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CHILDREN'S BELIEFS ABOUT THE CONCEPTS OF DISTANCE, TIME AND SPEED

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ABSTRACT: *The present study was designed to further systematic cross-cultural research in the area of children's beliefs about distance, time and speed by comparing responses of elementary level students in three different countries (Canada: 150, France: 120, Morocco: 130). A pencil and paper questionnaire was used to collect these beliefs. A striking parallel between responses of students in all three countries emerged. These results are discussed in terms of contradictory findings concerning the universality or ethnocentricity of children's beliefs about scientific phenomena*.

KEYWORDS: elementary level children, beliefs, universality, ethnocentricity, distance, time, speed, qualitative study

INTRODUCTION

There has been an impressive body of research on children's beliefs about scientific phenomena, such as force, speed, heat, temperature, energy, light and gravitation in both industrialized and non-industrialized countries (Driver, Rushworth & Wood-Robinson, 1994; Black & Lucas, 1993; Chen, 2009; Ravanis, Zacharos & Vellopoulou, 2010; Tao, Oliver & Venville, 2012). These studies show that many of the beliefs commonly held by children are inconsistant with scientific explanations and may interfere with the learning of the concepts in the science curriculum (Luykx, Lee, Lester, Hart, 2007; Aikenhead, 2002). In order for teachers to plan lessons that will help children overcome these obstacles they must understand how children think about scientific phenomena.

It has been infered from some of these studies that there are common features about these beliefs in various countries. However, it has also been infered from other studies that there are cultural differences. In America, for instance, inner city schools are often multilingual and multicultural. A resolution of these contradictory findings is important because increasingly children of different languages and cultural traditions are together in the same classroom and the appropriate teaching approach may depend on whether children's beliefs are universal or ethnocentric.

Driver, Squires, Rushworth & Robinson (1994) concluded from a comparison between studies that children from different countries have similar beliefs about scientific phenomena; such as heat, light and matter. However, more systematic cross-cultural studies point to cultural differences (Lowe, 1997; Maskill, Cachapuz & Koulaidis, 1997; Lynch, 1995, 1996a, b). Since those studies were conducted, there are very few cross-cultural studies that have

been made on the concepts of space, time and speed with younger children. However many studies have been conducted around the world with high school students about movement, speed and acceleration (Trudel and Métioui, 2011; Viennot, 2003; Rowlands et al., 2007; Carson and Rowlands, 2005). The results of these studies show that, in spite of similar beliefs about speed and acceleration, students have serious difficulties in learning the science of these notions. For example, the majority confuse speed and accelation (Trudel and Métoui, 2011). It is clear that further specific cross-cultural research is needed in the area of children's beliefs about various scientific phenomena.

The concept of speed with its related concepts of distance and time has not been studied extensively from a cross-cultural point of view. Only two of such studies were found. The first study (Mori, Kitigawa & Tadang, 1974) shows that Thai children have less tendency to judge the length of time by the length of distance than Japanese Children; an observation that is thought to be linked to language differences, specifically the concepts of *short* and *long*. The second study (Mori, Kojima & Tadang, 1976) indicates that Thai children's judgement about speed develops more quickly than their Japanese counterpart. The effect of language is also thought here to be a factor because of differences about the concepts *rapid* and *early*. The present study is exploratory and was designed to further systematic cross-cultural research in the area of children's belief about distance, time and speed by comparing the responses of elementary level students in three different countries (Canada, France, Morocco).

METHODOLOGY

The population for this study consists of 400 French speaking children in grade five and six from Canada, and equivalent CM_2 from France, and Morocco. The ages ranged from 9 to 12 years old. Identification of students and maintenance of anonymity was achieved by giving students a number. The groups were labelled by letter code: E_{Pi} , 120 students from Poitiers (France); E_{Ci}, 150 students from Montreal in Quebec and the region of Clare in Nova scotia (Canada) and $E_{Mi,}$ 130 students from Tangier, Casablanca and Fes (Morocco). None of the students had received formal instruction in the scientific concept of speed as a relationship between distance and time.

The questionnaire uses a paper and pencil form. The questions were constructed on the basis of studies conducted by Invernizi, Marioni & Sabadini, 1989, Canal (1986), Crépault (1981), Fraisse & Vautrey (1952), and Piaget (1946). In the first part of the questionnaire, students are presented with 5 races involving two similar vehicles (Appendix 1). They are asked to mark the vehicle which will win the race and explain why. The races vary in terms of either similar or dissimilar distances to travel, and similar or dissimilar points of departures. In the case of race # 5, the points of departure are similar and the distance to travel is dissimilar as in race # 2, but the course is circular rather than straight. In the second part of the questionnaire, students have to decide which vehicle will win races #1, #2, and #3 and explain why that is on a course with similar distances but with vehicles that are dissimilar in terms of their size, the size of their wheels, or their load (Appendix 2). Finally, in the third part of the questionnaire, students are asked to explain what speed means to them, and what time means to them (Appendix 3).

RESULTS

Three themes emerged from the data in relationship to the three parts of the questionnaire: similar and dissimilar distances and points departure; size of car, size of wheels, and load; meaning of time and speed. Themes 1 and 2 each contain 3 categories of responses, and theme 3 presents four categories of responses for the question on speed and six categories for the question on time.

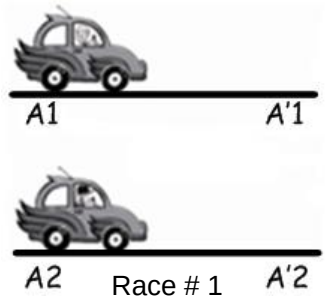
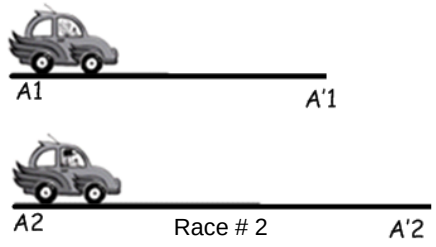
Analysis of theme 1 : similar and dissimilar distances and points of departure

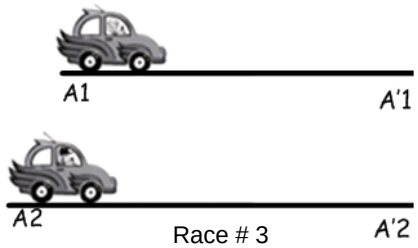
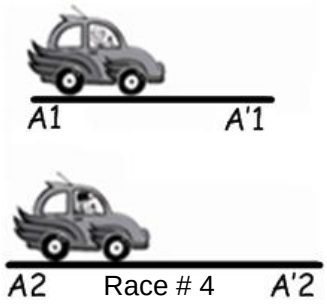
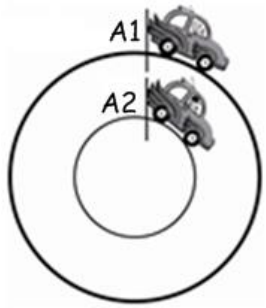
In races #1, #2, #3, #4, and #5 which are part of theme 1, subjects have to predict that either car A_1 or A_2 will win the race without knowing the time involved in running the course. The analysis of the data shows three categories of responses:

Category 1: The car which will have to travel the shortest distance will win the race
Category 2 : The car which will win the race is the closer to the point of arrival
Category 3: No response, undecipherable response, no explanation or incomplete.

For the 5 races, we present in the table 1 the percentage of the answers for each category.

Table 1. Percentage of the relative answers to the theme 1

	Category 1 The car which will have to travel the shortest distance will win the race	**Category 2** The car which will win the race is the closer to the point of arrival	**Category 3** No response, undecipherable response, no explanation or incomplete
	**Canada** (14%) **Morocco** (8%) **France** (25%)	**Canada** (60%) **Morocco** (81%) **France** (56%)	**Canada** (26%) **Morocco** (11%) **France** (19%)
	**Canada** (83%) **Morocco** (82%) **France** (88%)	**Canada** (11%) **Morocco** (10%) **France** (5%)	**Canada** (6%) **Morocco** (8%) **France** (7%)

	**Canada** (85%) **Morocco** (74%) **France** (90%)	**Canada** (12%) **Morocco** (24%) **France** (5%)	**Canada** (3%) **Morocco** (2%) **France** (5%)
	**Canada** (85%) **Morocco** (77%) **France** (93%)	**Canada** (10%) **Morocco** (19%) **France** (2%)	**Canada** (5%) **Morocco** (4%) **France** (5%)
	**Canada** (75%) **Morocco** (76%) **France** (88%)	**Canada** (23%) **Morocco** (16%) **France** (5%)	**Canada** (2%) **Morocco** (8%) **France** (7%)

In the case of the race # 1, the data indicates that a majority of the students adhere to the category 2 by refusing the similarity of both points of departure. They believe that the cars have dissimilar points of departure and therefore the one that is closer to the point of arrival will win the race. It is as if they see the problem in terms of distance, in spite of the fact that there is no obvious difference between the two points of departure. One student noted that the difference is in the order of one millimetre. The majority of responses in the first race # 1 (Canada, 60%, Morocco, 81%, France, 56%) come under category 2 which points to the belief that the car closest to the point of arrival will win the race. The following statements illustrate these beliefs:

"Because A_1 is like one cm more than A_2". (Canada - E_{C6})
"Because the car A_2 has much less distance to travel". (Canada - E_{C31})
"The car A_1 will win because the distance is small". (Morocco - E_{M2})
"Because in measuring, you can see that A_2 is shorter than A_1". (Morocco - E_{M9})
"Because it is a little mm. less". (France - E_{P2})
"Because the segment A_2 is a bit longer than the segment A_1". (France - E_{P4})

In the case of races #2, #3, #4, and #5, the majority of responses are classified in category 1, similar and dissimilar distances and points departure, because of the belief that the car with the shortest distance to run will win the race. For example, the majority of responses (Canada, 85%, Morocco, 77%, France, 93%) in the race #4 come under category 1 which refers to the

belief that the car which has the shortest distance to travel will win the race. Statements that illustrate this belief are as follows:

"Because there it has smaller course". (Canada - E_{C8})
"The course of car A_1 can fit twice in the course of car A_2". (Canada - E_{C44})
"It has a smaller course and it is ahead". (Morocco - E_{M2})
"Because the course of car A_2 is longer than the course A_1". (Morocco - E_{M8})
"Because it has a smaller course". (France - E_{P1})
"The car A_1 will win because the distance is near". (France - E_{P8})

For example, the majority of responses in race # 5 (Canada, 75%, Morocco, 76%, France, 88%) come under category 1 which refer to the belief that the car which will have the shortest distance to travel will win the race. The following statements illustrate this belief:

"It has a smaller round to make than the other car". (Canada - E_{C28})
"Because the circle is smaller". (Canada - E_{C66})
"Because the second car (A_1) will make a large circuit". (Morocco - E_{M17})
"The car A_2 will win the race because the distance of car A_1 is long". (Morocco - E_{M35})
"A_2 because it has the smallest circle". (France - E_{P18})
"Because the round is the smallest". (France - E_{P42})

Finally, a small percentage of responses are classified in category 3, which is no response, undecipherable response, no explanation, or incomplete response. What characterizes these responses is that they are subjective and do not stay within the parameters of the races. The following examples are from responses to the first race:

"Car A_1 was out of gas". (Canada - E_{C6})
"I have chosen the second car because it is beautiful". (Canada - E_{C12})
"I have taken this car because it pleases me and it will win". (Morocco - E_{M1})
"Because I want it". (France - E_{P20})
"Because I want this car to win". (France - E_{P24})

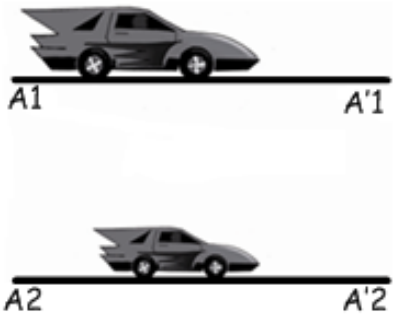
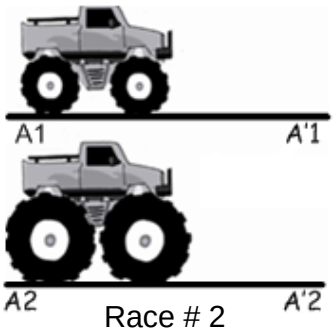
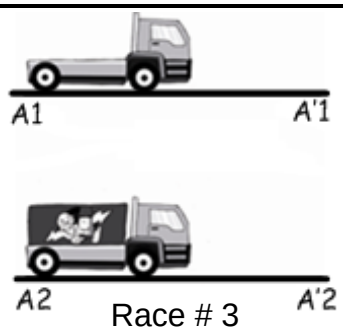
Analysis of theme 2 : size of car, size of wheels, and load

In races # 1, # 2, and # 3, which are part of theme 2, subjects have to predict that either vehicle A_1 or vehicle A_2 will win in a race in which the distance and points of departure are similar but where vehicles differ either in size, in size of wheels, or load. Also, the time involved is unknown. The analysis of the the data shows three categories of responses:

Category 1: The size of the vehicle, the size of the wheels, or the weight of the vehicle, determines which vehicle wins the race.
Category 2: The vehicle which has the shortest distance to travel will win the race.
Category 3: No response, undecipherable response, no explanation or incomplete response.

For the 3 races, we present in the table 2 the percentage of the answers for each category.

Table 2: Percentage of the relative answers to the theme 2

	Category 1 The size of the vehicle, the size of the wheels, or the weight of the vehicle, determines which vehicle wins the race	**Category 2** The vehicle which has the shortest distance to travel will win the race	**Category 3** No response, undecipherable response, no explanation or incomplete response
 Race # 1	**Canada** (77%) **Maroc** (68%) **France** (65%)	**Canada** (16%) **Maroc** (20%) **France** (28%)	**Canada** (7%) **Maroc** (12%) **France** (7%)
 Race # 2	**Canada** (73%) **Maroc** (68%) **France** (72%)	**Canada** (17%) **Maroc** (19%) **France** (12%)	**Canada** (10%) **Maroc** (13%) **France** (16%)
 Race # 3	**Canada** (90%) **Maroc** (88%) **France** (98%)	**Canada** (4%) **Maroc** (7%) **France** (0%)	**Canada** (6%) **Maroc** (6%) **France** (2%)

In race # 1, a majority of students (Canada, 77%, Morocco, 68%, France, 65%) give responses for which vehicle A_1 or A_2 will win the race in terms of its size. For example, most students put forward the belief that vehicle A_1 will win the race because it has a large tank of gas, big wheels, big motor or longer length, which to their eyes are indispensable factors to win the race. Following are examples of their beliefs:

"It will win because it can contain more gas than the other". (Canada - E_{C1})
"Because it has a big motor". (Canada - E_{C12})
"Because the car is big, it moves fast". (Morocco - E_{M15})
"Because car A_1 is bigger than A_2 , therefore its motor must be more powerful". (Morocco - E_{M25})
"Car A_1 will win because it is bigger, it has the most speed and power". (France - E_{P10})
"Me, I believe that it is A_1 because it is the longest". (France - E_{P26})

A smaller proportion of students thinks that it is the smaller car that will win the race because it is light and less massive. The following examples illustrate the belief:

"Because it is smaller, it goes faster". (Canada - E_{C1})
"I have chosen this car because it is smaller and cuts in the wind". (Canada - E_{C57})
"Car A_2 will win because the car is light". (Morocco - E_{M8})
"The car that I have chosen will win the race because the smaller cars run faster than the bigger ones". (Morocco - E_{M19})
"Because the smallest is lighter". (France - E_{P9})
"It is because A_2 is smaller and when it is smaller, it goes faster". (France - E_{P17})

In race # 2, a majority of students (Canada, 73%, Morocco, 68%, France, 72%) give responses for which vehicle A_1 or A_2 will win the race by refering to the dimension of the wheels to justify their choice. For example, most students claim that vehicle A_2 will win the race because its wheels are bigger and, therefore the vehicle will move faster. The following statements illustrate the belief:

"Because the A_2 has bigger wheels, it will run faster". (Canada - E_{C8})
"Because it has bigger wheels, it allows it to move faster with less effort from the motor". (Canada - E_{C19})
"Because the wheels of the car A_2 are bigger than the A_1 therefore it should move faster and farther". (Morocco - E_{M25})
"Because the wheels are big". (Morocco - E_{M28})
"Car A_2 will win because it has bigger wheels, therefore the speed will go faster and will hold better on the course". (France - E_{P10})
"The second will win because it has bigger wheels and it goes faster". (France - E_{P25})

However, a smaller number of students claim that it is rather vehicle A_1 which will win the race since its wheels are small, and therefore it will move faster. Examples of this belief are as follows:

"Because the wheels are smaller and less heavy, it gives speed". (Canada - E_{C1})
"I have chosen this vehicle because it is smaller and faster". (Canada - E_{C7})
"The vehicle A_1 will win because its tires are small, it goes fast". (Morocco - E_{M30})
"It will win because it has smaller wheels". (France - E_{P32})

In race # 3, a majority of students (Canada , 90%, Morocco, 88%, France, 98%) give responses for which the vehicle with the lesser load will win the race. Examples are as follows:

"It will win because it is lighter than the other and will be able to go faster because it does not have a load". (Canada - E_{C1})
"Because the vehicle is empty, therefore it goes faster". (Canada - E_{C21})
"Car A_1 will win because light". (Morocco - E_{M3})
"Because the truck A_1 is not loaded, therefore it goes faster". (Morocco - E_{M27})
"Because it is less heavy than the other (more speed)". (France - E_{P43})

Contrary to the data of the previous theme, there is a low percentage of responses referring to distance to justify the choices made. However, in these responses students (Canada, 16%, Morocco, 20%, France, 28%) put forward that the vehicle that will have the shortest distance to travel will win the race. It is to be noted that in race # 3, this percentage is very low (Canada, 4%, Morocco, 7%, France, 0%).

Finaly, the category 3 reports what is considered an absence of response, indecipherable responses, no explanation, or incomplete responses. Many students invent very imaginative types of explanations.

Analysis of theme 3: meaning of time and speed

In the last part of the questionnaire, students were asked to explain what speed means to them and what time means to them. To predict which vehicle will win each of the 8 races, no students refer to the *time* involved to run the distance given. However, a few students refer to the word *speed* without elaborating.

Analysis of theme 3: The speed

To the question explain what speed means to you, four categories of responses were found about what students believe about speed. Examples are given to illustrate the different categories of beliefs.

Category 1 : Speed is associated with rapidity or acceleration (Canada, 53%, Morocco, 73%, France, 51%). Examples are as follows:

"Something that runs very fast". (Canada - E_{C26})
"Speed, for me, is when I hurry to do my homework and finally am able to look at television". (Canada - E_{C63})
"Speed, is to start faster, accelerate, run, etc.". (Morocco - E_{M8})
"Speed, to go very fast". (Morocco - E_{M28})

"Speed, is opposed to slowly". (France - E_{P9})
"For me, speed means going fast, accelerating". (France - E_{P31})

Category 2 : speed is associated with parts of the vehicle, such as its motor, its mass, etc. (Canada, 5 %, Morocco, 0%, France, 7%). Examples are as follows:

"When something is smaller and less heavy, it goes faster". (Canada - E_{C1})
"It is when there is less weight". (Canada - E_{C41})
"It is when the vehicle or other light thing and a big motor". (France - E_{P27})
"Speed means that one of the vehicles has more power than the other". (France - E_{P60})

Category 3 : speed is associated with accidents, gains in the races or gains in time (Canada, 17%, Morocco, 15%, France, 7%). Examples are as follows:

"Speed is a way to amuse myself". (Canada - E_{C7})
"Speed is dangerous because we can have accidents". (Canada - E_{C21})
"Speed is saving time". (Morocco - E_{M10})
"Speed is something that brings success". (Morocco - E_{M11})
"Speed for me means winning". (France - E_{P33})
"Speed, for me means winning over the others". (France - E_{P36})

Category 4 : no response, indecipherable response or incomplete response (Canada, 25%, Morocco, 22%, France, 35%)

Analysis of theme 3: The time

To the question Explain what time means to you, six categories of responses were found about what students believe about time. Examples are given to illustrate the different categories of beliefs :

Category 1 : time is associated with hours, minutes, seconds, days, years, or centuries (Canada, 19%, Morocco, 20%, France, 28%). Examples are as follows:

"Time is hours". (Canada - E_{C7})
"Well, time is seconds, minutes, hours, days, weeks, months, and after, years" (Canada, E_{C48})
"Second, minute, hour, year, century". (Morocco - E_{M16})
"Time, the moment - time, instant - time, the days, the minutes, etc.". (Morocco - E_{M26})
"They are numbers that are in hours, minutes and seconds". (France - E_{P7})
"Time, for me, means the hour of the day". (France - E_{P36})

Category 2 : time represents the duration of an event, or the speed of an event (Canada, 19%, Morocco, 16%, France, 18%). Examples are as follows:

"A way of seeing things if we are late, know what we did in the race in terms of minutes, what time is it, know at what moment we are". (Canada - E_{C2})
"How long will it take, to run the race". (Canada - E_{C12})

"Time, for me, means that I have an exam, it must be finished in time". (Morocco, E_{M4})
"Time means how fast it goes". (Morocco - E_{M79})
"Time for us is the duration of something". (France - E_{P5})

Category 3 : time is associated to life, joy, slowness, something important, or conduct(Canada, 38%, Morocco, 39%, France, 35%). Examples are as follows:

"Time means waiting". (Canada - E_{C2})
"Time, is life". (Canada - E_{C6})
"Time means for me that it seriousness". (Morocco - E_{M5})
"Time, is precious, it is like gold, for example a minute is lost, it is like a year is lost". (Morocco - E_{M9})
"Time : to go very fast". (Morocco - E_{M35})
"Time means speed". (France - E_{P5})
"Time means slowness". (France - E_{P33})

Category 4 : time is associated with climates (Canada, 3%, Morocco, 1%, France, 7%). Examples are as follows:

"The sun, the wind, the rain". (Canada - E_{C14})
"Time means what hour it is or the weather outside". (Canada - E_{C65})
"It means the sun, the rain". (Morocco - E_{M4})
"Time makes me think of rain". (France - E_{P23})

Category 5 : time is associated with a measuring instrument such as a watch, or a clock. (Canada, 4%, Morocco, 2%, France, 5 %). Examples are as follows:

"The hands that turn". (Canada - E_{C5})
"Fo me, it is maybe stupid, but time makes me think of a clock that does its 24 hours and that starts again". (Canada - E_{C74})
"Time means minutes, hours, and time is located in watches". (Morocco - E_{M30})
"Time is like a watch, it turns". (France - E_{P12})
"It is another work for clock. To tell the time". (France - E_{P75})

Category 6 : no response, indecipherable responses, incomplete responses (Canada, 17%, Morocco, 22%, France, 7%) Examples are as follows:

"Time is like a period that lasts a long time". (Canada - E_{C9})
"Time is a way of knowing where we are in the immense sphere". (Canada - E_{C17})
"Time means a smaller path". (Morocco - E_{M3})
"Time passes quickly, therefore we must earn it". (Morocco - E_{M41})
"Sometimes it goes fast, sometimes it goes slow". (France - E_{P13})

DISCUSSION

The most noteworthy feature that comes out of the data is the striking parallel between responses of students in all three countries, each part of a different continent, and in public and private schools. It appears that grade five and six students in Canada, and equivalent CM_2 in France and Morocco, have similar beliefs when they predict which car will win the race. They are also capable of making these predictions and giving the reasons for them. The similarity occurs whether there are differences in length of track and spatial order of departures, size of car, size of wheels, and load. The students' responses are also similar when they attempt to explain what time and speed mean to them.

The data is consistent with Piaget's viewpoint in informal context where children who have not reached the formal operation stage of reasoning do not grasp the concept of speed as a relationship between distance and time. It is surprising to note that the students refer only to distance and caracteristics of the cars to elaborate their explanations in a way which is similar to those of Piaget's subjects some fifty years ago. One might have thought that in the present technological environment of television, video and electronic games, children would bring different ideas to explain which car would win the race. The data is also consistent with the work of Fraisse &Vautrey (1952a, b), Canal (1986), and Invernizzi, Marioni & Sabadini (1989) which shows a confusion in childrens' minds about time and distance, distance and speed, and time and speed, and the use by children of preconceived ideas and unfounded justifications, examples of which are the relationship between speed and the power of the vehicle, and speed and the robustness of the vehicle.

IMPLICATION FOR PRACTICE

In our study, the theoretical knowledge contribution is based on the findings that children in three continents have the same preconceptions about time, distance and speed which points the universality of their beliefs. Therefore, this study supports the hypothesis of universal children's beliefs about time, distance, and speed. One teaching implication for children who share similar beliefs about scientific phenomena is that the same teaching methods can be used for different cultures and native languages.

In the present study students have a greater similarity in language than those of the cross-cultural studies which uses the beliefs of Thai and Japanese Children. For the children who are in the same class and have different beliefs about scientific phenomena, a strategy of teaching that takes into consideration multiple representations is a possibility. In this approach, children who hold different notions of time, space, and speed could be invited by the teacher to explore with one another, implicitly or explicitly, their different points of view. However, such a strategy for teachers who are not used to work with children's beliefs requires training and practice in the application of this method.

FUTURE RESEARCH

A limitation of this study is that it involves only children from urban areas. It is possible that children from rural or remote areas may yield different results. Also, it would have been

informative to make clinical interviews with a number of children in each country to find out more about their views on time, distance and speed. More systematic cross-cultural research is needed because the present study is an exploratory one and it is possible that further research using different experimental situations in different contexts of language and culture might reveal cross-cultural differences about phenomena that will be studied in science classes.

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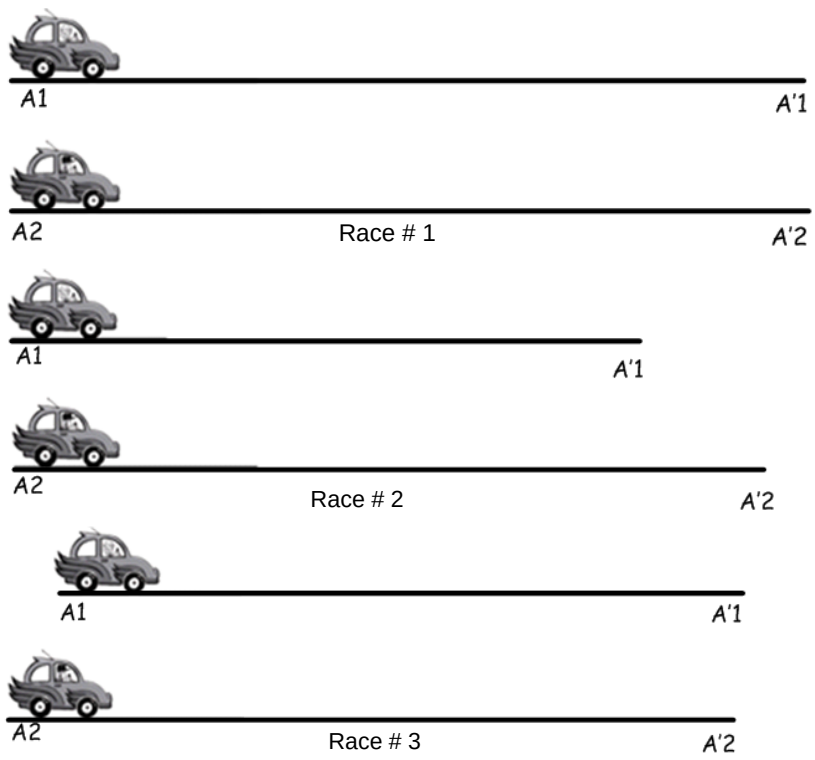
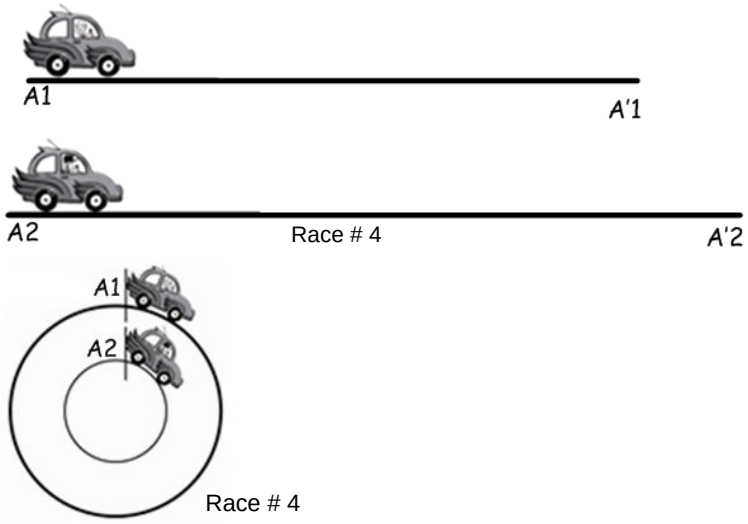
APPENDIX 1

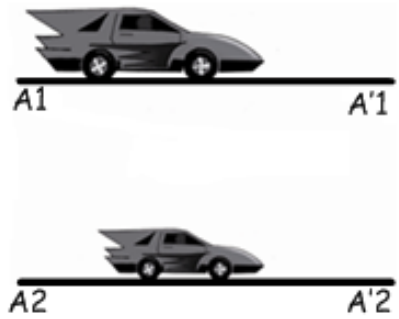
For every race, put a cross on the car that, according to you, will be winning. Explain why the car that you chose is going to win the race.



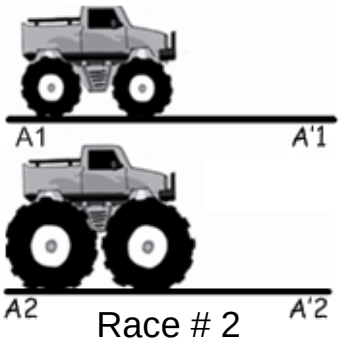


APPENDIX 2

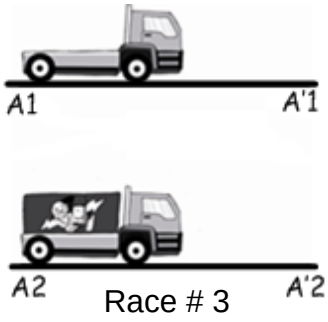
For every race, put a cross on the car that, according to you, will be winning. Explain why the car that you chose is going to win the race.



Race # 1



Race # 2



Race # 3

APPENDIX 3

Now, explain what speed means to you.

_____

Finally, explain what time means to you.

_____