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On the Use of Two Versions of the Force Concept Inventory to Test Conceptual Understanding of Mechanics in Lao PDR

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In this study, we investigated why Laotian students had a low score, when they were tested by the Force Concept Inventory (FCI). About 400 first year university students answered the FCI or a Lao version of the FCI (LFCI) with the contexts of some questions changed. The students answered a questionnaire and 34 of the students were interviewed. The students found the FCI/LFCI questions difficult and the phenomena in some of the questions unfamiliar, for example questions about ice hockey. The results show that the low score cannot be explained by specific alternative conceptions and only to a very small part by unfamiliar context. The explanation seems to be that the students relied on everyday life experiences when they answered the questions.

Keywords: Alternative Conceptions, Everyday Life Experience, FCI, Physics Concepts

INTRODUCTION

Physics education research has shown that students have difficulties in understanding basic physics concepts and the difficulties are not easily overcome (McDermott, 1984; McDermott & Redish, 1999). To improve the situation there has been a trend to focus more on basic concepts, where ideas are first developed at a conceptual level with little or no mathematics in contrast to traditional approaches where definitions are introduced in mathematical form (van Heuvelen, 1991; Gautreau & Novemsky, 1997). Laos has not yet followed this trend to concept learning. Physics teaching in Laos is very formal and teachers mainly discuss mathematical formulas and train students to solve end of chapter problems (Luangrath & Vilaythong, 2010).

Studies of students' conceptual knowledge in physics are made with the help of different instruments. One well known tool for studying students' knowledge of mechanical concepts is the Force Concept Inventory, FCI (Hestenes, Wells, & Swackhamer, 1992; Halloun, Hake, Mosca, & Hestenes, 1997).

In a pre-study 2006, the FCI was sent to freshman students before and after their mechanics course at the National University of Laos (Luangrath & Vilaythong, 2010), revealing that the average percentage score of correct answers was very low both at the pre-and post-tests. The aim of this paper is to analyze why students in Laos, even after studying mechanics, obtain a low score on the FCI. There could be several reasons for the low score. An obvious reason is that the students have a weak understanding of physics concepts. Another reason could be that it was difficult for students to understand the questions in the FCI since these were developed in a Western cultural context.

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PREVIOUS RESEARCH

Students' alternative conceptions in mechanics

Since the 1970s a great amount of educational research has focused on the ideas students have in relation to scientific concepts (Bayraktar, 2009; Driver, 1989; Halloun & Hestenes 1985; Hestenes, Wells, &

State of the literature

- There are a lot of studies using the Force Concept Inventory (FCI) to test students' understanding of mechanics concepts. Many studies also use FCI to identify students' misconceptions/alternative conceptions.
- Some papers discuss to what extent students have clear alternative conceptions/misconceptions or if they just have some vague ideas.
- There are some studies that focus on the importance of context in multiple choice questions in mechanics. Most of these studies are made in Western countries.

Contribution of this paper to the literature

- This paper analyses the answers of students from Lao PDR to the FCI and to an inventory built on the FCI with a changed context in some of the questions. Possible alternative conceptions of the students are identified, and the importance of the context of the questions is discussed.
- The paper offers new insights into the importance of everyday life experiences for students' interpretation of the questions and for their answers. Students' everyday life experiences often lead them to answers that are not correct according to the presumed interpretation of the questions and to Newtonian mechanics.
- The paper emphasizes the importance of changing teaching to include a conceptual focus and more student activity.

Swackhamer, 1992; McDermott, 1984; Sabella, 1999). These ideas have been described as "misconceptions", "alternative conceptions" or "commonsense beliefs". Some of the researchers describe students' misconceptions as rather fixed theory-like conceptions while others see them as alternative ways of seeing things that are appropriate in different contexts. In this paper we describe Lao students' ideas about concepts in mechanics.

The most common observed alternative conceptions or commonsense beliefs related to mechanics are the following.

- *Students believe that heavier objects fall faster than lighter ones (Bayraktar, 2009; Hestenes et al. 1992; McDermott, 1984).*
- *Students often interpret interaction via a conflict metaphor, where strength is attributed to those who are bigger, heavier, or more active. Objects with greater mass, or a more active object, are thought to exert a greater force (Bayraktar, 2009).*
- *Students sometimes think that, when a force acts on an object, the object gains, what is called, impetus. When the force does not act on the object any longer, the impetus is thought to remain but to diminish. The object continues to move until the initial "force" (impetus) is used up (Bayraktar, 2009; Hestenes, et al.1992), some students also believe in a circular impetus. Hestenes et al. (1992) explain it by a "training metaphor". The students think that the objects tend to do what they have been trained to do.*
- *Students believe that a force is needed to keep an object moving. As a consequence they think that it should be a force in the direction of motion (Bayraktar, 2009; McDermott, 1984).*
- *Students cannot discriminate between position and velocity and between velocity and acceleration (Hestenes et al., 1992; McDermott, 1984).*

Hestenes et al. (1992) have designed the Force Concept Inventory to probe students' beliefs related to concepts of mechanics. The wrong answers to the FCI can inform about students' alternative conceptions and those answers can then be an important starting point for teaching in mechanics.

Von Aufschnaiter and Rogge (2010) criticize research about misconceptions, because this research often regards conceptions as something students possess. Von Aufschnaiter and Rogge focus on how students establish and use conceptions. They call it an explorative approach when students argue in a way that they seem to have no conceptual ground and only describe what they observe. When the students have grasped some idea about the underpinning rules but not explicitly refer to these rules they call it an intuitive rule-based approach. For both these levels of understanding they use the notion "missing conceptions", and they find it more promising to focus on missing conceptions than on misconceptions. On the third level students explicitly express conceptual knowledge which is called an explicit rule-based approach. Von Aufschnaiter and Rogge (2010) also conclude that some misconceptions can occur as a result of repeated experiences with phenomena of the everyday world. They point out that all model-based concepts are difficult for students and an effort to utilize everyday experiences can create misconceptions.

The Force Concept Inventory

The Force Concept Inventory is a multiple-choice test, consisting of 30 questions that cover central concepts of Newtonian mechanics. No calculation is needed to answer the questions. The non-correct answers correspond, according to Hestenes et al. (1992) to common student misconceptions that have been found in physics education research. The FCI focuses on issues of force, and is designed to monitor students' understanding of the conceptual field of force and related kinematics.

Hake (1998) collected FCI scores from colleges, high schools, and universities in USA, in which the FCI has been used both as pre-test and post-test. The average score of the pre-test ranged from 20% correct answers in some high schools up to 50% correct answers in some universities, and in a few prestigious universities the average score reached 70%. Hake (1998) shows that interactive-engagement methods can increase the effectiveness of the teaching of the mechanics courses.

Savinainen and Scott (2002a) regard the Force Concept Inventory to be an important tool in physics education. They conclude that the FCI allows the teacher to analyse students' thinking in terms of particular alternative conceptions and in this way the teacher is in a better position to plan and to implement new stages of teaching. In a second paper Savinainen and Scott (2002b) show that teaching with a conceptual focus, use of interactive approaches and research-based instruments such as the FCI enhanced the learning of the students in a Finnish school.

Many studies have examined the role of context in the questions of the original FCI. Schecker and Gerdes (1999) show an example of a question related to a golf ball flying through the air, and the students were asked about which forces were acting on the ball. The students were also given a question describing a football player that shot against a goal. Also in this case the students were asked about the forces acting on the ball. Even though the physics is identical in the two questions twice as many students answered the latter question correct. This shows that the context may have a strong influence when students answer the questions in the FCI.

McCullough and Meltzer (2000) remark that the questions in the FCI have contexts that appear stereotypically male and it is administered in the male-dominated social context of the physics classroom. McCullough (2006) developed a modified gender-oriented version of the FCI. They re-expressed all 30 items of the original FCI by using female and daily-life context instead of the male and school-oriented context in the original. They found significant discrepancies for four test items.

In our pre-study, the students described that it took a lot of time to read the questions of the FCI and that many questions were difficult to understand (Luangrath & Pettersson, 2008). The students also wanted more explaining pictures. Another version of the FCI with more pictures and another context in some of the questions was therefore designed. We call this version the Lao version of FCI (LFCI).

Research questions

In our pre-study the average score of correct answers on the FCI was low both on the pre- and the post-test. Could the low score be explained by the students possessing alternative conceptions or did the students perhaps not understand the questions? Another reason for the low score on the FCI could be that the context of some questions were developed in a Western cultural context and therefore was not suitable for our students.

The aim of this study was to analyze why students in Laos, even after studying mechanics obtain a low score on the FCI. Therefore, we formulated the following research questions:

- *In what way do the answers to the FCI questions suggest that the students have alternative conceptions in mechanics?*
- *How do the students explain that some questions of the FCI and LFCI are difficult to understand? What is the importance of pictures, context and everyday experiences?*

METHODS

Background

This research was conducted in 2007 and 2008 at the School of Foundation Studies at three universities of Laos (National University of Laos, Souphanouvong University, and Champasak University). Teaching in the Lao universities was during the period 1996 to 2008 divided into two main parts: A one year long School of Foundation Studies (SFS) program and four or more than four year long programs in the different faculties. The SFS program had the task to improve students' knowledge of natural and social sciences in order to prepare them for future studies at the different faculties. The SFS natural science stream had one compulsory Physics Foundation Studies course. Students who wanted to study at the Science, Architecture and Engineering faculties had to get a high score of physics, while the students who wanted to study in other faculties just had to pass this course. In 2009 the system changed to a new system. Freshman students will now go directly to the faculty they choose. The SFS program is still the same, but it is now located at the different faculties

Students at the School of Foundation Studies study mechanics for 5 weeks and they have one lecture and one tutorial each week, and a lab session for every second week. The tutorials include various exercises taken from the textbook and are intended to deepen and widen the knowledge from the lectures. More than 80% of the questions in the end of each chapter of the textbooks are questions that require calculations. The other questions are theoretical and ask about definitions and formulations of physical laws.

Instruments

In this study we used two versions of the Force Concept Inventory to assess the conceptual understanding of the students, the original version (FCI) and a Lao version (LFCI). Both versions are multiple-choice tests, consisting of 30 questions. The physics of each question of the LFCI is identical to the corresponding question in the original FCI, but the physics is put in another context and some questions are supported by more pictures.

The LFCI version was constructed by changing the context of the questions of the FCI. Fourteen of the questions were taken from the Gender Force Concept Inventory (McCullough 2006) and had a different context than in the original FCI. We also changed the context of questions number 17 and 29. Number 17 is about the force on the cable lifting an elevator. Many of the Lao students are not so familiar with elevators and this was changed to the forces on a rope lifting a bucket of water from the bottom of a well. Question number 29 is about an empty office chair in the FCI. This was changed to an ordinary chair and a picture of the chair was also given. Besides these changes we also added pictures and some mathematical notations (such as, "$F>P$" as a complement to "The horizontal force is greater than the weight of the couch.") in another nine questions. The LFCI and the FCI were translated to Lao language before they were given to the students.

Procedure

In the beginning of the second semester 2007 the SFS-students at three universities in Lao PDR were tested by two versions of the inventory. The FCI and LFCI were given to the students after they had studied kinematics, the three Newton's laws of motion, energy and work. The first author explained why we used this test, and told them to use their own knowledge and not to copy the answer from other students. The students sat in the classroom with their teacher present, when they answered the test. 264 students answered the FCI and 221 students answered the LFCI. The students had 50 minutes to find the answers to the questions. If more than 10% of the questions were not answered by a student, the answers from that student were not included in the analysis of the answers to the inventories. 206 students for the FCI and 204 students for the LFCI remained and were included in the analysis.

Directly after the students had answered the test they had 5-10 minutes to fill in a questionnaire about the test. All students that answered the FCI or the LFCI also answered the questionnaire. The questionnaire consisted of the following questions:

- *What do you think about the FCI/LFCI?*
- *Choose one question that you think was easy to understand! Why was this question easy to understand?*
- *Choose one question that you think was difficult to understand! Why was this question difficult to understand?*
- *Did the pictures help you to understand the questions? Why?*

Students who got the highest score were selected to an interview, because we wanted to get a better picture of the difficulties for the students to understand the questions. In a previous study, we interviewed students who got the highest and lowest scores. The students who got the highest score could give some reasons and explain about problems to understand the questions, but the students who got the lowest score could not explain why they found the questions difficult to understand. Therefore, we decided to choose the students who got highest score this year. The questions for the interview were the same as the questions in the questionnaire, and we used 10 to 20 minutes per person. 34 students were interviewed.

In the year 2008, we sent the FCI and the LFCI tests to the SFS students at the National University of Laos. This time the students worked in small groups (three to four students per group) with the questions. They had 60 minutes to discuss and answer the questions of the test. Three groups, totally 11 students, were recorded by video camera; one of the groups answered the FCI and two groups the LFCI.

Analysis

To be able to conclude if the students have alternative conceptions in mechanics we calculated the percentages for the different alternative answers of the FCI for the five questions 1, 4, 7, 11 and 19. These questions were selected because they illustrate the understanding of different physics concepts. Among the different given alternative answers there are answers that correspond to known common alternative conceptions. We carefully looked at the percentages for the different answers and discussed if they showed any clear alternative conceptions.

We calculated the average score of correct answers for each question of both the FCI and the LFCI to see if the changed context of the questions had any impact

Table 1. Summary from post-test of 206 students' answers to five questions in the FCI

Nunber/question	A	B	C	D	E	2 or no answer
1/Free fall of two balls	58	44	55	28	15	6
	28%	21%	**27%**	14%	7%	3%
4/Collision of two objects	51	53	28	16	49	9
	25%	26%	14%	8%	**24%**	4%
7/Circular motion	20	70	31	37	42	6
	10%	**34%**	15%	18%	20%	3%
11/Hockey puck moving on ice	20	59	75	28	21	3
	10%	29%	36%	**14%**	10%	1%
19/Moving blocks	37	33	32	72	25	7
	18%	16%	16%	35%	**12%**	3%

The correct answers are given by bold figures

on the students' answers. We then looked for questions that showed a significant difference in the average score between the FCI and LFCI versions. For questions with a difference larger than 10 percentage units we tried to identify possible explanations to the differences.

The students' answers to the first question in the questionnaire were sorted into positive and negative comments on the tests and the motivation for these negative and positive comments were categorized. In questions 2 and 3 we told the students to choose only one question as easy or difficult to understand, but many students chose more than one question and we decided to include all suggested questions in our analysis. We counted how many students that had suggested each question and we made lists of the easy and difficult questions, respectively. Few students wrote why they thought the questions were easy or difficult to understand. To get some knowledge about this we had to rely on the interviews. From the last question in the questionnaire we noted how many students wrote that they were helped by the pictures in the test.

In the interview, we transcribed students' answers of the interview questions in Lao. After that we looked at the answers for examples where the students talked about why questions were easy or difficult to understand or commented on the context of some of the questions. We also looked for students discussing everyday life experiences.

The first author looked at the video recordings many times and transcribed everything students talked about in Lao. She looked for examples when students referred to their everyday life experience during their discussions and she translated these examples into English. We found one especially interesting example that we describe in this paper.

RESULTS

Do the students show alternative conceptions?

The results in table 1 show the students' answers to five questions from the FCI in 2007. We selected those five questions because these questions illustrate the understanding of different physics concepts. Question 1 is about free fall, question 4 is about the collision of two objects, question 7 is about circular motion, question 11 is about forces acting on a moving object, and the question 19 is about the concepts of position and velocity. We wanted to see if the students showed any of the alternative conceptions described above, when answering these questions. Some students did not follow the instruction, they chose two answers or some of them did not choose any answer. The numbers of those students are given in the last column in the table.

Question 1 is about two metal balls of about the same size but one weighs twice as much as the other. The balls are dropped from a roof of a single storey building at the same instant. The students are asked what time it takes for the balls to reach the ground. The following five alternatives are given: A) About half as long for the heavier ball as for the lighter one. B) About half as long for the lighter ball as for the heavier one. C) About the same time for both balls (correct answer). D) Considerably less for the heavier ball, but not necessarily half as long; E) Considerably less for the lighter ball, but not necessarily half as long.

From the answers we see that 42% (A+D) of the students chose the two alternatives where the heavier ball falls faster than the lighter one, while 28% (B+E) of the students chose the alternatives where the lighter ball falls faster. 27% of the students chose the correct

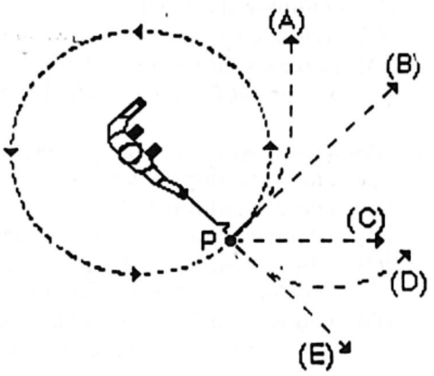

Figure 1. Picture to question 7 in the FCI

alternative C, which says that the fall takes about the same time for both balls. Some of the students may have the described alternative conception that the heavier ball falls faster than the lighter ball, but we cannot conclude that from these results. If the students just choose alternatives randomly 20% of the students on the average should land on each alternative and 40% of the students on two alternatives. We can also see that the students' answers are spread rather evenly over four of the five alternatives. We cannot from these results conclude that the students have the alternative conception that the heavier ball falls faster than the lighter one. The students rather seem to have missing conceptions according to the definition by von Aufschnaiter and Rogge (2010) or perhaps the everyday experiences lead them to a wrong answer.

Question 4 is about a big truck that collides head-on with a small car. The students are asked about the forces exerted to each car during the collision. The following five alternative responses are given: A) The truck exerts a greater amount of force on the car than the car exerts on the truck. B) The car exerts a greater amount of force on the truck than the truck exerts on the car. C) Neither exerts a force on the other; the car gets smashed simply because it gets in the way of the truck. D) The truck exerts a force on the car but the car doesn't exert a force on the truck. E) The truck exerts the same amount of force on the car as the car exerts on the truck (correct answer).

There are 33% (A+D) of the students who answered that the truck exerts a greater force on the car than the car exerts on the truck, while 26% of the students answered (B) that the small car exerts a larger force on the truck than the truck exerts on the car. Also in this case the answers are spread over most of the alternatives. We therefore cannot say that the students do have any specific alternative conceptions. Also in this case the students seem to have missing conceptions and they seem to reason in an intuitive way.

Question 7 talks about a steel ball that is attached to a string and is swung in a circular path in a horizontal plane. At the point P, which is shown in figure 1, the string suddenly breaks near theball. Students are asked what path the ball will follow after the string breaks. The five alternative responses are shown in the figure 1.

There were 34% of the students who chose the alternative B, which is the correct answer. Some students think that the ball must continue to move in a circular path (alternative A). 10% of the students chose alternative A, while 53% chose the alternatives C, D or E. In this problem a third of the students chose the correct alternative and according to their answers to the questionnaire they seem to have reasoned out of everyday life experiences. One example from interview indicates that this was the case. A boy student said that he made a similar toy as in question 7 when he was young.

The question 11 is related to a set of questions about a hockey puck moving on ice. The students are asked which forces that are exerted on the puck after it has received a kick. The following five alternative answers are given: A) a downward force of gravity. B) A downward force of gravity and a horizontal force in the direction of motion. C) A downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion. D) A downward force of gravity and an upward force exerted by the surface (correct answer). E) None. (No forces act on the puck).

There were 65% of the students who chose alternative responses B and C. They presumably thought that when an object is moving a force is needed in the same direction as the moving object. Only 14% of students chose alternative D which is correct answer. 10% of students thought that no forces acted on the object. Here many of the students seem to have the misconception that it must be a force in the direction of motion, perhaps because they don't treat friction as a force.

Question 19 talks about two blocks moving from left to right. The blocks are shown at successive 0.20-second time intervals. These blocks are represented by the numbered squares in the figure 2. Do the blocks ever have the same speed? The following five alternatives are given: A) No. B) Yes, at instant 2. C) Yes, at instant 5. D) Yes, at instants 2 and 5. E) Yes, at some time during the interval 3 to 4 (correct answer).

From the answers we see that 18% of the students chose answer A. They thought that the blocks never have the same speed. There were 35% of the students that chose answer D, which is the alternative where the blocks were at the same position. Only 12% of the students selected the correct answer. As an answer to the questionnaire many of the students explained that they did not understand what the 0.20 second time intervals meant. The conclusion here is that the students could not interpret this figure.

As a summary we conclude that it does not seem to be alternative conceptions that explain the results of

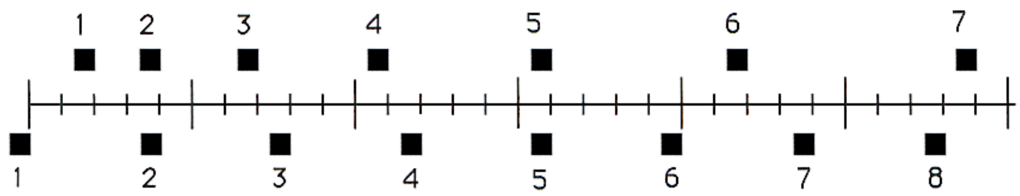

Figure 2. Picture to question 19 in the FCI

21. *Which of the paths below best represents the path of the rocket between points "b" and "c"?*

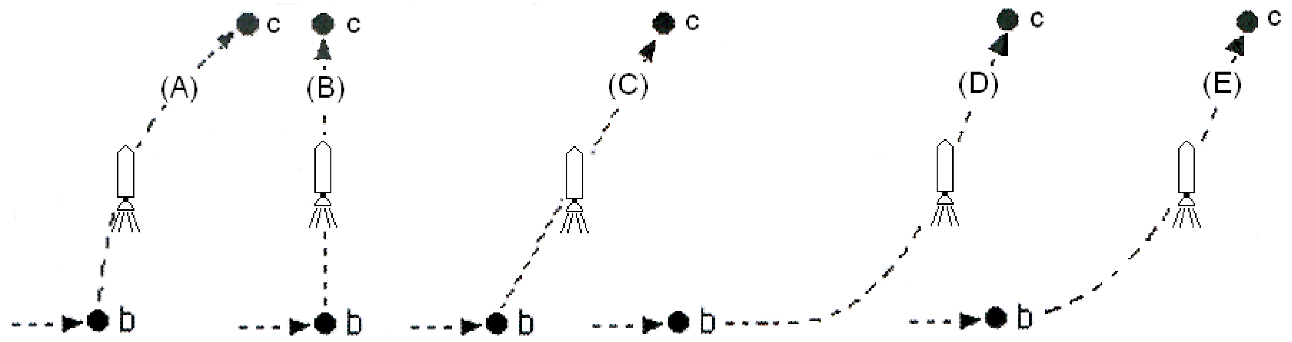

Figure 3. Question 21 in the LFCI

these five questions. The students in most cases seem to have only an intuitive understanding from their everyday experiences and no physics conceptual ground for their answers. They just chose an answer they thought was reasonable or in accordance with their everyday life experiences. It is also possible that some of the students just guessed. It is only for question number 11 we suspect that many students selected their answers based on the misconception that there must be a force in the direction of motion.

Students' difficulties to understand the questions

To find the answer of the second research question we analyzed students' answers to the questionnaire and the interview questions. About 75% of the students had positive comments about the FCI. They wrote that the FCI was a good and interesting test and that some questions in the test helped them to remember and to understand the physics they learned before. 90% of the students had positive comments about the LFCI. They wrote: "The LFCI test is a good and interesting test. It probes our physics knowledge and also helps us to learn new physics knowledge." These students also wrote that this test improved their ability to read and think.

The students had the same negative comments to both tests. About 25% of the students had negative comments on the FCI, and about 10% of the students had negative comments on the LFCI. They wrote that the FCI and LFCI tests are difficult, and they commented that it was not easy to imagine the phenomena in some questions. The students remarked that they did not understand the meaning of the questions because these were only explained in words. The students told us that all questions in the tests were qualitative and questions of that kind are different from the end-of-chapter questions in their textbook. The latter questions either ask for the formulation of a physical law or ask the student to calculate some quantity. Only a few students thought that these tests were simple tests and they continued to explain that in some questions the phenomena were easy to imagine, but in other questions it was difficult to imagine the phenomena.

The students were asked to choose one question which they thought was easy to understand and also to explain why it was easy. However, many students chose more than one question of both tests (FCI and LFCI). In fact all questions were chosen as easy by at least one student. Questions 6 and 7 were chosen as easy by 17% and 25%, respectively, of the students tested by the FCI. These two questions deal with circular motion, and were the most popular choices.

The students tested by the LFCI also chose questions 6 (17%) and 7 (22%) as easy questions but also question 17, 29 and 30 were popular choices. 18%, 21% and 17% respectively of the students chose these questions. Question 17 and 29 were changed from the original FCI to the LFCI. In question 17 the context was changed from an elevator to a bucket with water moving up from a well. In question 29 "an empty office chair" was changed to a "chair". The number of questions, that the students wrote were easy to understand for the LFCI, was larger than for the FCI.

23. *At point "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond point "c"?*

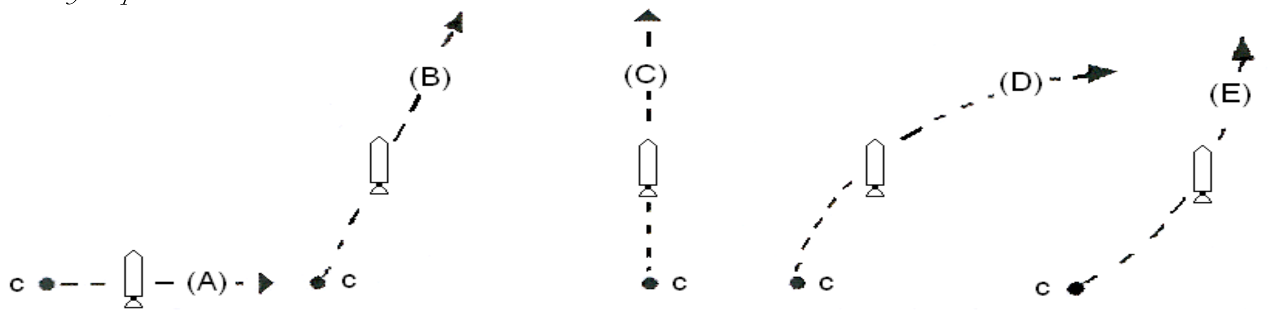

Figure 4. Question 23 in the LFCI

The students were also told to choose one question which they thought difficult to understand and explain why they thought it was difficult. Also in this case, many of the students chose more than one question from both the FCI and the LFCI. For example the most frequent choice was question 8, talking about a hockey puck moving on ice (25%) in the FCI and about the butter moving on the griddle (11%) in the LFCI.

When the students were asked if the pictures helped them to understand or not, about 72% of FCI-students and 77% of the LFCI-students said that many pictures in the questions helped them to understand the meaning of the questions. About 28% of FCI-students and 23% of the LFCI-students wrote that some pictures in the test made them confused.

Through the interview we got some explanations of why the students thought that a question was easy or difficult to understand. Two boy students, tested by the LFCI, said that for some questions they could imagine the phenomena and relate it to their everyday life. One boy student showed an example about a tennis player. He said that usually he plays tennis every weekend, but he has never thought about forces acting on his racket. Another student said that the phenomenon of this question was easy to imagine, because tennis was a popular sport for him. This question is about the forces on the tennis ball after the hit. The students did not score well on this question on either the FCI or the LFCI even if they thought that the question was easy to imagine. The pictures in the LFCI version that illustrated what happened when the tennis ball was hit did not help the students to realize what forces acted on the ball after the hit. A majority of the students chose the two answers that included a force by the hit. Some students also said that question 6 and 7 about circular motion were easy to understand, when they saw the pictures they could decide the answer to these questions. One boy student said that, when he was young he made a similar toy as in question 7 (Figure 1). About 35% of the students chose the correct answer to this question and in this case the everyday experiences may be a reason to the relatively high level of correct answers for the Lao students.

Some students gave examples of questions that were difficult to understand. Some students said that question 8 was difficult to understand. This question is about an ice hockey puck and the students could not imagine the phenomenon in this question. They did not know this sport, and it was difficult for them to decide the answer of this question. One boy student said that he had seen this sport on TV a couple of times, but he did not understand it. This question was changed in the LFCI to be about butter on the griddle. One girl student said that, the phenomenon of this question was easy to imagine. She continued to explain "we can find this phenomenon when we use pork's oil to cook food in the winter season." In a questionnaire in 2008 we got a suggestion from a student in a group. He suggested that the context of question 8 should be changed from butter moving on the griddle to a bar of soap moving on a wet floor. In 2010, we changed the context of this question to a bar of soap moving on the floor. Some students said this year that the phenomenon was easy to imagine and they could try by themselves when they take a shower. However, the percentages of correct answers did not change when the context was changed from ice hockey to butter on the griddle or to a bar of soap on the floor. The students still have the same missing conceptions.

The pictures in questions number 19 and 20 about velocity and acceleration were difficult to understand according to the students. The pictures in these questions are very clear, the students said, but it is difficult to understand the meaning of the successive 0.20 second time intervals. Question 21 about a rocket in outer space was also difficult to understand. Some students said that they had never seen a rocket move from left to right before it moved up to the sky. Usually, they see the rocket move up from the ground to the sky directly.

Some students tested by the FCI said that the pictures in the questions helped them to understand, but some pictures made them confused such as in question 12 about a cannon ball. Some of the students said that the cannon ball moved very fast so they could not imagine the direction of it. In question 17, about the force on an elevator, some students said that they could not imagine the phenomenon, when the elevator moves up and down, because when they stand inside the elevator they cannot see any cables.

As a summary we conclude that changing context, adding mathematical notation and increasing the number of pictures did not increase the average score of correct answers to the FCI/LFCI. The students, though, found these tests (FCI and LFCI) interesting and thought they could learn physics through them. The students, however, also found the tests difficult, because it was difficult for them to understand the questions that were explained only in words. This was a different kind of questions compared to the questions at the end of the chapters in the physics textbooks that the students solve in class. The students also thought that in many cases it was difficult to imagine the phenomena in the questions. For example questions about ice hockey were difficult to understand. When this question was changed to a question about butter on a griddle it became easier to understand, but the percentages of correct scores did not become higher. Even if the correct score is not changed it is essential that the students understand what the questions are about and that the students become interested and want to know the answers.

An example of everyday life experiences influencing the interpretation of questions

In 2008 the students discussed and answered the FCI questions in small groups. Here we show part of the discussions of two questions that involve rockets. We want to show how the students use their everyday life experiences about rockets when they interpret these questions and discuss the alternative answers.

The question number 21 involves a rocket in outer space drifting sideways to point b, which is shown as a horizontal arrow at the bottom of the pictures in figure 3. At point b the engine is started, and it is asked what path the rocket will follow between b and c. In outer space, the only force that could act on the rocket is the force from its own engine. Therefore, the correct alternative is E.

A group with four students, three boys (Thai, Mone, Souk) and one girl (Ny) discussed this question. Before the students started to discuss, they read the question carefully and then Thai said:

Thai: You can see the pictures; the direction of the rocket should be alternative D.

Mone: The launching pad for a rocket is not vertical; they put it like the direction in C. I think that the rocket's direction must be C, therefore the alternative C must be correct. [When he explained he used his hands to show the direction of the rocket when it moved up to the sky].

Thai then argued that the alternative C was not a correct answer. Mone asked Thai, if the alternative C is not the correct answer, which alternative will then be correct. However, Thai didn't say anything. Ny suggested her friends to consider another alternative direction of the rocket.

Ny: You should consider a different way. I think that when the rocket's engine starts working, the rocket must go to the sky in the B direction. So I think the B answer should be the correct answer.

Souk:No, I don't think so. I think that, when the rocket's engine works it must go to the sky immediately. The suitable direction should be the B or C direction, but I agree with Mone's idea; I think the correct answer should be C.

Thai: I think the rocket's direction must depend on the force from the engine. If the engine's force is very strong that rocket must go to the sky in the B direction, if the engine's force is not strong enough it will go to the sky in the D direction. Ok, I still stick to my idea that alternative D is correct.

Souk gave several examples from rocket festivals in different places in Lao PDR. The students used their everyday life experiences of rockets from rocket festivals. They did not take into consideration that the rocket should be in the outer space.

We also show an excerpt from the same group discussing around question 23. This question is referring to the same rocket as above whose engine is now turned off. It is asked which path the rocket now will follow (see figure 4). When the engine stops, there is no force on the rocket which will then continue in a straight line. This leads to B being the correct answer (if the answer to question 21 was correct).

All students used some seconds to read this question. After that Ny asked her friends about the velocity of the rocket. She said:

Ny: In this case, the engine stops working so no force acts on the rocket. How about the velocity? Is it equal to zero or not?

Souk: No it is not equal to zero, but it will be equal to zero at the top point. I think that when the rocket's engine stops, that rocket must move down immediately, and when that rocket is moving down quite close to the ground its velocity must increase. In this case, the correct answer should be D.

Mone: No, I don't think so. At point c the rocket's engine stopped working and the rocket must continue to move in the same direction, so that direction must be the A direction.

Thai, Ny and Souk agree that after the rocket's engine has stopped the rocket is still moving, because it has velocity, and they select the path described in D, whereas Mone chooses the A alternative. The students reason about a rocket on earth that must fall down to the ground when the engines stop working. If the rocket had been close to the earth, the best path to describe its motion would have been D. The students also here seem to think about rocket festivals.

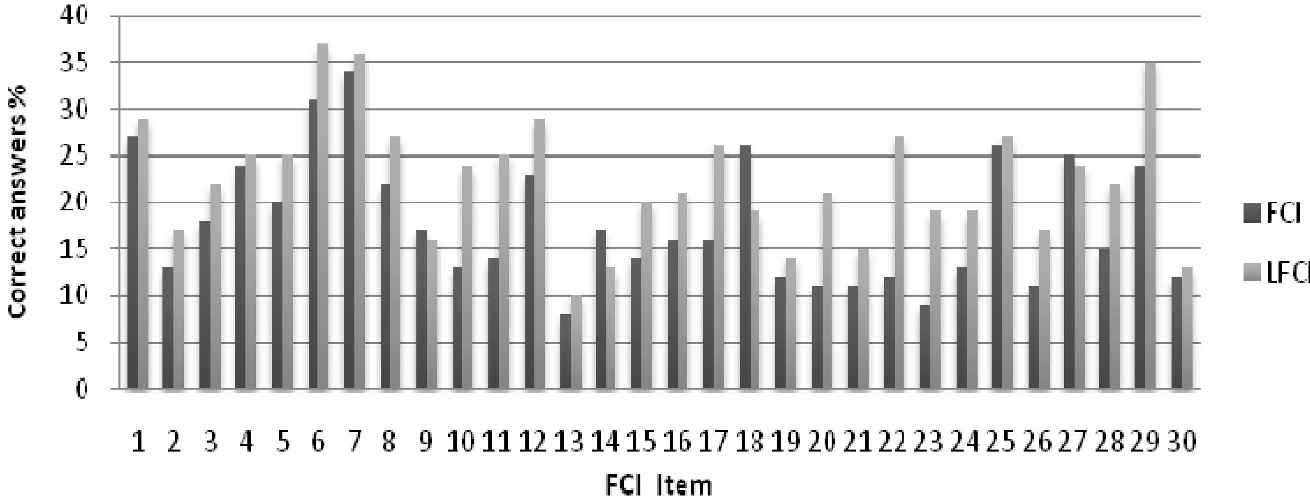

Figure 5. Post-test percentage of 30 questions in two versions of the FCI in 2007

Consequence of more pictures and a change of context on the results

To see if more pictures and changes of context of the questions modified the percentages of correct scores we compare the scores of the two tests, FCI and LFCI, for all 30 questions. This is shown in figure 5. Half of the questions were changed from FCI to LFCI either in context, mathematical notation or in the number of pictures. The comparison shows that in most questions the percentages of correct scores are quite similar. There are seven questions that show at least a 10% difference. It is hard to give firm explanations to the differences but we have noted some plausible causes. In two of the questions it is asked for the forces that act on an object. In the LFCI, pictures showing the forces have been added to all the alternative answers. The students got in these questions both a textual and pictorial representation of the alternative answers which might have helped some students. In another question a picture of moving blocks (see figure 2) has been changed to a picture of joggers that clearly shows that they are moving in contrast to the blocks that seem to be at rest. A more familiar situation could be the explanation for another question where the context was changed from a moving elevator to a bucket of water being wound up from a well. The students never see or experience the cables in an elevator shaft but they might have tried to fetch water from a well. In a series of questions about a rocket we had included pictures of the rockets in figures showing the path of the rocket (see figures 3 and 4). The pictures also showed when the engine was running and when it was shut off which can have reminded some students that the engine was running when they were asked about the change of speed of the rocket. However, even if these changes in the questions resulted in an improved score it must be remembered that it affected only a small part of the students. When taking the average of all 30 questions the positive effects vanish almost completely. The average score for all questions is 18% for the FCI and 21% for the LFCI. Changing context, adding mathematical notation, and increasing the number of pictures did not result in a better average score.

DISCUSSION

The score of correct answers to the FCI is low in this study, around 20%, even after instruction. Hake's (1998) compilation of FCI scores from high schools and universities in USA shows much higher scores for the universities (50-85%). It is only a pre-test in one high-school that had the same low results as in this study. A study of first year engineering students in Indonesia (Cahyadi, 2004), however, revealed a low score on the pre-test comparable to our result from Laos. The scores that we report in this paper are extremely low considering that they are taken from a post-test.

An interesting question is, if it is possible to explain this low score by the fact that the students have alternative conceptions. It is, however, difficult to draw conclusions about students' alternative conceptions from the FCI results. In most questions the answers are spread quite evenly on the five alternatives, which could be interpreted that students more or less guess the answer. This can be seen in question 1, where about 28% of the students selected the two answers in which the lighter ball fell down faster than the heavier ball. This cannot be explained by a traditional commonsense belief. In the article by Hestenes et al. (1992) only 0 - 7% of the students in a class made the same choice in the post-test. It is very unusual in USA that students think that a lighter ball falls faster than a heavier one and we have no reason to think that Laotian students are different and have this as a common alternative conception. We assume that many Laotian students guessed when answering this question. The reason for guessing could either be that the students do not have any clear idea about falling objects or they could have problem to understand the question.

It is only in one question that we suspect that the students have a clear alternative conception, that a force is needed to keep an object moving. Hestenes et al. (1992) presuppose that students have rather stable beliefs. Frank, Kanim and Gomez (2008) suggest that answers to questionnaires rather can be explained by students having a variety of different physical intuitions. It is possible that our results could be better explained by intuitions built on everyday experiences than on alternative conceptions.

We have seen examples when the students only use their everyday life experiences and not the laws of physics, when they try to find answers to the questions. One example was in a question about circular motion. Many students said in the interview that the picture helped them to understand the question, and when they saw the picture they could decide the answer. We also note that this question has the best score of all questions, even if it still is a low score. About one third of the students selected the correct answer although circular motion was not part of the curriculum and therefore not treated in the lectures. This makes it even more probable that the students only used their everyday life experiences and not their knowledge of physics when answering this question.

In questions about a rocket moving in outer space the students in the group discussion used their everyday life experience from the rocket festival in Laos. The students did not refer to physics concepts at all when they discussed these questions. They thought that the rocket should move down to the ground again and that the velocity of the rocket should be zero at the top point of the orbit. This group chose an answer that was in accordance with their ideas. Many of the students probably thought in the same way because about one third of them chose that alternative in the question. Hestenes et al. (1992), however, showed that only 0 - 4% of the students in USA made the same choice. The students from USA are perhaps used to think about rockets moving in outer space, while Laotian students rather think of rockets moving quite close to the earth.

When the students explained why some questions were difficult to understand, it was also clear that they tried to use their everyday life experiences to understand the questions. For example in a question about a cannon ball, a student in the interview said that he could not imagine the direction of the ball when it moved out from the cannon, because it moved very fast. Some students referred to a similar problem when they tried to answer a question about forces on an elevator. They thought it was difficult for them because they could not observe the cables. As the students use everyday life experiences to understand the questions, an unfamiliar context is a factor that makes it difficult for them. The best example of this is a question about ice hockey. Several students said in the interview that they had no experience of this sport. One student said that he had seen this sport on TV, but he did not understand it at all.

The Lao version of the FCI showed a small improvement in the scores of about one quarter of the questions but the average score of the whole test had a negligible improvement. This result is in accordance with the result of McCullough (2004) who tried to alter the FCI question to more female oriented contexts. In some questions this resulted in different changes in the score for men and women, respectively, but averaged over all students their gender version did not show any difference to the original FCI. The result of our study support the findings from other researchers (McCullough, 2004, Stewart, Griffin and Stewart, 2007) that a low score on the FCI can only to a very small part be explained by unfamiliar context in the questions.

The Lao students have a low total score on the FCI. This investigation shows that the students seem to use their everyday life experiences and not knowledge of Newtonian mechanics when they answer the FCI-questions. Savinainen et al. (2002a) conclude that pre-test scores of the FCI are uniformly low for beginning students and no large gains have been seen with conventional instruction, that is lecturing and quantitative problem solving. Savinainen et al. (2002b) suggested a changed teaching in which the FCI was used to evaluate student learning followed by a new approach to teach mechanics. The new approach included a conceptual focus and classroom interactions, and resulted in a large gain in the post-test scores. A large improvement in post-test scores was also found with engineering students in Indonesia when the teaching was changed to include reading quizzes, in-class demonstrations and peer discussions (Cahyadi, 2004). These studies show that it would be a good advice to Lao universities to try to change the teaching in the suggested directions.

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