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Cultural Factors in the Origin and Remediation of Alternative Conceptions in Physics

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ABSTRACT. Over a wide range of subject areas students exhibit persistent conceptions contrary to the prevailing scientific concepts. The same alternative conceptions in physics are reported to exist across many countries, within a variety of cultural and environmental contexts. Also, many alternative conceptions show striking similarities with difficulties encountered in the historical development of physics. What is the reason for these similarities? Is intuitive science learned or triggered? And, if similar brain structures are responsible for common-sense theories, in what way then are cultural factors still important in the teaching-learning process? The influence of cultural factors will be discussed on the basis of literature available on this topic. Data collected by the authors in the Netherlands, Indonesia and countries in Africa are also taken into consideration. A distinction is proposed between alternative conceptions some of which may be universal and some dependent on culture. The same distinction is made regarding ways of reasoning and epistemology. It is suggested that the effectiveness of methods for the remediation of alternative conceptions is strongly influenced by cultural aspects of the teaching-learning process.

1. INTRODUCTION

In the past decade numerous studies have revealed the existence of alternative conceptions as important determinants of students' conceptual development in science. Research into the character and content of alternative conceptions in a range of science subject-areas, has been conducted in various countries, both western and non-western. Studies into the remediation of alternative conceptions have also been carried out in a range of educational systems and cultural backgrounds. This paper will survey results of research on strong alternative conceptions of students with respect to concepts in physics. The following questions are raised: (1) to what extent are these alternative conceptions universal; (2) what types of cultural influences are to be expected and have been found in the character of alternative conceptions and their remediation in science education; and (3) what can, in general, be said about the origin of alternative conceptions?

The paper begins with a discussion of some general aspects of alternative conceptions. Then follows a brief overview of historical and cross-cultural data that point to the universality of some main 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 and traditional beliefs, reasoning patterns, and teaching and learning style. After reviewing the cultural factors, we then try to discuss alternative conceptions in the light of the question 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 regarding the terms: concept, conception, alternative conception, and preconception.

Concept is the scientific idea 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 idea of the meaning of a concept. Such an interpretation has some idiosyncratic features, even if the individual is a scientist.

Alternative conception, or 'misconception', refers to a conception which in some aspects is contradictory to, or inconsistent with, the concept as intended by the scientists. 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 ideas have some robustness and persistence 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. Frequently however, preconceptions are taken to be the conceptions held before exposure to the teaching of a new topic. Such conceptions may have been influenced by previous schooling in related topics. The term 'alternative conceptions' includes 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*

Numerous 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 overview, see for example: Gilbert and

TABLE I
Reliability of scales (as indicated by the Cronbach alpha) for secondary students in the Netherlands, selecting answer options relating to correct concepts or alternative conceptions in multiple choice tests on electricity and mechanics (Licht & Thijs 1990).

Cronbach alpha	Electricity		Mechanics	
	Correct	Altern	Correct	Altern
Lower forms	0.57	0.76	0.48	0.42
Higher forms	0.86	0.83	0.66	0.51
All forms	0.86	0.85	0.77	0.54

Watts (1983), Driver and Erickson (1983), Driver et al. (1985), Novak (1988), Perkins and Simmons (1988), Confrey (1990), Pfundt and Duit (1991), and Wandersee et al. (1994).

Most student ideas are fragmented and not logically integrated (Solomon 1983). However, if students lack an 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 than a pre-test; 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.

Alternative conceptions do not necessarily lack the articulation and consistency of the correct student conceptions. For example, Licht and Thijs (1990) have researched the consistency 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 I. The Cronbach alpha reliability coefficient is a measure of the consistency with which subjects respond to the different items of a test. Random response would result in a low alpha. An acceptable alpha, that lies in between 0.6 and 1.0, means that students answer with some consistency across items; what common conception there is, has to be inferred from a close study of the various test items. The alpha is usually keyed to the correct responses to the test. However, one way of expressing the consistency of students' alternative conceptions is to calculate the Cronbach alpha based on a correction key according to alternative conception answers, rather than the correct physics answers (Licht & Thijs 1990). This cross-sectional study indicates that reliability generally increases throughout years of schooling, both for the scientific and the alternative conceptions, certainly in electricity. So the alternative conceptions, though chosen by fewer students in higher grades, are gradually used more consistently. The increase of consistency, be it also in an alternative way, may be a result of instruction. However, it is doubtful whether alternative conceptions really deserve the status of *alternative frameworks* (Driver & Erickson 1983), which are consistently used across a variety of contexts. Secondary school students normally do not use alternative conceptions in the consistent way that would justify the term 'alternative framework' (Kuiper 1994).

2.3. *Parallels in history*

Many authors have drawn attention to the similarity of students' conceptions at different levels of education with the 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; see also Vosniadou and Brewer (1987) and Nersessian (1989). An interesting discussion of the systematic structure of concepual revolutions in the history of science is given by Thagard (1992). One of his theses is, that new theoretical concepts generally arise by a new way of combining existing concepts. However, it should be realized 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 influence 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 Galíleo, 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, though of course historical differences remain.

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; diSessa 1983; Watts 1983; Clement 1983; McDermott 1984; Halloun & Hestenes 1985; Gunstone & Watts 1985; Licht & 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 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 motion*
No clear distinctions are made 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.

Many remediation studies with western students (e.g. Minstrell 1982; Champagne et al. 1985; Clement 1987; Thijs 1992; Thijs & Bosch 1994) have been published; they report on some (partly) 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'-like 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 Galileo'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:

> 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 (Dijksterhuis 1961, p. 30).

Cross-cultural research in mechanics includes the following. Thijs (1987, 1988) studied conceptions of Dutch and Zimbabwean high school students as a function of instruction. Wolff et al. (1988) assessed mechanics conceptions of 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 in Lesotho and the Netherlands. Boeha (1990) interviewed 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 Berg (1990) studied Indonesian student ideas on forces in rest situations, testing 450 and interviewing 20 high school students. Alternative conceptions of force were similar to those found elsewhere and conceptions were quite consistent across test formats (essay, multiple choice, interview). Lee et al. (1992) conducted a study among 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 hundreds of urban and rural students (grade 8–12) in Zimbabwe and interviewed a number of students on ideas about force. With the same test instrument he also investigated samples of students from Botswana, Lesotho, and Swaziland, and 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. They found similar results as reported in western remediation studies.

3.2. *Heat and temperature*

Studies regarding conceptions of heat and temperature (Erickson 1979, 1980; Stavy & Berkovitz 1980; Shayer & Wylam 1981; Wiser & Carey 1983; Erickson & 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 (a quantity that is dependent on the quantity of matter) rather than an intensive one.
(b) Lack of distinction between temperature and heat.

(c) Perception of heat as material (caloric fluid like Lavoisier).

As to historical parallels, the study of Carey (1992) is worth mentioning. She reports on 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.* (Carey 1992, 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 30 students from grades 7–11 and administered a test to 250 students from 7 secondary schools. The test focussed on temperature as intensive variable, the difference of heat and temperature, and specific heat as intensive property. The test had a high reliability. 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 secondary school students (forms 2 and 3) 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 formation. A comparative study of Fetherstonhaugh et al. (1987) indicated how secondary students in many countries (Australia, New Zealand, France, Sweden, USA) hold similar alternative conceptions of the way light travels and interacts with mirrors and lenses and the way we are able to see objects. These alternative conceptions do not vary much with age and grade level. Some alternative ideas (Ramadas & 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 approximately 200 elementary school teachers and biology education students. Test results had a high reliability. Follow-up interviews, conducted with 15 biology education students, 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. 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 (about 40% on different questions) turned out to have a consistent conception that brighter light travels faster and that obstacles like lenses, filters, and mirrors slow down the light after passing.

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 & van Zee 1985; Joshua & Dupin 1987; Shipstone et al. 1988; Licht & Thijs 1990; McDermott & 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 & Thijs 1990). These alternative conceptions surface very early in electricity education. Some, such as (a) and (c), are even encountered in students at the elementary school level (Osborne 1983).

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) 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 these studies were looking for western misconceptions only and may have been blind for indigenous alternative conceptions. However, Katu et al. (1992) followed up a written test with in-depth interviews in which 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 positive to the negative 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 conceptions known from western students. So culture and differences in man-made aspects of the environment may have only a limited influence on the formation or construction of certain physics conceptions. The question of which would fall fastest, a small light stone or a big heavy one, would have drawn similar answers from the ancient Greeks, and today's Americans, Dutch, and Indonesians (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 as regards 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 in physics (see Table II).

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. Regarding 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

To what extent can the non-western studies reported above be criticized for not having investigated sufficiently the anthropological ecology of student conceptions? 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 & Freyberg 1985), while in other studies a sub-sample of written answers were followed up by interviews. Few studies involved extensive anthropological interviews (Hewson & Hamlyn 1984). One study used teacher experiment methodology (Katu et al. 1992), a relatively new methodology (Steffe 1991) in

TABLE II
A selection of studies reporting 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; diSessa 1983; Watts 1983; Clement 1983; McDermott 1984; Halloun & Hestenes 1985; Gunstone & Watts 1985; Licht & Thijs 1990. Remediation studies: Minstrell 1982; Champagne et al. 1985; Clement 1987; Thijs 1992; Thijs & Bosch 1994.
Non-western research
Thijs 1987; Thijs 1988; Wolff et al. 1988; Boeha 1990, Arum & Berg 1990; Kuiper 1991; Kuiper 1994; Lee et al. 1992. Remediation studies: Thijs et al.1993.
Historic parallels
Saltiel & Viennot 1985, Halloun & Hestenes 1985, Whitaker 1983, Steinberg et al. 1990.

HEAT & TEMPERATURE
Western research
Erickson 1979; Erickson 1980; Stavy & Berkovitz 1980; Shayer & Wylam 1981; Wiser & Carey 1983; Erickson & Tiberghien 1985.
Non-western research
Hewson & Hamlyn 1984; Kristyanto & Berg 1991; Berg 1992.
Historic parallels
Carey 1992.

LIGHT
Western research
Stead & Osborne 1980; Goldberg & Dermott 1987; Fetherstonhaugh et al.1987; Ramadas & Driver 1989.
Non-western research
Berg & Sundaru 1990.
Historic parallels
Karrqvist 1981; Karrqvist 1983.

ELECTRICITY
Western research
Osborne 1983; Cohen et al. 1983; Shipstone 1984; Mc Dermott & van Zee 1985; Joshua & Dupin 1987; Shipstone et al. 1988; Licht & Thijs 1990; McDermott & 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.

which the researcher interacts 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; Katu et al. 1992; Thijs et al. 1993).

The reported cross-cultural results indicate the similarity of *types* of alternative conceptions, not so much their relative *frequencies* in a population of students. Frequencies may be different for a particular level of education, or age, of the students. However, it would not be easy to compare frequencies across countries, unless it can be ensured 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 percentages of children at different stages are quite task and context dependent, while the nature and sequence of stages are quite stable (Sternberg 1982). In analogy with this, we prefer to concentrate on types of alternative conceptions rather than compare percentages for each type.

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 (0.7–0.9), and reasonable consistency was obtained (agreement in more than 80% of the cases) with results of 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 spontaneously in school anyway (as seen in interviews and essays).

Futhermore, 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, will probably find differences in free associations with concepts. However, we think that many such associations do not play a role in school physics tests, where problem solving behaviour in concrete situations is 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 everyday life. In biology, the link between language and beliefs with school science (Stahl 1992) might be stronger than in physics, as we will discuss in section 6.

There is also a risk of over-interpretation of culture related differences. Culture is a complex phenomenon, with many interacting variables and no clear separation between dependent and independent variables. The history of cross-cultural cognitive psychology (including Piagetian comparisons) shows many pitfalls (Sternberg 1982). Furthermore, in cross-cultural comparisons of students, one deals with subjects who have studied or are studying science in school from books and with methods, which are very similar across countries. In the next section we will focus our discussion on cultural factors.

5. CULTURAL FACTORS

To what extent is the cultural context responsible for the specific character of formation and remediation of alernative conceptions in science education? This section will discuss possible influences of various aspects of culture. Following (UNESCO 1982) we define culture as *the whole complex of distinctive spiritual, material, intellectual and emotional features that characterize a society or a societal group*. Cultural factors in relation to alternative conceptions include: language, environment, social structure characteristics, traditional values and beliefs, modes of thought and epistemology. There is ample research evidence that cultural factors are very important in the science learning and teaching process (Wilson 1981). Below we give a brief summary of the importance of cultural factors in teaching-learning under the headings of language, world-view and traditional beliefs, reasoning patterns, and teaching and learning style. Then we discuss the general impact of culture 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 African and Asian mother tongues respectively. In particular the use of logical connectives in science seems to be difficult. 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 is it related to the formation of preconceptions?

A few articles discuss the language dependence of science concept learning. 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) report in their study of Northern Sotho speaking students (grades 7–10) that the use of English enhances the recognition of science concept definitions. Rollnick (1990) reports on the other hand, that the use of the mother tongue (SiSwati), rather than English, facilitated the learning and expression of science concepts among Swazi students.

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 views on the relationship between language and thought are found to 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. This is the well-known Sapir-Whorf hypothesis (Whorf 1956). On the other hand there are those who state that there are universal roots in human cognition and capacity for language. There is Chomsky's view that a system of universal grammar is an innate mental structure in humans (Chomsky 1968). An extreme position is taken by Fodor (1975) who suggests the availability of an innate language that provides a system of conceptual representations. However, as Churchland (1978) points out critically, *Fodor is silent on the matter of how his theory is to deal with the wealth of theoretical concepts bequeathed us from the sciences, such as 'electron', 'wavicle', 'force field', 'valence', etc.* (p. 153).

The reality of the relationship between language and thought is probably a mixture of both extremes. Applying this to conceptual development in science, one might suspect on the one hand that there may be some 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 may 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 and traditional beliefs*

Odhiambo (1972) states that the African world-view is monistic and does not distinguish the material world from the spiritual world. He suggests that the African must modify his monistic world-view in order to embrace science. Horton (1971), however, argues that there is a striking similarity in terms of the structure and function of theoretical thinking in African traditional thought and western science. As a key difference, on the other hand, he identifies the (lack of) critical approach to established principles, and the (lack of) 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.

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, *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* (Ogunniyi 1987, p. 109).

There are many other 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.

In contrast to the traditional hindrance as suggested by the above articles, Kuiper(1991) could not trace immediate effects of traditional beliefs on Zimbabwe students' understanding of the concept of 'force'. 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. 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 alternative conceptions of force. The additional interviews he administered did not reveal traditional conceptions of force that might change this picture of similarity.

Culture does not seem to be responsible for the formation of strong physics preconceptions as such, since students seem to distinguish well between school science and other domains. On the other hand, however, it is to be expected that culture will influence the effectiveness of remediation of these conceptions. This can also be seen from the data of Kuiper shown in Figure 1 (see also section 6.2).

5.3. *Reasoning patterns*

As can be argued (Thijs 1984), a culture should have certain traits if the scientific enterprise is to flourish. In that sense, science can be seen as a *cultural enterprise*. This observation has implications for teaching and learning which refer to contents of teaching (cf. Maddock 1981; Ingle & Turner 1981; Knamiller 1984; Swift 1992), teaching the nature of science (cf. Masakata Ogawa 1986), but also: reasoning patterns and teaching style. In other words, culture has an important bearing on modes of science teaching and learning. In this section we will focus on reasoning patterns. By the term 'reasoning' we indicate the process of reaching

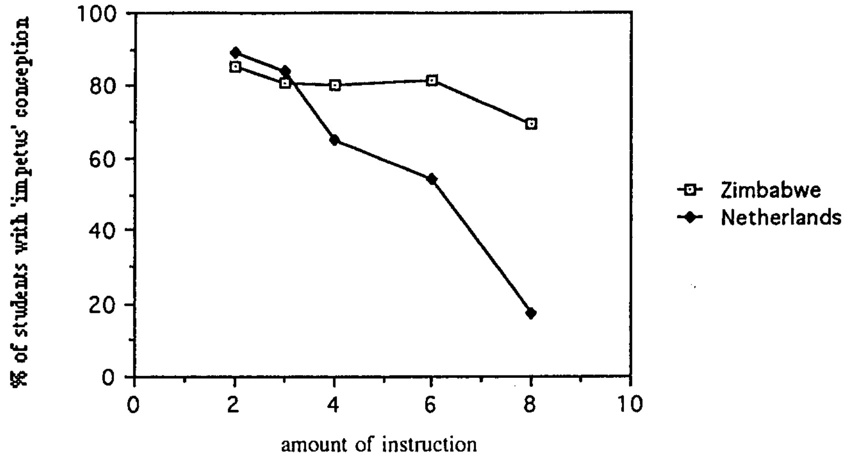

Figure 1. Percentage of students with 'impetus' misconception versus amount of instruction (Thijs & Kuiper 1990).

conclusions by using arguments. Differences in reasoning may arise regarding the following questions: what type of process? (consistent and coherent?) and what type of arguments? (based on empirical observations, or some other authority?). We now discuss a few articles which consider the specificity of reasoning patterns in various cultural contexts.

In the West Indies, George and Glasgow (1988) studied 'street science', i.e. local cultural beliefs and reasoning with regard to nutrition, health, reproduction and child care, and food production. They focussed on differences in content and reasoning between conventional science and street science. Their conclusion is that patterns of reasoning in street science are much more direct and less complicated than patterns of conventional science with its interaction of variables, tentativeness and questioning attitude. The substance of West Indian street science is clearly different from street science in most industrial western countries.

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). And he suggests that *the differences may have as much to do with different traditions of organising knowledge, as they do with the lack of chemicals or laboratories* (King 1986, p. 66).

As to cultural specificity of reasoning, Valerie Curran (1980) summarizes cross-cultural perspectives on cognition as follows:

> 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 processes 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 (Valerie Curran 1980, 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 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* (Lewin 1993, p. 9).

Because of differences in contexts, we may expect differences in reasoning between students of western and non-western countries. In the *remediation* of alternative conceptions these differences will certainly play a role. However these differences apparently (section 3) do not affect the *formation* of the strong physics preconceptions.

5.4. *Teaching and learning style*

A characteristic difference between the teaching as observed in western and non-western classrooms, is the degree of students' participation. Prophet (1988), for example, 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 sub-categories of teacher-initiated and student-initiated activities. 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 non-western countries, e.g., Ajeyalemi (1986), McDonald and Rogan (1988) and Kuiper (1991). Many non-western teachers give 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. This attitude can get reinforced if the teacher, due to poor training, lacks self-confidence.

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. However, they still question, whether these were the right skills to be promoted for this education system in this culture. On the other hand, our own personal experiences suggest that Indonesian students could adjust well to a highly interactive classroom. With some innovative teachers students would be active while the next hour with a traditional teacher the same students would be quite and passive.

The main obstacles for achieving interactive teaching in developing countres may 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) rather than student attitudes, cf. Beeby (1979).

To summarize, it is widely reported that students in non-western classrooms have learned less than western students to question natural phenomena or seek explanations. Also, the perception of the role of the teacher results in a rather authoritarian teaching style, which does not promote independent questioning and a critical attitude on the part of the students. Teaching and learning styles seem to be major cultural variables that may affect the effectiveness of approaches to remedy alternative conceptions.

5.5. *General impact of culture*

Okebukola and Jegede (1990) have studied the importance of cultural factors in concept attainment of students. The authors contend that the non-scientific explanations that students are used to within traditional communities, could exert hindering influences on the acceptance of scientific explanations. See also Jegede and Okebukola (1991a, 1991b). However, the lower achievement of rural students on tests of Jegede and Okebukola could also be explained by lower quality of rural education and more authoritarian patterns of teacher–student interaction rather than traditional beliefs.

In contrast to Jegede and Okebukola, we claim that the hindering effects of traditional beliefs on science understanding are *not located in the contents of these beliefs* as such. We would think that in the perception of students the domains of science/physics and tradition/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 believe that there is a serious interference between the contents of traditional/superstitious beliefs and scientific understanding, since 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)*. For the remediation of alternative conceptions, the impact of traditional beliefs may be that students have problems in focusing on 'how' questions and moving away from the concern of traditional beliefs which attempt to address value laden 'why' questions. In other words, the types of questions raised in the traditional domain is the main issue, rather than the contents of the traditional beliefs as such.

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'.

We would suggest that the real problem for western and non-western students learning science is, to realise that there is a difference between their preconceptions and science concepts. 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 student 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* (Lin 1983, 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. However, in non-western environments the students' transition into the reductionist worldview of science may be even more difficult.

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. We may expect cultural influences in the formation of some alternative conceptions themselves, mainly biological ones. 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 origins of alternative conceptions and models of organising principles. We agree with the statement given by Wandersee et al. (1994):

> An overview of the origins of alternative conceptions must, by its nature, remain speculative. The evidence for origins is often inferential at best, and certainly such origins are difficult to document. This is especially true of the alternative conceptions derived from

> direct observation and perception, where the primary data are often statements of self-report by the subjects involved (p. 188).

Above authors would expect, however, *that alternative conceptions have their origins in a diverse set of personal experiences including direct observation and perception, peer culture, and language, as well as in teachers' explanations and instructional materials*. (claim 5, p. 188)

Is intuitive science: learned or triggered? This question was raised by Preece (1984). As he observed, it is widely held that children's intuitive science concepts are learned (also on the basis of nurture) from their everyday experiences, both perceptual and linguistic. This leaves unanswered the question of why such ideas are deeply rooted. One of the reasons mentioned as a cause for persistence of alternative conceptions is that teaching usually focusses on content and neglects reasoning, inquiry, and epistomology which produced the knowledge (Perkins & Simmons 1988). Preece, however, argues that many intuitive ideas about everyday physical phenomena are built into the hardware of the brain (nature) and are triggered by appropriate experiences.

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. Their 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 & Wittrock 1983, p. 493).

The generative learning model does not specify which of the information processing elements (filtering, organizing, coding, and storing) would be culture dependent. However, a central role is assigned to the long-term memory as a reference library in the meaning making process and possibly indirectly influencing the information processing (filtering etc.). One would expect the memory to have a sizeable cultural component. Yet, should we conclude that the processing of school physics concepts is culture free?

The Piagetians concentrated their studies on universal mental processes and structures which were assumed to be rather 'content' independent. Researchers concerned with alternative conceptions took issue with that claim 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 paragraphs 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 concerning 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. (Could such a 'gestalt' be part of Fodor's innate language?)

(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. The most important elements are basic cause–effect considerations, which are not necessarily culture dependent as such; these models of common-sense reasoning seem to be universal.

Head (1986) suggests at least five possibilities for the origin of pupils' ideas: (1) Everyday 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 a 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, the every day experience might be even more deeply rooted and harder to modify. We would therefore suggest that the strong alternative conceptions of physics may 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 physics preconceptions. Chi refers to research evidence and argues that the fundamental conception that underlies most of the students' conceptions 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. Other examples are the historical phlogiston theory of heat and the fuel thinking associated with energy.

To summarize, strong alternative conceptions of students in physics which have immediate historic parallels and are found cross-culturally, can be characterized by thinking in terms of substance, that is, treating physical concepts as substance-based entities. We would suggest that these conceptions may be inborn and/or triggered by sensory experiences. 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 & 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' is shown in Figure 1. The co-ordinate 'amount of instruction' corresponds to the number of school years as far as forms (1–4) are concerned. Since the amount of physics instruction in higher grades is about twice as intensive, forms 5 and 6 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 form 1 (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 than 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).

In other words, Figure 1 suggests that preconceptions are the same across two cultures, but that the effectiveness of instruction in reducing these alternative conceptions is different, depending on many factors, part of them cultural. We think that especially the lack of student–teacher interaction is to blame.

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 sensory experiences, as most physics preconceptions (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 & 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 & 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 biological concepts, is much easier to implement than the second category, which refers to most physical science concepts. The physical preconceptions have a strong element of substantial thinking in common. This element also represented a main stumbling block for concept development in the history of science. To give some examples of substantial thinking we could refer to: (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 and human brain. 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 idiosyncratic. This applies to biological conceptions on growth, health, illness, etc. The remediation of all alternative conceptions and the success of a particular teaching strategy may be influenced by culture.

Our thesis should be compared with the claim of Wandersee et. al (1994), who suggest that "the alternative conceptions that learners bring to formal science instruction cut across age, ability, gender, and *cultural boundaries* (our emphasis)". As they observe, "studies that search for differences in substantially divergent cultures often find an 'overlay' of traditional views that are quite distinct from explanations offered by contemporary science". However, as they claim:

> We think it is important to note that these 'traditional' ideas often constitute a second layer of explanations that may contribute to a mosaic of alternative conceptions that includes so-called intuitive conceptions found in western countries. This population mosaic, in turn, may reflect the individual conceptual-propositional mosaics (p. 186).

Above authors seem to generalize our claim, that alternative conceptions in physics are universal constituents of culturally different repertoires, to other science subjects as well.

7. CONCLUSIONS

Most alternative conceptions in physics found in western countries are also encountered in non-western countries. Therefore cultural and environmental variables may have limited influence on the formation of conceptions regarding 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 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. 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 and/or triggered by experience.

(2) Other alternative conceptions, which are influenced by culture, are formed at an older age, and 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) 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 (classrooms with student questions and interaction as compared to classrooms with little or no interaction). This is where culture and teaching intersect.

(5) 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, students seem to be quite good at keeping them separate.

(6) As regards the need for research we would suggest the following. 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, and different student-teacher relationships.

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