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A comparative cross-cultural study of the prevalence and nature of misconceptions in physics amongst English and Chinese undergraduate students

Abstract

We report on a small-scale comparative cross-cultural study the purpose of which was to undertake a preliminary exploration of the prevalence and nature of misconceptions in certain areas of physics amongst English and Chinese undergraduates studying non-science subjects. The study employed semi-structured interviews with 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 age 16 and 15 respectively. The results, in which students were asked a series of questions which were marked as correct or not, showed that whilst similar misconceptions exist amongst both English and Chinese undergraduates their prevalence was significantly higher amongst the English students (Chinese scored 27.7% higher, $p < 0.01$, $r = 0.64$). It also emerged that when such misconceptions exist English and Chinese undergraduates explain these by drawing upon very similar, erroneous, analogies and these appear to be only nominally culturally independent in the sense that they are based on globally shared everyday experiences. If the prevalence of misconceptions amongst English undergraduates is to be reduced, research into the way in which specific areas of physics are taught in China might prove beneficial. It might also be possible to reduce the prevalence of misconceptions in both groups if a better understanding could be developed of how, and why, undergraduates use certain, erroneous, analogies.

Purpose: 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.

Sample: 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 age 16 and 15 respectively.

Design and methods: The study employed semi-structured interview schedule containing eight questions.

Results: 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, $p < 0.01$, $r = 0.64$).

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.

Conclusion: 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.

Keywords

Misconceptions; undergraduates; cross-cultural; physics

Introduction

There has been a substantial amount of research in the area of student misconceptions in science albeit much of it undertaken back in the 1980s and predominantly having focused on students within the 11 to 16 age range, with only a much smaller number of studies involving undergraduate university students. Whilst the latter studies have found that undergraduate students, including those studying science subjects, still retain (or have reverted back to) misconceptions that are similar to those held by younger students, the prevalence of these misconceptions amongst undergraduates has not been closely examined.

Indeed, despite the large body of literature in the area of school student misconceptions from around the world there has been relatively little cross-cultural research to directly compare the prevalence of common scientific misconceptions amongst students from different cultural backgrounds. Indeed, whilst previous research does suggest the international nature of many misconceptions (Osborne, 1983) there is little evidence as to whether the prevalence of such common misconceptions varies from culture to culture. Any such finding might identify those teaching approaches in a particular country that are more effective in reducing the prevalence of internationally shared student misconceptions. Whilst constructs such as the Force Concept Inventory (Hestenes et al., 1992) have been designed to test conceptual understanding of mechanics it has tended to be used with physics undergraduates (e.g. Hake, 1998: USA 18-19; Redish et al., 1997: USA 18-19; Zhou et al., 2008:

Canada 19-20) rather than being used as a means of contrasting the prevalence of specific misconceptions between different countries.

This study set out to examine 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 was a cultural difference.

Research strategy and methods

The study involved 40 undergraduate students aged between 18 and 21 of whom 20 were English and 20 Chinese. The sample was drawn equally from two universities in the North of England with all of the students having ceased their formal science education at age 16 in England and 15 in China: ages that mark the respective end of compulsory science education in each country. Data were collected using a semi-structured interview schedule (Appendix A) containing eight questions that was designed to investigate a range of misconceptions in the area of physics that have frequently been discussed in the literature. When each of the eight questions on the interview schedule had been answered students were asked to explain their thinking with regards to any of the eight questions, or parts thereof, which the researcher, asking the questions, had recorded as being scientifically incorrect. We would emphasise here that at no point were the students informed that they were only being asked to provide explanations for incorrectly answered questions but rather they were told that this additional information, regarding some of their responses, was simply an attempt to better understand their reasoning. The purpose of this was to see whether the reasoning used by both English and Chinese students bore any similarity. There were a few cases when students offered unsolicited explanations of their thinking when they were answering the question correctly and when this occurred their comments were also recorded. 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 to avoid translational issues associated with scientific terminology (Baker & Taylor, 1995; Mori et al., 1976) and to enable a non-Chinese speaking researcher to interview students from both countries. The interview schedule was piloted with four undergraduate students – a male and female from each of the two countries – prior to its use, with no problems being reported. In terms of content areas the questions related to four areas of physics: force and motion; light and vision; electric circuits; and heat and temperature. Whilst it was not possible to ascertain that all of the undergraduates had studied all of these areas in their school science, all of the questions related to material that should have been covered (DfEE/QCA, 1999; Lingbiao, 2004) as part of the primary and/or secondary science curriculum (Table 1) in both countries.

In terms of ability in English, all of the Chinese undergraduates had met the English language entry requirements stipulated by their respective UK university for entry onto undergraduate programmes taught 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.

Due to difficulties associated with obtaining a truly random sample from amongst the very large undergraduate student population not studying a science subject at both universities it was decided to make use of a convenience sample. Students were approached at various locations on both campuses and asked a number of preliminary questions: Nationality, age, and the age at which they had ceased to study science, to ascertain whether they were suitable subjects for the study. Having previously checked the entry requirements at both universities it was found that a student who had ceased to study any science at the age of compulsion in their respective country would be ineligible

to enter any degree programme in either the faculty of science or medicine at either university.

Whilst five English and two Chinese students who were approached and found to be suitable declined to take part, we have no reason to believe that the other 40 students who did agree to take part were not representative of the larger populations at both universities that would have met the same suitability criteria for taking part in this study.

In a study such as this reliability requires stability of responses over time (Cohen et al., 2011) and so to evaluate the reliability of the study instrument (questionnaire), a test-retest method was adopted. At the end of the interview each participant was invited to take part in a further stage of the study one month later and of these 8 English and 10 Chinese students agreed to do so and provided their email addresses. After a period of one month the same questions were sent to these participants by email and of these 4 English and 4 Chinese students returned completed questionnaires. The answers given by all 8 students in the retest were identical to those they had given a month earlier in the first test and so we are confident that the questionnaire responses were reliable.

In terms of statistical methods in analysing the responses, we use Cronbach's alpha to estimate internal consistency reliability of the instrument (Arthur et al., 2012, p. 50). 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 (Field, 2013, pp 79-83).

The questions

In this section we provide details of the misconception each question was designed to probe for (all eight questions contained within the interview schedule can be seen in Appendix A) and link these to the literature relating to previous studies in those areas. When referring to the literature we also include when appropriate (within the parentheses) details of both the country in which the study was undertaken and the age of the students.

The first question relates to a situation in which an object is rolled at a steady speed on a friction-free surface in which there is also no air resistance (adapted from Driver, 1983). In a study by Langford and Zollman (1982: USA 16-18) it was found that many children harboured the misconception that there must be a force constantly acting on such an object to keep it moving at a steady speed as without a constant force the object would 'use up' the force and stop even under friction-free conditions. Similar findings have also been reported by Gunstone and Watts (1985: Australia 9-19).

Question two (adapted from Clement, 1982: USA 18-21) asked students to consider the forces acting on a stationary book placed on a table where it has been found (Minstrell, 1982: USA 16-18, Viennot, 1979: France 17-21) that there is a widespread misconception that "no movement [of the book] means no force" (Gunstone & Watts, 1985, p.94: Australia 9-19). It was found (Minstrell, 1982) that the students' understanding as to why the book did not drop to the floor did not, in general, include the scientific notion of balanced forces but was grounded in the idea that "the table was merely in the way" (Minstrell, 1982, p.13).

Question three focused on the misconception that an object moving in a given direction must have a force acting on it in the same direction as the motion (adapted from Clement, 1982: USA 18-21). For example, in a study by Watt and Zylbersztajn (1981: UK 14), it was reported that many students thought that there must be a force acting upwards on a ball for as long as it continued to move upwards after leaving the thrower's hand to explain the fact that the ball was moving in the upward direction. Similar findings regarding force and the direction of an object's motion have also been found by Clement (1982: USA 18-19) and Gunstone (1984: Australia 15-16).

The fourth question (adapted from Guesne, 1985: France 10-14) relates to light and vision in which previous research (Andersson & Karrqvist, 1983: Sweden 12-15; Guesne, 1984: France 10-14) has found that a common misconception amongst children is that the eye sends out rays to objects and

these rays return to the observer's head with 'messages' or 'pictures' so that people can see the objects.

Question five (adapted from Osborne, 1983: New Zealand 12-15) probes misconceptions about the flow of current in simple electric circuits. Previous research has identified three common misconceptions. The first of these is a unipolar model (Osborne, 1981: New Zealand 12-15) in which children do not have a concept of a closed circuit and instead consider that electric current moves from one end of battery through one wire to a bulb to make it light up. An alternative misconception, referred to as the 'clashing currents' model (Osborne, 1983), involves a belief that electric current comes out from both ends of a battery and travels from opposite directions to meet and 'clash' inside the bulb which explains why it lights up. The third, widely held misconception, is an attenuation model (Shipstone, 1984: UK 11-17) in which it is believed that electric current will be 'consumed' or 'used up' by the bulb in the circuit after flowing through it, therefore the first bulb to encounter the electric current, as it moves from one terminal of the battery around the circuit towards the other terminal, will be brighter than any subsequent bulbs as there will be sequentially less electric current left for subsequent bulbs to 'use up' in a series circuit. Research into the attenuation model (Chiu & Lin, 2005: Taiwan 9-10; Tsai et al., 2007: Taiwan 12-17) found that this was the model most frequently held by secondary school students and that, unlike the unipolar and 'clashing currents' model, was very resilient to change even after instruction.

Question six (adapted from Shipstone, 1984: UK 11-17) relates to a more complex circuit in which a variable resistance, the resistance of which is increased and decreased, is placed in a series circuit. Research by Shipstone (1984) found there to be a widely held misconception amongst students that a variable resistor could only affect the brightness of bulbs placed after [relative to their perception of the direction in which the current is flowing] it in a series circuit. This so called "sequence model", is closely aligned to the attenuation model (Chiu & Lin, 2005; Shipstone, 1984; Tsai et al., 2007), and has also been reported by Paatz et al. (2004: Germany 16) who found that even more

academically able participants are likely to develop and/or have retained this misconception post instruction.

The seventh question (adapted from Fotou & Abrahams, 2013: Greece 9-17) asked students about two objects of the same size but different mass falling under gravity and ignoring air resistance. Previous research (e.g. Anderson, 1990: Sweden 12-16; Gunstone & White, 1980: Australia 18) has found that students frequently have the misconception that in such a situation the heavier object will reach the ground before the lighter object. In contrast a study by Bar et al. (1994: Israel 4-13) reported that Israeli students were more likely to predict that the two objects, dropped under the conditions described above, would hit the ground together drawing on their knowledge of Galileo's experiment which is specifically taught in the Israeli curriculum.

The eighth and final question (adapted from Erickson & Tiberghien, 1985: France 4-13) focused on heat and temperature, an area in which there is a common misconception amongst students that temperature and heat are synonymous (Harrison et al., 1999: Australia 15-16; Niaz, 2000: Venezuela, 18-21). It has, furthermore, been reported (Choi et al., 2001: S. Korea, 9-11) that there is also a misconception that different materials would have different temperatures when placed in the same environment even when they had been allowed to reach thermal equilibrium with their common shared surroundings. For example Paik et al. (2007: S. Korea 4-11) have reported that when students were asked to predict whether a piece of metal and a piece of wood put in the same warm water would be at the same temperature they believed, erroneously, that the wood would be warmer and have a higher temperature because of their experience that wooden objects normally felt warmer to their touch than metal ones in the same environment. Likewise it has been reported (Choi et al., 2001; Lewis & Linn, 1994: USA 11-14; Paik et al., 2007) that similar misconceptions, again based on personal experience, meant that many students believed that metal foil – that they recollected as having felt cold to their touch - would be more effective, if wrapped around an ice

cube, at keeping it from melting than wrapping it in a material cloth as the latter felt warm to their touch and would therefore heat the ice.

Summary of physics content by question

The National Curriculum for science was implemented in both primary and secondary schools in England and Wales in 1988 and has undergone subsequent revisions (1995, 1999, 2004, 2005, 2007 and, more recently, in 2014). The age of the English students involved in the study meant that they all would have followed the 1999 version (Department for Education and Employment and the Qualifications and Curriculum Authority (DfEE/QCA), 1999). All of the physics topics probed in the study were part of either the primary or secondary science curriculum in both England and China that was in force whilst students in both countries were in school up to the age of 16 and 15 respectively. Table 1 shows a summary of the physics content of each question in the interview schedule along with the title it is referred to in the text.

Table 1: Summary of question items and their link to the National Curricula in England and China

Item Title	Underpinning Physics content	Title of physics content in the National Curriculum (Taken from QCA, 1999)	Title of physics content in the Chinese curriculum (Taken from Lingbao, 2004)
1 Rolling ball	Newton's first law of motion	Key Stage 1: To recognise that when things speed up, slow down or change direction, there is a cause (p.19)	Grade 3-6 Elementary: Material world: motion and force Grade 7-9: Middle: Mechanical motion and force
2 Box on table	Newton's third law of motion	Key Stage 2: That when objects [for example, a spring, a table] are pushed or pulled, an opposing pull or push can be felt (p.26)	Grade 3-6 Elementary: Material world: motion and force Grade 7-9: Middle: Movement and interaction: mechanical motion and force
3 Swinging ball	Force resolution	Key Stage 2: How to measure forces and identify the direction in which they act (p.26)	Grade 3-6 Elementary: Force
4 How we see	Scattering of light into the eye	Key Stage 2: That we see things only when light from them enters our eyes (p.26) Key Stage 3: That non-luminous objects are seen because light scattered from them enters the eye (p.35)	Grade 7-9 Middle: Light
5 Simple circuit	Electricity in series circuit	Key Stage 3: That the current in a series circuit depends on the number of cells and the number and nature of other components and that current is not 'used up' by components (p.34)	Grade 7-9 Middle: Electricity and magnetism
6a-d Complex circuit	Effect of a variable resistor	Key Stage 3: That the current in a series circuit depends on the number of cells and the number and nature of other components and that current is not 'used up' by components (p.34) Key Stage 4: The qualitative effect of changing resistance on the current in a circuit (p.43)	Grade 7-9 Middle: Electricity and magnetism
7 Free-falling objects	Newton's second law of motion	Key Stage 4: Why falling objects may reach a terminal velocity (p.55)	Grade 3-6 Elementary: Motion and force Grade 7-9 Middle: Mechanical motion and force
8a Melting ice	Difference between heat and temperature	Key Stage 2: That temperature is a measure of how hot or cold things are (p.25) Key Stage 3: The distinction between temperature and heat (p.36)	Grade 3-6 Elementary: Forms of energy
8b Metal and wood in snow	Thermal equilibrium	Key Stage 2: That some materials are better thermal insulators than others (p. 25) Key Stage 3: How insulation is used to reduce transfer of energy from hotter to colder objects (p.36)	Grade 3-6 Elementary: Forms of energy
8c Metal and cloth containers	Conductors and insulators of heat	Key Stage 2: That some materials are better thermal insulators than others (p. 25) Key Stage 4: How insulation is used to reduce transfer of energy from hotter to colder objects (p.56)	Grade 3-6 Elementary: Forms of energy

Results and Analysis

Overall results

Throughout the remainder of this article, English and Chinese students are identified by the capital letters E and C respectively and their gender is indicated using the letters m and f with a unique number being attached to distinguish between English, and Chinese, students of the same gender. For example Ef7 will be used when quoting an English female student (student number 7).

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

Table 2: The sample by gender and nationality

		Nationality		Total
		English	Chinese	
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 (Field, 2013, pp 709). 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 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 compares histograms between Chinese and English students in the percentage score on the questionnaire. It is evident that Chinese students are scoring much higher than their English counterparts.

Figure 1: Histograms for the total percentage score by nationality

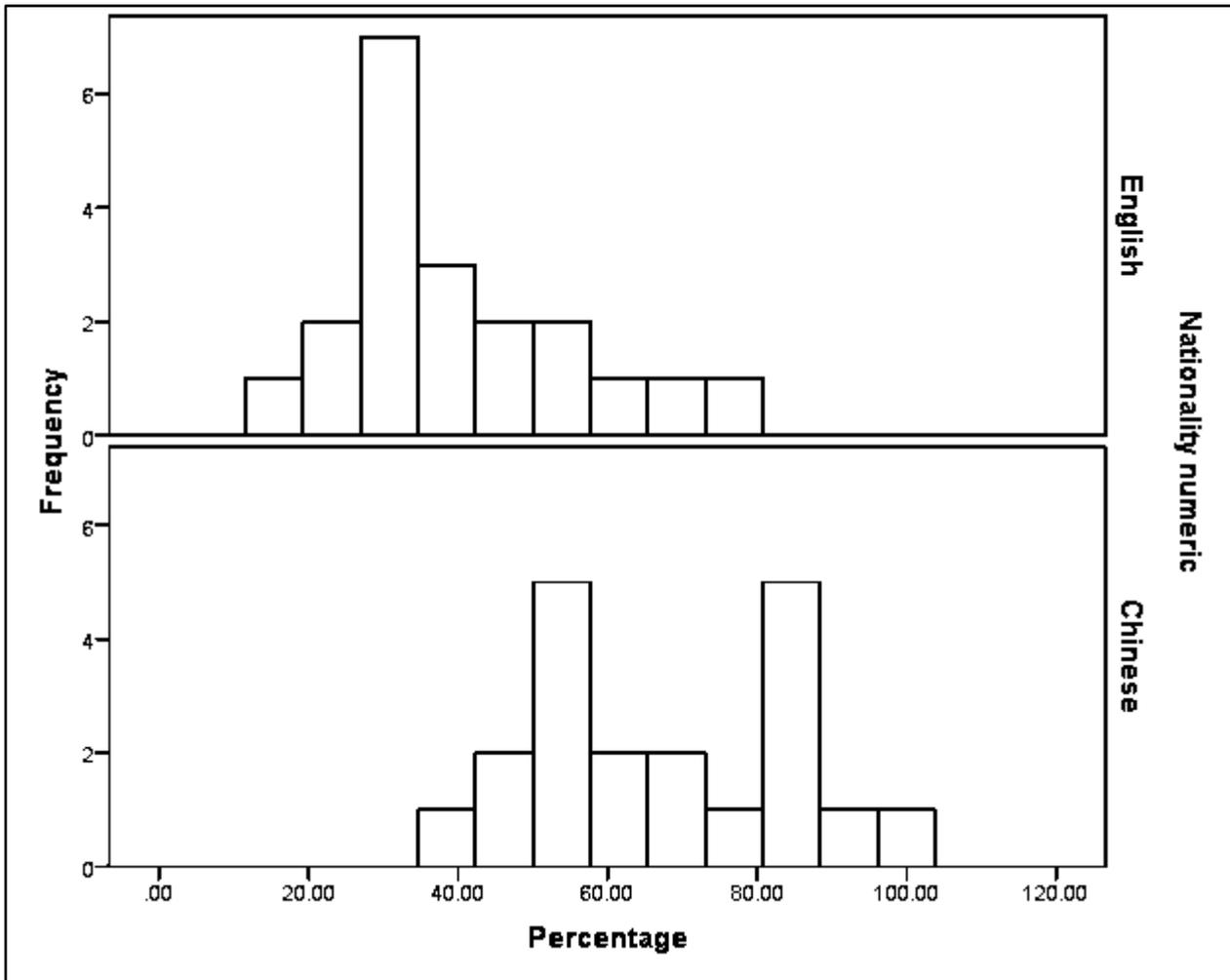


Figure 2 shows error bars for the percentage correct on the questionnaire by nationality which confirms that, typically, the English students are getting approximately 60% of the items wrong whereas for the Chinese, the corresponding figure is 32%.

Figure 2: Error bars for total percentage score by nationality.

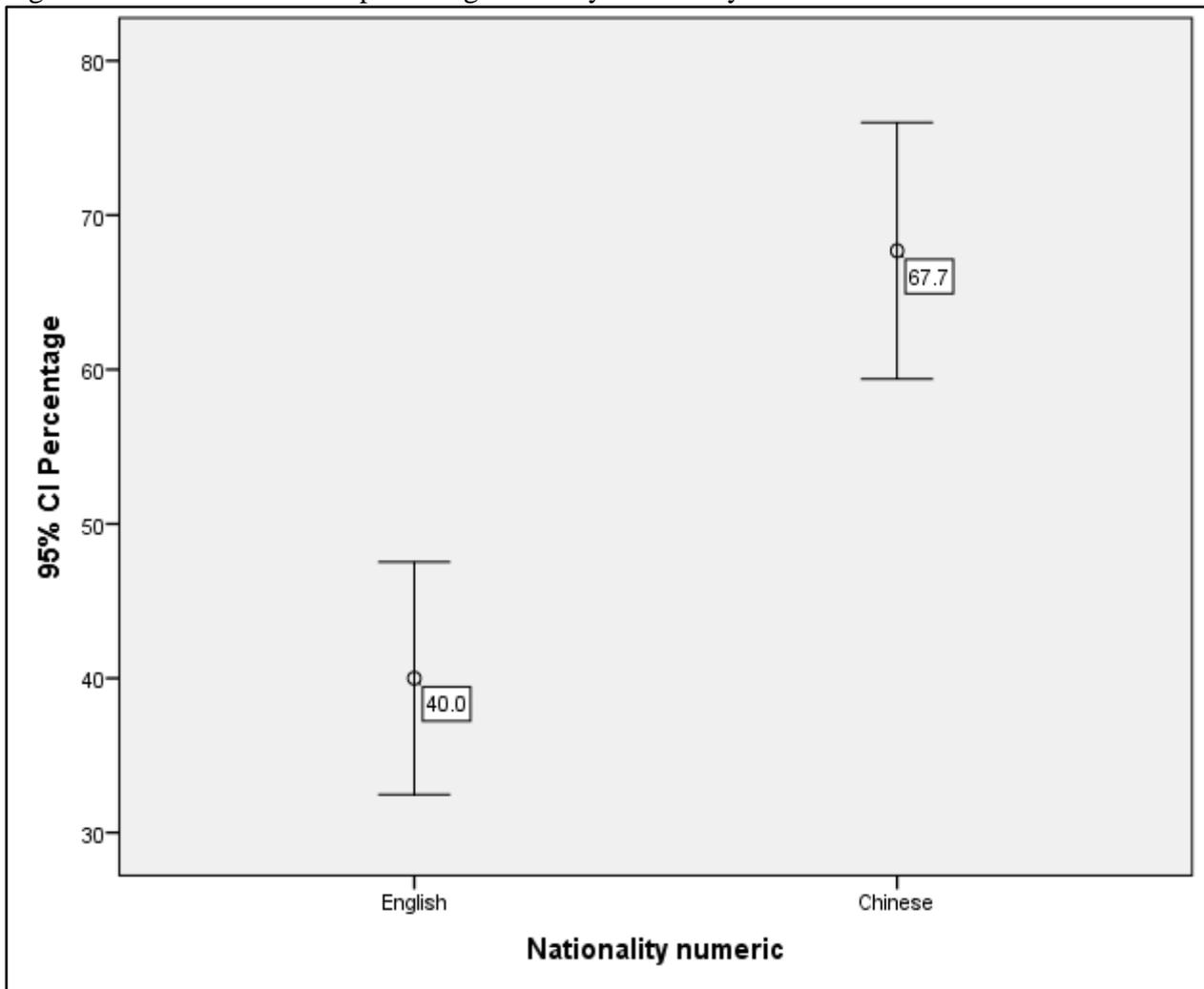


Table 4 shows detailed results of comparing item responses by nationality using the independent sample t-test. A positive t-value indicates that Chinese students are more likely to give the correct response than English students. The table is ordered by effect size (smallest to largest) and these can be broadly interpreted as follows: 0.1, small 0.3 medium; 0.5 large; (Field, 2013, pp 79-83). 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 Langford and Zollman (1982). Indeed, all of the English students who got this question wrong offered by way of an explanation, as the following examples illustrate, a response that involved them referring to either the 'force', the 'push', or the 'energy' either no longer acting or running out:

Ef1: I think it will continue for a while and stop, because there is no force that continues acting on the ball.

Ef19: The ball will stop after a while because it will finally run out of energy.

Ef20: It will stop eventually because the push will run out, when the push runs out the ball will stop.

In contrast the only Chinese undergraduate to get this question wrong did not appear to believe, as the following quote illustrates, that something was ‘running out’:

Cf13: I am not quite sure about this I just feel it will stop. There must be something to stop it, like gravity or something.

Indeed, their explanation indicates that they appear to consider 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. In contrast to the English students, who referred vaguely to a ‘force’, ‘push’, or ‘energy’ either no longer acting or running out, the Chinese student attempted to explain their belief by drawing on, and identifying, a specific force albeit that the force of gravity was not the appropriate force in this question.

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 Minstrell’s (1982: USA 16-18) study 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 (see for example: Abbott, 1981; Parsons, 2006) – 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 incorrect answer were similar as the following representative examples illustrate:

Ef10: There must be a gravity force, and a force pulls up and this [points to the arrow in the direction of movement] is the central [sic] force on the ball that makes it swing.

Cf13: The string pulls the ball up and the gravity down and this force between them [points to the arrow in the direction of motion] makes the ball go that way. I just remember this. I might have learned it before.

This suggests 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 (Gunstone, 1984: Australia 15-16), or that, having initially adopted the scientific explanation at school, they have subsequently reverted back to their (similar) pre-scientific misconception.

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' (see Appendix A) was that they had simply guessed at the answer:

Cf3: I do not really know why, I never thought of how we see. But I feel if there is light then we can see things and if in dark, we cannot, so light is important.

Cm7: I do not quite understand why, I just guessed the answer, this option seems more reasonable.

These responses appear to indicate that rather than having any firmly held misconceptions about light and vision these two undergraduates' explanations arose as a result of spontaneous reasoning about a situation that they had never previously considered.

Questions 5: Whilst no student from either group selected option 'a' or 'b' (the unipolar and 'clashing' currents' model respectively - see Appendix A) there were undergraduates in both groups, the prevalence was greater amongst the English than the Chinese, who retained a belief in the attenuation model. The following explanations illustrate the similarity of their misconceptions:

Ef18: Because L1 is near the battery it can get more current than L2 so I think it may be brighter.

Em11: The first bulb is closer to the power source so it can get more power, so of course it will be brighter.

Cm2: The bulb [points to L1] itself has resistance and it will reduce the current a little bit, this makes L2 less bright than L1.

Cm3: L1 is before L2 and so it will use up some current so the bulbs L2 will get less current, so it is not as bright as L1.

The explanations offered above are very similar to those reported (Chiu & Lin, 2005: Taiwan 9-10; Tsai et al., 2007: Taiwan 12-17) amongst secondary school students who believe in an attenuation model.

Question 6: Although, on average, across the three parts of this question the Chinese undergraduates got approximately 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. The similarity of their explanations is illustrated below from two typical responses from both an English and Chinese student:

Ef 10: The [variable] resistance is behind L1 so it makes no difference [to L1].

Cf13: Because the current go [sic] from L1 to L2 and L3, the L1 won't be affected.

Our findings support the claims by Paatz et al. (2004: Germany 16) 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:

Ef20: This [the elephant reaching the ground first] is so obvious [laughing].

Em13: The mass of elephant is bigger and there is enough distance for it to speed up, so of course [laughing] it will hit 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:

Cf14: Because it (the elephant) is heavier, the gravity will be stronger. Oh, wait, I remember we learned this in physics class it seems they hit the ground at the same time, but I forget why.

One of the Chinese students who selected the incorrect answer did so on the basis of what appeared to be a mistaken recollection of a school experiment.

Cf17: I do not know [pause], I just think of the experiment of paper and ball, the ball hit the ground first. And I think the dog and elephant are similar with the paper and the ball, so I think the elephant will hit the ground first too.

Whilst the nature of the experiment itself was not discussed the authors are familiar with a similar experiment, in which two identical sheets of paper are simultaneously dropped after one has been crumpled up into a small ball, to demonstrate the effect of air resistance. It is possible that this undergraduate (Cf17) was thinking of a similar experiment but mistakenly thought that the ball of paper had a greater mass compared to the sheet of paper.

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 recollected having specifically learnt 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 by Bar et al. (1994).

Question 8: One English student, who got the incorrect answer, was unclear about the difference between heat and temperature:

Em13: I don't quite understand the difference between heat and temperature.

However, three Chinese students seemed to confuse time and heat as the following example shows:

Cf3: They [the larger amount of ice] need more time to melt, not heat. It has nothing to do with size, I think.

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. Examples of such comments are shown below:

Em7: I just think metal is normally colder, and the wood will stay warm.

Cf19: I do not quite understand this, I just following my feeling. I guess maybe metal always feels colder.

Interestingly, whilst three Chinese students appeared to realise that the temperature of the metal and the wood would be the same, they still, as the following example illustrates predicted the incorrect answer because they were unable to discard a belief that:

Cf11: Maybe their temperature is the same, but I feel metal is colder than wood. It's just my feeling.

Whilst 13 English students, as against only 5 Chinese, got 8c incorrect their reasons were, once again, very similar and drew on shared experience such as, in the examples below, that refrigerators which they all knew are used to keep things cold, are made of metal:

Ef18: I just think a fridge is made of metal, so metal might be better.

Cf15: Containers for keeping things cold like the refrigerator are normally made of metal. It can better stop the cold inside leaking out, so it is better.

Such comments by both English and Chinese students support the findings by Choi et al. (2001: S. Korea, 9-11) and Paik et al. (2007: S. Korea 4-11) that such misconceptions are often based on personal experience.

Limitation

There are a number of limitations to this study that need to be considered. One of these relates to the ages of the students and the fact that the sample drew from students across all three years of undergraduate study (i.e. 18-21). The implication of this being that amongst English students there was a potential range of 2-5 years, and amongst Chinese students of 3-6 years, from when they ceased to study compulsory science. It might therefore reasonably be assumed that if the ability to

recollect scientific fact diminishes with time then, all else being equal, Chinese students would be disadvantaged to a greater extent compared to students from England. The results from this study suggest that if such a disadvantage exists then the size of the difference between students from both countries reported here is an underestimate of the true size of the difference between them. Another possible limitation is that Chinese students were required to respond to questions in a language that was not their first and that this might have placed them at a relative disadvantage to the English students. We would make two points with regards our decision to use English as a medium for the interview schedule. First, it should be noted that whilst students from both countries sometimes asked for a question to be repeated there was no indication amongst the Chinese students of a lack of mis-comprehension based on language difficulties. The second point is that even if the use of English had presented an undetected problem in terms of comprehension it would reasonably have been expected to have been a greater problem for the Chinese students. However, given that Chinese students in this study did better than those from England then our findings are, again, likely to be an underestimation of the any difference.

Conclusions and implications

The first finding to emerge from, what is essentially a preliminary study, is 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. The second finding is a 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.

The fact that this preliminary study has found that the prevalence of certain common misconceptions amongst the Chinese undergraduates was lower than amongst English undergraduates suggests that

the teaching of some of these topics in China might be more effective in replacing misconceptions with the correct scientific explanation. Indeed, the example of question 7, in which the Chinese students had a statistically significantly lower prevalence of the misconception that, if air resistance is neglected, heavy objects fall faster than lighter ones, appears to owe much to the specific mention of Galileo's experiment in the Chinese curriculum. Such an approach, in which the teaching of this topic specifically draws on Galileo's experiment, has also been found by Bar et al. (1994), in a study in Israel, to be an effective means of replacing that common misconception amongst students with the correct scientific view.

We therefore suggest that larger cross cultural studies need to be undertaken to ascertain the prevalence of enduring misconceptions across a much broader range of topics in physics, chemistry and biology so that teaching approaches that are more effective in reducing the prevalence of specific misconceptions – such as the use of Galileo's experiment – can be introduced and trialled in countries where the prevalence of those particular misconceptions is currently much higher.

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Appendix A

Age: Gender: Male Female Nationality: E or C

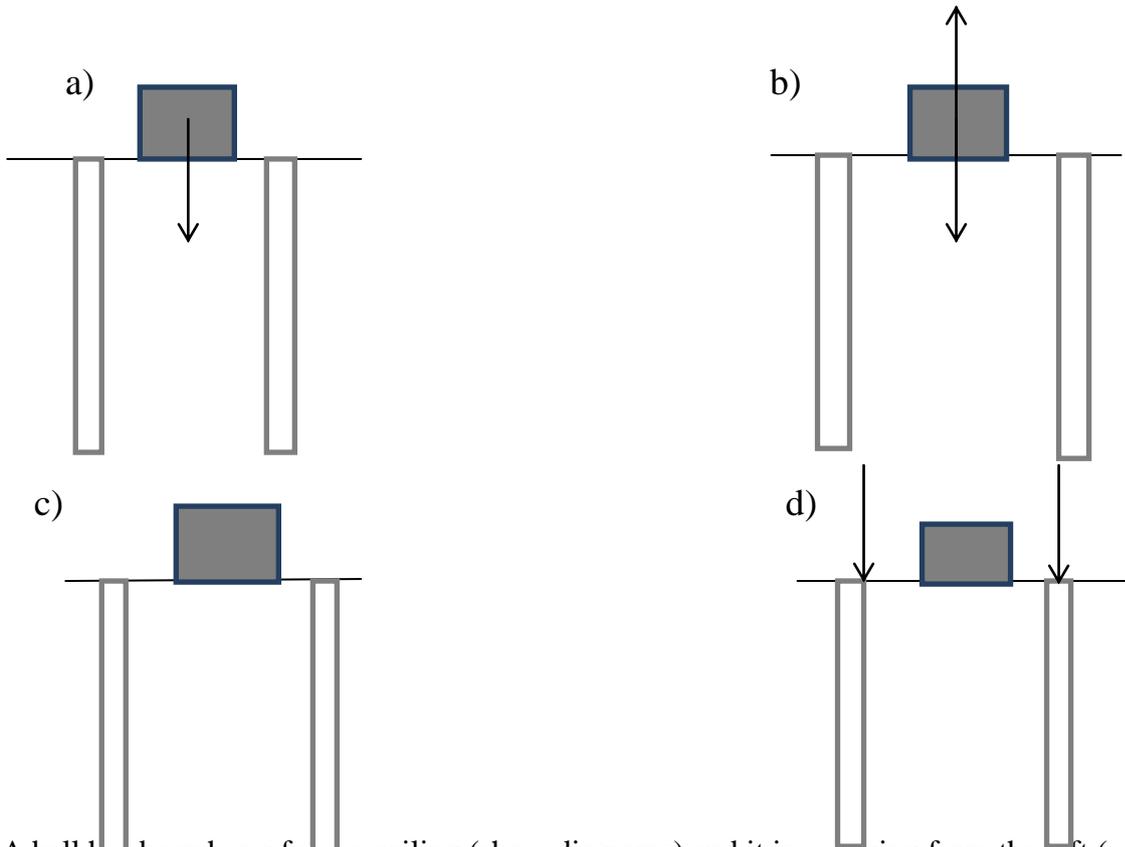
1. A ball is set in motion so that it moves at a steady speed on a friction free surface with no air resistance or obstacles in its path. Can you tell me which of the follow you think best describes the ball's subsequent motion?

a) the ball will stop in a very short time.

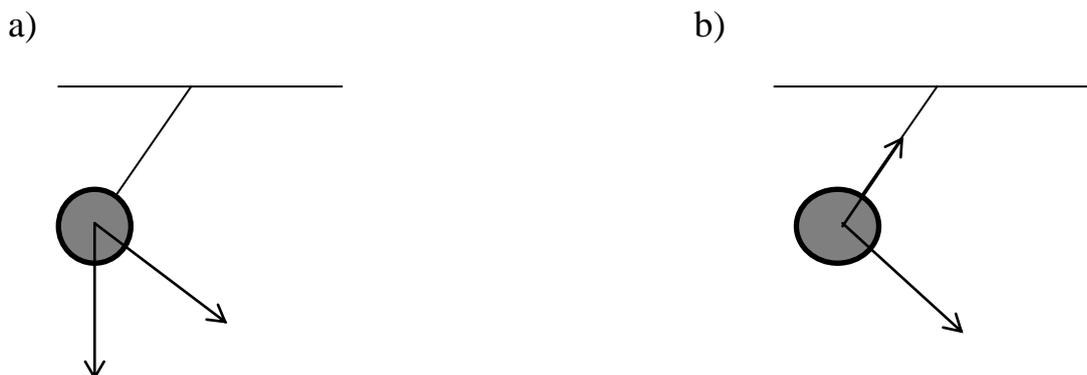
b) the ball will eventually stop after a long time.

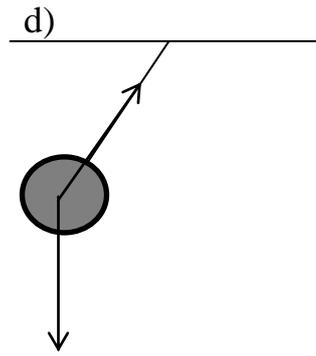
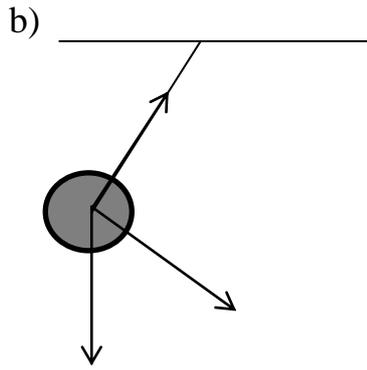
c) the ball will keep moving at a steady speed.

2. A box has been placed onto a table (show diagrams). Can you tell me which of the four diagrams you think best describes those forces that might be acting?

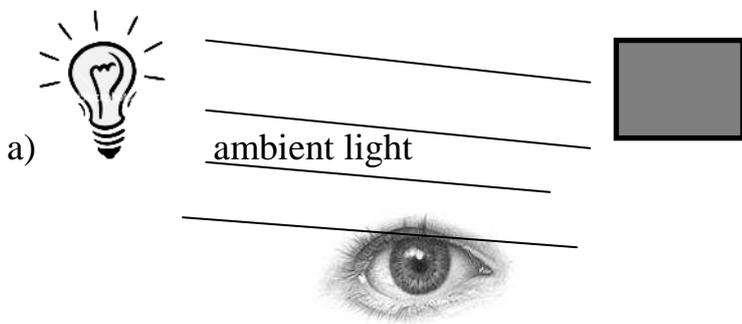


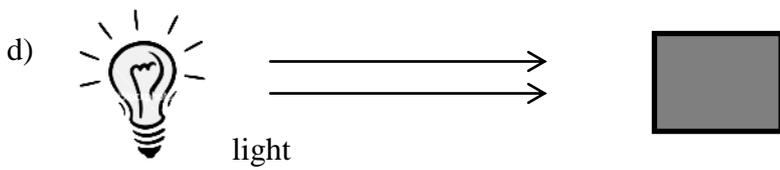
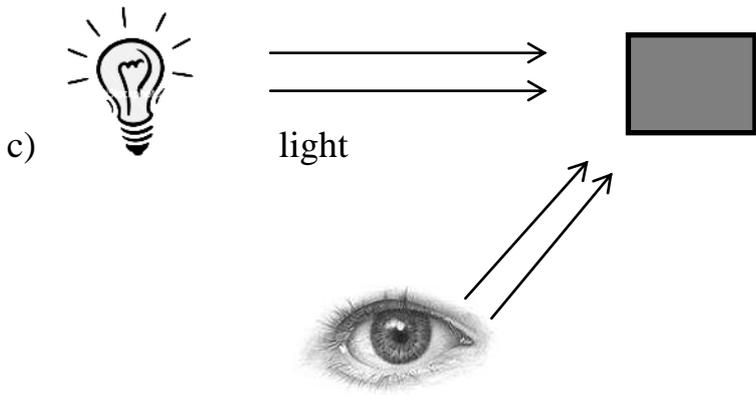
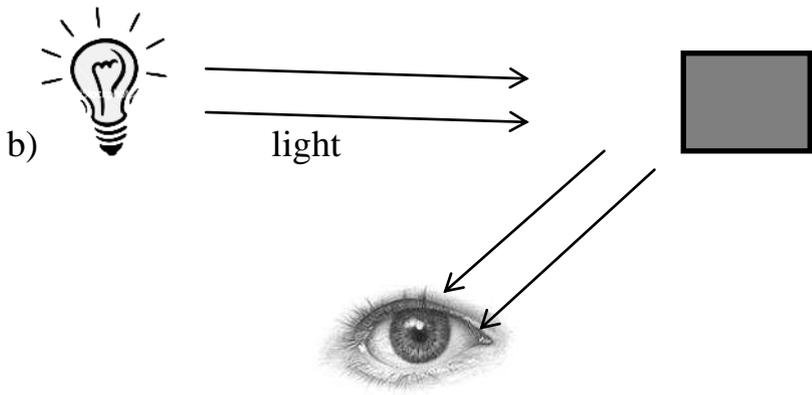
3. A ball has been hung from a ceiling (show diagrams) and it is swinging from the left (where you see it) towards the right – you can neglect air resistance. Can you tell me which of the four diagrams you think best describes the forces acting on the ball?





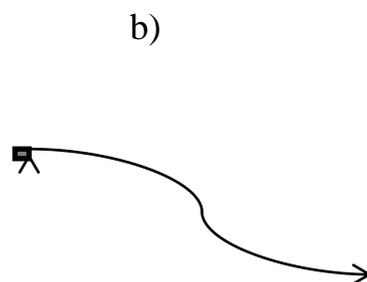
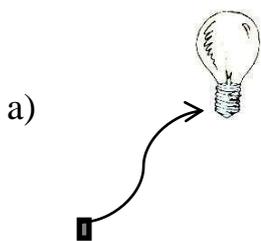
4. Which one of the four diagrams below (show diagrams to student) do you think best represents how a person sees the blue square?





5. Consider the four diagrams below (show diagrams). The arrow head shows the direction in which it is claimed the electric current flows. The brightness of the bulbs – NOTE: emphasise to the student that all of the bulbs are identical and that in the case of c and d $L_1=L_2$.

Only one of the four diagrams below correctly describes both the direction of current flow (as indicated by the arrow heads) AND the brightness of the bulb[s] (as stated) which do you think it is?

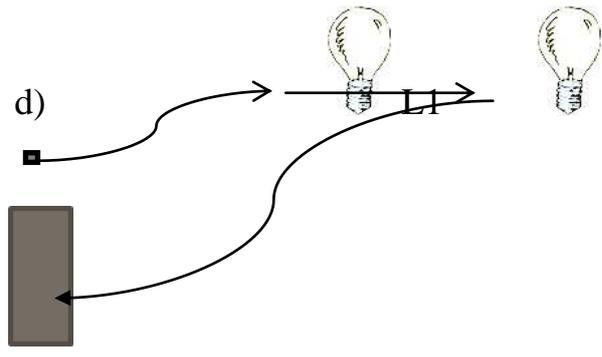
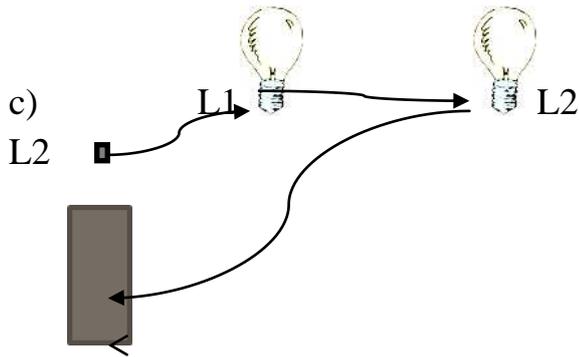




L1 is brighter than L2

L1 and L2 are equally

bright



6. The following questions relate to Figure 2 (show diagram to student) in which the three bulbs are the same – that is: $L1=L2=L3$. Please tell me which of the following statements is true or false.

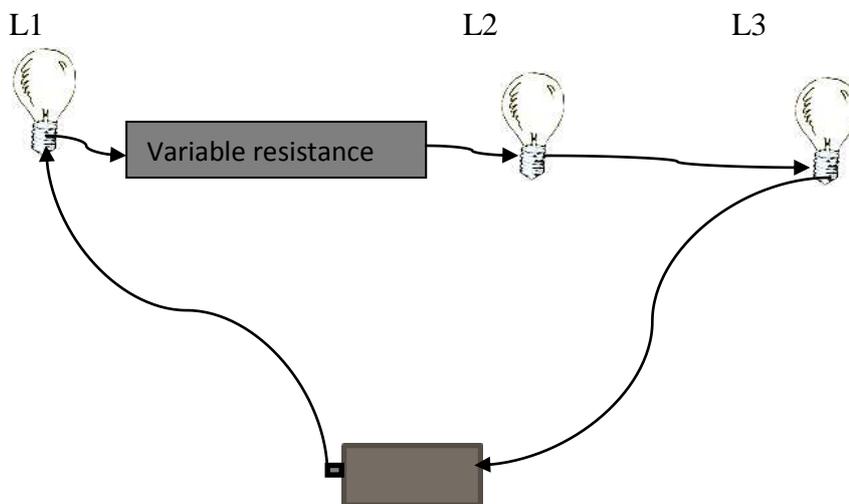


Figure 2

- a) L1 is brighter than L2 and L3. T or F
- b) L1, L2 and L3 are equally bright. T or F
- c) If the variable resistance increases L2 and L3 will become dimmer whilst L1 will remain unchanged. T or F
- d) If the variable resistance decreases L2 and L3 will become brighter whilst L1 becomes even brighter than L2 and L3 T or F

7. Two identically sized boxes are dropped from the top of a building at the same time, one carrying a small mouse and one carrying a big elephant. If we ignore air resistance [emphasise this to the student], which of the following three statements best describes what will happen to the two boxes?

- a) The box with the mouse will hit the ground first.
- b) The box with the elephant will hit the ground first.
- c) Both boxes will hit the ground at the same time.

8. Can you please state which, if any, of the following three statements are either true or false:

a) A large amount of ice needs more heat to melt it compared to a smaller amount of ice. T or F

b) If a piece of metal and a piece of wood [emphasis that these are about the same size) are placed in the snow for a couple of hours, the metal will be colder than the wood.

T or F

c) To slow the rate at which an ice cube melts it is more effective to put it inside a metal container than to wrap it in a cloth.

T or F

Thank you. Ask student if they would agree to take part in a further on-line questionnaire in about a month's time. If yes write email address here: