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A Comparative Cross-Cultural Study of the Prevalence and Nature of Misconceptions in Physics amongst English and Chinese Undergraduate Students

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Abstract
Despite the large body of literature regarding student misconceptions, there has been relatively little cross-cultural research to directly compare the prevalence of common scientific misconceptions amongst students from different cultural backgrounds. Whilst previous research does suggest the international nature of many misconceptions, there is little evidence as to whether the prevalence of such common misconceptions varies from culture to culture. The purpose of this study was to undertake a preliminary examination of the prevalence and reasons for some previously studied scientific misconceptions amongst English and Chinese undergraduate students so as to ascertain whether there is any evidence of cultural difference. Such a finding could help to identify teaching approaches in either country that are more effective in reducing the prevalence of common student misconceptions. The study involved a convenience sample of 40 undergraduate students – 20 English and 20 Chinese drawn equally from two universities in the North of England – whose formal science education ended at ages 16 and 15 respectively and employed a semi-structured interview schedule containing eight questions. The results showed that whilst similar misconceptions existed amongst both English and Chinese undergraduates, their prevalence was significantly higher amongst the English students (Overall mean score for scientifically correct answers amongst Chinese students was 27.7% higher, $p < .01$, $r = .64$). Often when English and Chinese undergraduates had similar misconceptions, they tended to explain these by drawing upon very similar erroneous analogies and these appear to be only nominally culturally independent in that they are based on globally shared everyday experiences. Differences in the prevalence of misconceptions amongst English and Chinese undergraduates appear to arise from differences in the way in which specific areas of physics are taught in both countries. It might be possible to reduce the prevalence of misconceptions in both countries if a better understanding could be developed of how, and why, undergraduates use certain erroneous analogies, and why some teaching approaches seem more effective in reducing the prevalence of misconceptions than others.

1. Introduction
Despite the large body of literature in the area of school student misconceptions from around the world there has been few cross-cultural studies to *directly* compare the prevalence of common scientific misconceptions amongst students from different cultural backgrounds. Whilst previous research does suggest the international nature of many misconceptions [1] there is little evidence as to whether the *prevalence* of such misconceptions varies across cultures. This study examined the prevalence and the reasons for some of the previously studied scientific misconceptions amongst a group of English and Chinese undergraduate students to ascertain whether there were cultural differences.

2. Research strategy and methods
The study involved 20 English and 20 Chinese undergraduate students aged between 18 and 21. The sample was drawn equally from two universities in England with all of the students having ceased their formal science education at the end of compulsory science education - 16 in England and 15 in China. Data were collected using a semi-structured interview schedule containing eight questions that was designed to investigate misconceptions in the area of physics that have frequently been discussed in the literature. In total there were 13 individual items in the interview schedule with each scored 1 or 0 depending on whether the answer given was correct or not. A total score out of 13 was calculated for each respondent and converted to a percentage. The questions in the interview schedule were written in English, none of the Chinese students had lower than an International English Language Testing System (IELTS) average of 6.0 or any individual component score (listening, reading, writing and

speaking) lower than 5.5. All of the questions related to material that *should* have been covered as part of the primary and/or secondary science curriculum in both countries. Cronbach's alpha was used to estimate internal consistency reliability of the instrument [4]. When comparing responses between groups we use independent sample t-tests, recognising that the sample is small, and with a focus on effect sizes (Pearson correlation coefficient) rather than significance levels [5].

3. Results and Analysis

Table 2 gives an overview of the sample by nationality and gender.

Table 2: The sample by gender and nationality

		Nationality		
		English	Chinese	Total
Gender	Female	12	11	23
	Male	8	9	17
Total		20	20	40

Cronbachs' alpha for the 13-item scale is 0.70 which is a value that is usually taken as acceptable [5]. Two items detracted from this value (perhaps indicating that they are measuring a different construct). These are items 3 (Force resolution) and 8a (Difference between heat and temperature). However, in forming the total (percentage) score across the scale we have kept these items in. Table 3 provides the overall percentage of English and Chinese students that were able to select the *correct* scientific answer for each question.

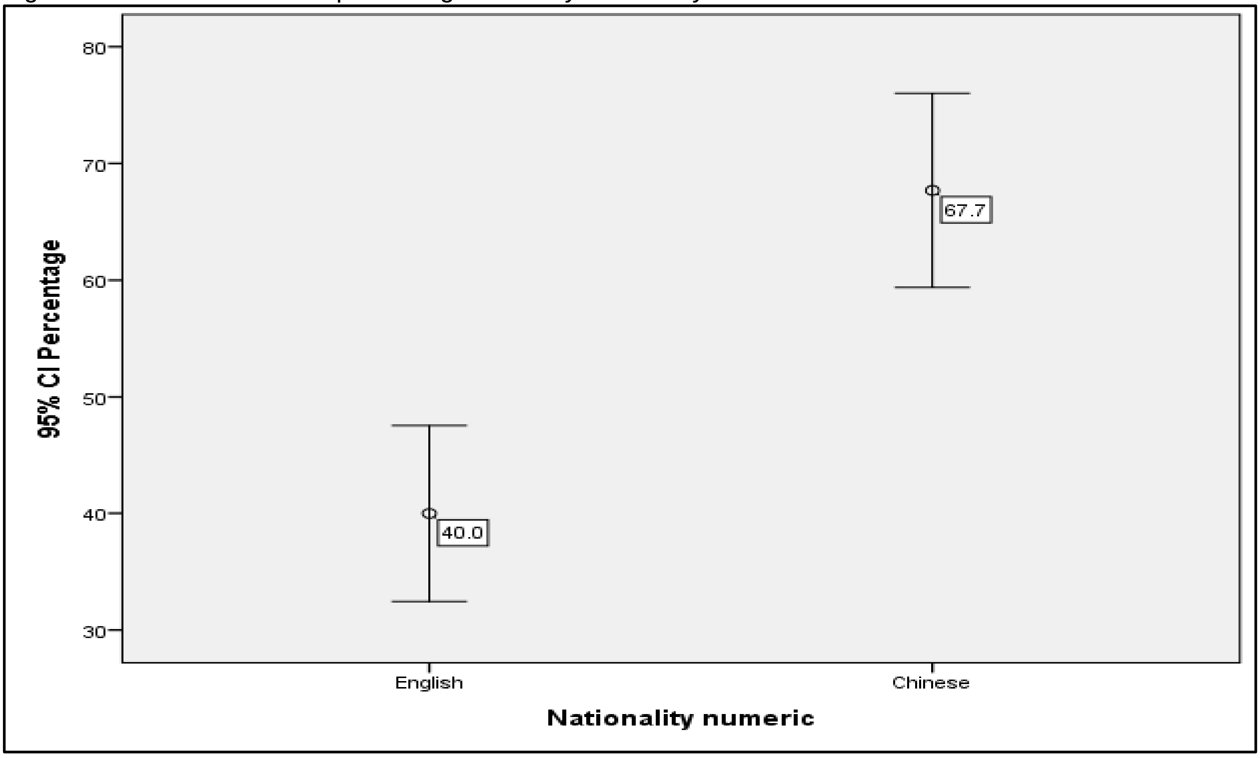
Table 3: Percentage of students that chose the scientifically correct answer

Question	**English %**	**Chinese %**
1 – Newton's first law of motion	45 (9)	95 (19)
2- Newton's third law of motion	80 (16)	95 (19)
3 - Force resolution	40 (8)	75 (15)
4 - Scattering of light into the eye	65 (13)	85 (17)
5 - Electricity in series circuit	55 (11)	75 (15)
6a - Effect of a variable resistor	30 (6)	55 (11)
6b - Effect of a variable resistor	20 (4)	55 (11)
6c - Effect of a variable resistor	15 (3)	55 (11)
6d - Effect of a variable resistor	50 (10)	70 (14)
7 – Newton's second law of motion	25 (5)	80 (16)
8a - Difference between heat and temper temperature	55 (11)	50 (10)
8b - Thermal equilibrium	5 (1)	15 (3)
8c - Conductors and insulators of heat	35 (7)	75 (15)

[Note: Figures in parentheses are the actual number of students out of 20 choosing the correct answer]

Figure 1 shows error bars for the percentage correct on the questionnaire by nationality which confirms that, typically, the English students are getting approximately 60% of the items wrong whereas for the Chinese, the corresponding figure is 32%.

Figure 1: Error bars for total percentage score by nationality.



Overall the English students are typically getting approximately 60% of the items wrong whereas for the Chinese, the corresponding figure is 32%. Table 4 compares item responses by nationality using the independent sample t-test. A positive t-value indicates that Chinese students are more likely to give the correct response than English students. The table is ordered by effect size (smallest to largest) and these can be broadly interpreted as follows: 0.1, small 0.3 medium; 0.5 large [5]. Again, it is clear that for all but one item (8a), Chinese students score more highly on average than did their English peers.

Table 4: A comparison of item responses by nationality

Response being compared	t	df	p-value	effect size (r)
8a - Difference between heat and temperature	-0.31	38	0.76	-0.05
8b - Thermal equilibrium	1.04	38	0.30	0.17
6d - Effect of a variable resistor	1.29	38	0.21	0.20
5 - Electricity in series circuit	1.32	38	0.19	0.21
4 - Scattering of light into the eye	1.46	38	0.15	0.23
2 - Newton’s third law of motion	1.44	38	0.16	0.23
6a - Effect of a variable resistor	1.61	38	0.12	0.25
3 - Force resolution	2.33	38	0.03	0.35
6b - Effect of a variable resistor	2.39	38	0.02	0.36
8c - Conductors and insulators of heat	2.71	38	0.01	0.40
6c - Effect of a variable resistor	2.85	38	0.01	0.42
7 – Newton’s second law of motion	4.07	38	<0.01	0.55
1 – Newton’s first law of motion	4.01	38	<0.01	0.55
Percentage total across the 13 items	5.17	38	<0.01	0.64

By contrast, when comparing responses by gender, there was little evidence of any systematic difference (p=0.31, r=0.05 across the questionnaire as a whole).

Question 1: What emerged was that the explanations offered by English undergraduates, who believed that the ball would stop either relatively quickly, or would at least eventually stop (Table 3), were similar to those reported by [6]. Indeed, all of the English students who got this question wrong offered as an explanation a response that involved them referring to either the 'force', the 'push', or the 'energy' either no longer acting or running out. In contrast only one Chinese undergraduate got this question wrong but rather than thinking that something was 'running out' they suggested that the conditions stipulated in the question – i.e. that it was a frictionless, obstruction-free, surface and that there was no air resistance – must have neglected something.

Question 2: Of the *four* questions on the general theme of force and motion (1, 2, 3 and 7) this was the only one in which the difference was non-significant (p=0.16, r=0.23) with the majority of English undergraduates also selecting the scientifically correct answer. This finding differs from [7] in which it was reported that nearly half students in high school thought only gravity acted on a stationary book resting on a table. This suggests that in teaching about a pair of balanced forces – this specific example of an object on a table has appeared in many English science text books and revision guides over the past 35 years – there appears to be much less cultural difference.

Question 3: Whilst the difference in the prevalence of this misconception between English and Chinese undergraduates was statistically significant (Table 4) the explanations offered by those selecting the *incorrec*t answer were similar across cultures suggesting that either the misconception, that a force is needed in the direction of motion, was not replaced by the scientific explanation whilst these undergraduates were at school. Similar findings amongst school student have been reported [8].

Question 4: The results for this question showed that whilst a majority of undergraduates in both groups was conversant with the scientific explanation for how objects are seen by an observer the prevalence of those with misconceptions was higher amongst the English (Table 3). It was not possible, given that the number of Chinese undergraduates getting an incorrect answer (and not always the same incorrect answer), to observe any similarities in the explanations that they offered regarding their misconceptions with those offered by the English undergraduates who gave incorrect answers. Indeed, what did emerge in only this question was that the explanations offered by two of the Chinese undergraduates, one who selected option 'a' and the other option 'c' was that they had simply guessed at the answer rather than having any firmly held misconceptions about light and vision.

Questions 5: Whilst no student from either group selected the unipolar or 'clashing' currents' options there were undergraduates in both groups, the prevalence was greater amongst the English, who retained a belief in the attenuation model. Their explanations were very similar to secondary school students [9] who believe in an attenuation model.

Question 6: Although, on average, across the three parts of this question the Chinese undergraduates got approximates 2.5 times as many correct answers as those from England the main reason for incorrect answers given by students in both groups was their adherence to an attenuation model of electric current and therefore believed, as the following examples illustrate, that the variable resistance in the circuit would only affect those bulbs placed after it in the direction of the current arrow. Our findings support previous claims [10] that even more academically able participants are likely to use a "sequence model" when thinking about how components within an electric circuit will behave when the current, voltage or resistance are changed.

Question 7: Whilst the difference in the prevalence of this misconception is again statistically significant (Table 4) what also emerged very noticeably was the false confidence of those English students who selected the incorrect answer and opted for the answer that the elephant would reach the ground first. Although four Chinese undergraduates also thought that the elephant would reach the ground first one of them realised, during the subsequent interview, that they had selected the incorrect answer when they recollected having been taught this at school and another selected the wrong answer on the basis of what appeared to be a mistaken recollection of a school experiment. Furthermore, although students who selected the correct answer were not asked to explain their thinking a number of the Chinese students (although none of the English) mentioned that they knew the correct answer because they specifically recollected learning at school about Galileo's experiment in which two balls of the same size but different mass are dropped from the tower of Pisa and arrive at the ground at the same time, which is similar to the findings from Israel [11].

Question 8: In terms of believing that the metal would be colder than the wood after being placed in snow together for a long time the explanations given by both English and Chinese students are similar and appear to be based upon their own personal experience that metal feels colder than wood. Whilst 13 English students, as against only 5 Chinese, got 8c incorrect their reasons were again very similar and drew on shared experience such as the fact that refrigerators, which they all knew are used to keep things cold, are made of metal. Such comments by both English and Chinese students support the findings by [12] [13] that such misconceptions are often based on personal experience.

4. Conclusions

This study has found that overall there is a large difference in the prevalence of misconceptions in the areas of physics tested between English and Chinese undergraduate students studying non-science subjects and whose formal science education ended at age 16 and 15 respectively. Indeed, the prevalence of misconceptions amongst English undergraduates was found to be almost twice as high as that amongst the Chinese undergraduates. A second finding was the similarity in the explanations that undergraduates from both countries offered for their misconceptions: a similarity that appeared to reflect an exposure to common, culturally independent, everyday experiences/ observations.
Our findings suggest that irrespective of cultural background similar misconceptions, based primarily on common everyday experiences, can arise and endure or, even if replaced by scientific ideas whilst at school, revert back at university to pre-instructional misconceptions if formal science education has not been effective in replacing those misconceptions in an enduring manner.

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