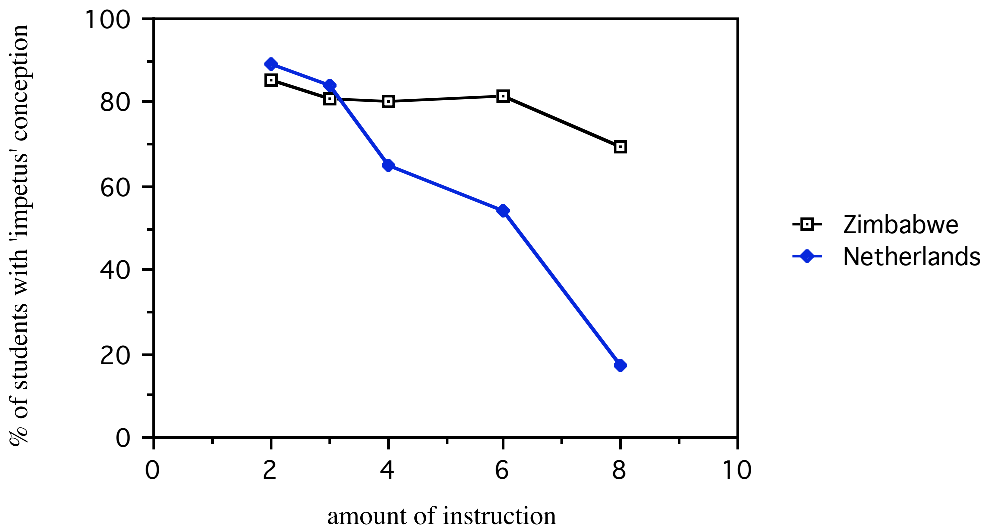

Figure 1. Percentage of students with 'impetus' misconception versus amount of instruction

In other words, figure 1 suggests that preconceptions are the same across two cultures, but that the effectiveness of instruction in reducing these alternative conception is different, depending on many factors, part of them cultural.

6.3 A distinction

In the following we will make a case for a distinction of preconceptions which have very early roots in childhood or even a genetic make-up and preconceptions which develop later and are more susceptible to linguistic and cultural influences. Preconceptions related to sense experiences (much more in physics), such as that heavier things fall faster, might be universal. On the other hand, value laden conceptions (much more in biology) might have a cultural or linguistic bias.

Everywhere young children learn (Gould and Marler, 1987) from similar sensory experiences in that the related part of the cortex in the brain, devoted to that type of signals, is expanded (Kandel and Hawkins, 1992). The brain structure and the cerebral pre-frontal cortex is formed everywhere in the same way in response to external sensory experiences. Alternative conceptions which are most resistant to change refer to those that are formed at an early age, and are based on sensory experiences, i.e. observations of falling objects, sensation of heat, etc. Preconceptions regarding force, light, heat and electricity, can expected to be culturally independent.

Following Chi, we suggest that there are basically two kinds of conceptual change. The first category, referring to most of the biological concepts, is much easier to arrange than the second category, which refers to most physical science concepts. The physical preconceptions have a strong element of substantial thinking in common. This character also represented a main stumbling block for science concept development in history. To give some examples of substantial thinking we could refer : (1) mechanics: the idea of a supply of force and 'impetus'; (2) heat and temperature: the 'caloric' fluid conception; (3) optics: the student conception that the image of an object travels as a whole from the object to the screen; (4) electricity: the idea of one or two electric fluids, and the notion of 'current consumption'.

Constructivism represents a model of learning that is, as Coburn (1992) states, *authentically sensitive to both culture and science*. We would suggest that ideas which have been constructed out of perceptual experiences are universal, as they refer to the commonality in human experiences. This characteristic applies to strong physical preconceptions. It may also be, as Driver and Erickson (1983) suggest, that not only sensory experiences are common, but that also the metaphorical use of language could be universal to some extent.

On the other hand, alternative conceptions which are constructed out of cultural repertoires are ideo-syncratic. This characteristic applies to biological conceptions on growth, health, illness, etc. The remediation of all alternative conceptions, including preconceptions, and the success of a particular teaching strategy will be strongly influenced by culture.

7 CONCLUSIONS

Most alternative conceptions found in western or industrial countries are also encountered in non-western countries. Therefore cultural and environmental variables may have limited influence on the formation of conceptions regarding nature and natural phenomena. A cultural fine-structure might yet be discovered, however, some main features of alternative conceptions seem to be quite universal. Percentages of students preferring one or another alternative conception and consistency of use may or may not differ between cultures, but this is difficult to assess due to the problem of securing comparable samples. Culture clearly does have an effect on beliefs associated with natural phenomena (superstitions), however, such beliefs do not seem to affect the formation of concepts in school physics. On the basis of the above discussion, the following tentative conclusions may be drawn.

(1) A reasonable hypothesis might be that the educational starting positions of pupils in various cultures are very similar as far as their preconceptions in physics are concerned. It could be that preconceptions are inborn, it could also be (more likely) that underlying and more general schemata are inborn. These conceptions are perhaps innate and triggered by experiences.

(2) Other alternative conceptions, which are influenced by culture and world-views, are formed at an older age, may be easier to change. These are non-universal. Examples: conceptions of health, illness, fertility, growth, etc. These are more value laden, related to biology rather than physics, more concrete and less abstract than the preconceptions of the first category.

(3) The scientific world view represents a foreign sub-culture in all countries and cultures, since no country or culture has ever reached any substantial rate of scientific literacy. Therefore, science is new to almost every young school pupil. All pupils in all cultures similarly need to be initiated into the secrets of science with its sometimes counter-intuitive character.

(4) However, the pupils' readiness to modify or replace their preconceptions differ from culture to culture. In other words, conceptual change is more subject to cultural colouring of meaning and more culturally embedded, than the preconceptions themselves. The amount of encouragement that pupils receive in this accommodation and assimilation process depends strongly on the scientific status, the impact and the scientific tradition in that particular culture. This may result in differing persistency of preconceptions in different cultures.

(5) All remediation methods to date rely heavily on discussions and arguments between students and between the teacher and students. The presence of arguments and discussion in the classroom is a major cultural variable, ameliorated by the low self-confidence of poorly trained teachers. The effectiveness of these instruments (such as cognitive conflicts and conceptual bridges and analogies) however, is strongly determined by the cultural aspects of the teaching-learning process (such as: independent questioning and critical attitude, as compared to: unreflective imitating behaviour). This is where culture and teaching intersect.

(6) Spiritual beliefs and religious expectations refer to another symbolic domain and as such do not interfere with the cognitive systems and concepts that science has created for the explanation of events in the material world. In most situations and contexts, domains of science (education) and metaphysics do no overlap or intersect in a critical way.

(7) As regards the need for research we would suggest as follows. There is not too much need for confirming alternative conceptions in every country, except as a data base to be used in teacher education and curriculum discussions. However, there is certainly a need to search for effective remediation strategies in other cultures which match the boundary conditions of developing countries, such as large classes and scant resources.

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