Questionable Authenticity of Some Problems in "Fundamentals of Physics" by Halliday, Resnick and Walker: An Initial Study of Students' Critical Considerations

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Abstract
This study is an initial exploration of students' abilities to analyze critically authenticity of physics problems, carried out with Spanish translation of the eight Edition of popular physics textbook "*Fundamentals of Physics*", written by Halliday, Resnick and Walker. Students (N = 34) involved in the study were those of applied physics taking a general first-semester course "Development of Complex Thinking Skills" at the Facultad de Ciencias Físico Matemáticas of the Benemérita Universidad Autónoma de Puebla (Puebla, Mexico). Among the aims of the course is development of 21st century 4C-skills (critical thinking, creative thinking, collaboration and communication) through self-regulated learning. In the segment of the course dedicated to critical thinking, students were informed about characteristics of authentic school problems and their task was to analyze authenticity of some problems in textbook "Fundamentals of Physics", they use in their Mechanics course. They were supposed to pay attention to authenticity of events, data and questions used in contextualized physics problems. Results show that students are able to perform critical considerations, focusing their attention mainly on the events' characteristics, less on the sense of questions asked and much less on data feasibility. Only one student indicated that given data in a problem seem unrealistic. Nevertheless, such a particular consideration is very important because many textbook reviewers, holding PhD in physics, were not able to detect that erroneous implicit density value in four editions during almost ten years. Some students paid attention to broader issues implied by supposed events (for example, about animal rights). Their critical considerations of negative role of non-authentic problems have in physics learning are briefly mentioned, too.
Keywords: Authentic school problems; Contextualization of physics problems; Students' critical thinking; Home physics experiments; Animal rights.

INTRODUCTION

Davies, Fidler and Gorbis, in their research report "*Future Work Skills 2020*" (2011), provided a list of six major drivers of changes in people's thinking about what professional work is and will be. These drivers are: (1) extreme longevity; (2) rise of smart machines and systems; (3) computational world; (4) new media ecology; (5) super structured organizations and (6) globally connected world.

To deal successfully with challenges of these changing work facets, according to Davies, Fidler and Gorbis, people need to learn and dominate ten future work skills: (1) sense-making; (2) social intelligence; (3) novel and adaptive thinking; (4) cross-cultural competency; (5)

computational thinking; (6) new media literacy; (7) transdisciplinary; (8) design mindset: (9) cognitive load management and (10) virtual collaboration.

The prominent and very active association "Partnership for Competence of the 21st Century" (www.p21.org) promotes a rather short list, well known as the 4C list, which contains only four basic competences whose descriptions are presented in Table 1.

Table 1*. 4C-List of 21st Century Skills*

Skill or competency	**Description**
Critical thinking	Looking at problems in a new way, linking learning across subjects & disciplines
Collaboration	Working together to reach a goal — putting talent, expertise, and smarts to work
Communication	Sharing thoughts, questions, ideas, and solutions
Creativity	Trying new approaches to get things done equals innovation & invention

The Autonomous University of Puebla (Puebla, Mexico) in its University Model "Minerva" (www.minerva.buap.mx), accepted in December of 2006 by University Council, has proposed an "integral formation based on constructivist theory of learning and with sociocultural and humanistic orientation". The foundation of general university formation are four obligatory courses for every professional career: (1) Human and social formation; (2) Development of complex thinking skills; (3) Development of skills for ICT use and (4) Foreign language.

In its specific curriculum for the Faculty of Physical and Mathematical Sciences, the course "*Development of Complex Thinking Skills*" has the following expected results of students' learning:

1. Students will strengthen their integral formation by developing cognitive skills to be able to formulate and evaluate their personal opinions in solving problems and making decisions, thus preparing themselves for interdisciplinary participation and lifelong learning.
2. Students will be able to solve simple conceptual and quantitative problems, using different forms of reasoning (logical, visual, arithmetic, algebraic and analogous)."
3. Students will improve personal administration of learning, knowing and applying phases, domains and resources of self-regulated learning."
4. Students will be prepared to learn to learn, to think critically and creatively, to work collectively, and to make reasoned and information-based decisions instead of following their beliefs and prejudices.

Since 2008, I was teaching that course almost every academic year. For a proper implementation of the course, I had to solve three demanding teaching problems. The first was to convince students, by using many arguments and examples, the course offers multiple opportunities to acquire competences for successful life and work in the 21st century. Finding convincing arguments and examples, to be shared with students, implied a serious reading of educational and economic literature in which these competences were scientifically defined and discussed (Slisko, 2016).

The second problem was to show to students that their level of even basic competences, gained through previous traditional, content-oriented and teacher-centered pre-university education, is not at a satisfactory level. In order to do it, I was initially applying "Test of logical thinking" (Tobin & Capie, 1981). Recently, the "Cognitive reflection test" (Frederick, 2005) was used, too. To make my point, I inform them about their rather poor performances on both tests, without uncovering their mistakes and corresponding correct answers.

Along the same line, the third teaching problem was to make quite clear that many of them are still "prisoners of routine or intuitive thinking". I start with a few old puzzles that show, in an obvious way, two basic types of human thinking (Evans, 2003). The first is a routine or common-sense thinking, based on everyday knowledge, experiences and beliefs. If that kind of thinking is used, puzzles seem impossible to solve or students give an incorrect solution. A correct puzzle solution requires non-routine and counter-intuitive thinking and it implies a critical and creative reasoning.

Critical Thinking in Solving Physics Problems: A Broader View

In problem solving, students should employ critical thinking skills in the analyses of problems and the synthesis and applications of previously learned concepts (McCormick, Clarck & Raines, 2015). Nevertheless, in mathematics and physics education, the role of critical thinking is not cultivated in such a broad sense.

Polya has introduced a well-known four-step strategy for problem solving in mathematics education (Polya, 1973):

(1) Understand the problem;
(2) Make a solution plan;
(3) Carry out the plan; and
(4) Look back.

Obviously, activation of critical thinking is reserved for the last step. Following Polya's vision, Reif, Larkin and Brackett (1976) authored the first article on physics problem-solving steps, in prestigious *American Journal of Physics*. They stated that these four steps should be used to teach student explicitly how to solve physics problems. The actions the steps imply and the expected results are the following:

(1) *Description:* List explicitly the given and desired information. Draw a diagram of the situation. (The result of this step should a clear formulation of the problem.)

(2) *Planning:* Select the basic relations pertinent for solving the problem and outline how they are to be used. (The result of this step should a specific plan for finding the solution.)

(3) *Implementation:* Execute the preceding plan by doing all necessary calculations. (The result of this step should be a solution of the problem.)

(4) *Checking:* Check that of the preceding steps was valid and that the final answer makes sense. (The result of this step should be a trustworthy solution of the problem.)

Again, critical thinking appears only in the last step to check if the answer makes sense. Such a place for activating critical thinking stays the same even in the most recent research ramification of Reif, Larking and Brackett's model (Gok, 2015). In the course, I try to give students a broader field for cultivating critical thinking. Although finding out "whether an answer makes sense" is very necessary, it is even more important to consider, in the first place, "whether a problem makes sense".

For successful implementation of that approach, it is necessary to inform students about the framework of "authentic school problems". Palm proposed a useful taxonomy of characteristics of "authentic school problems" should have (Palm, 2006; Palm, 2009). In the first place, a school problem is "authentic" if

(a) problem-related *event* or situation happens or could happen in the real world;
(b) numerical *data* describing event or situation are real or, in principle, possible and
(c) *question asked* in problem is reasonable.

A problem is "artificially contextualized" or has "questionable authenticity" if any of these characteristics is absent or violated. When students solve authentic word problems in school mathematics, they are likely to apply "real life" considerations in the solution process and in evaluation of obtained solutions (Palm, 2008). If students solve non-authentic problems, they frequently use superficial solution strategies and develop unproductive beliefs about mathematical word problem solving. These strategies and beliefs are main reasons for providing solutions that are inconsistent with the situations described in the word problems (Palm, 2008).

Task and Methodology Used in This Study

Understanding students' performances in solving different physics problems is a very active field in physics education research. The findings show a very complex role students' cognitive skills and processes play in planning, implementing and evaluating solution steps and results (Teodorescu et al., 2013; Adams and Wieman, 2015; Fabby & Koening, 2015).

Being so, students' task was not to choose and solve some physics problems in their textbook "*Fundamentos de Física*" (Halliday, Resnick & Walker, 2009), that is Spanish translation of "*Fundamentals of Physics*" (Halliday, Resnick & Walker, 2008). Instead, they were supposed to think critically about chosen problems' authenticity in terms of suggested events, data and questions.

The study had three phases. In the preparatory phase, students were informed about Palm's taxonomy and some examples of highly non-authentic problems found in physics and mathematics textbooks (Slisko, 2014). Their negative consequences for students' learning and beliefs were discussed, too. In the target-task phase, students had to carry out a two-week long homework. They were asked to examine and analyze authenticity of five chosen physics problems that appear in the mentioned physics textbook. The homework had to be prepared as a word document and sent via email to the teacher.

In the follow-up phase, one problem was discussed in details while one problem was transformed into an optional home experiment.

THE RESULTS OF THIS STUDY

24 of 34 students did the homework (70 % of students or 7 of 10 students) and provided 120 problems. As it was expected, some of these problems were repeated because they were selected and analyzed by various students. Quality of homework sent by students wasn't equal. Some

students only provided five problems without required analysis. Others wrote extended and carefully worded critical considerations.

In what follows, I present ten problems with selected critical considerations made by students. Categorization of critical-consideration type is also provided, based on Palm's taxonomy (event, data, question). As it will be seen, some considerations were focused on aspects that weren't mentioned by Palm. After some of these problems, I add a didactic comment.

Bird and Two trains

"Two trains, each having a speed of 30 km/h, are headed at each other on the same straight track. A bird that can fly 60 km/h flies off the front of one train when they are 60 km apart and heads directly for the other train. On reaching the other train, the bird flies directly back to the first train and so forth. (We have no idea why a bird would behave in this way.) What is the total distance the bird travels before the trains collide?" (Halliday, Resnick & Walker, 2008, Problem 11, p. 32)

Critical consideration (Event) The illogical aspect of this problem is not only the behavior of the bird. The bird moves quickly and consistently which most birds do not. Besides, this situation cannot happen actually with trains, since their routes are very supervised and programmed.

Critical consideration (Event + Data) We notice that it tells us that these trains are going to crash at some point. The problem suggests the idea of imagining two trains with constant speed about to collide, but does a bird come and go between these trains? The speed of the bird is in the average close to reality, but it would have to make endless turns and come. Would a bird really go from one train to another for so long? It is clear that it would not.

Critical consideration (Event + Data) Consider this problem somewhat exaggerated, since the response is almost immediate because of the given data. I do not think that a bird would repeat these movements for an hour and move that way. The bird, in any way, when feeling such a great vibration for the trains, would fly away in a vertical direction to the tracks. Even if it takes another angle, the horizontal distance of 60 km that the bird travels become monstrous.

Critical consideration (Event + Data) As I see the problem, the bird seemed to be very stupid or maybe it was hurt. But from any point of view, if it could take the flight at that speed, it could easily get out of the path of collision, without any need to go back and forth.

In its many formulations, this problem belongs to the group of the most popular motion puzzles of all times. Nevertheless, in this study it received biggest number of critical considerations related to its contextualization. The problem has also an interesting evolution in the textbook. In the first edition of "Fundamentals of Physics" (Halliday & Resnick, 1970), it had a different formulation:

"Two trains, each having a speed of 30 miles/hr., are headed at each other on the same straight track. A bird that can fly 60 miles/hr. flies off the front of one train when they are 60 miles apart and heads directly for the other train. On reaching the other train, the bird flies directly back to the first train and so forth. (a) How many trips can the bird make from one train to the other before they crash? (b) What is the total distance the bird travels?" (Halliday & Resnick, 1970, Problem 3, p. 39)

This formulation, with slight changes, was kept in the second, third, fourth and fifth edition. In the sixth edition, the question (a) was taken out and the problem appeared only with the question (b). The textbook answer given to the question "how many trips can the bird make from one train to the other before they crash?" was "infinite number" or "mathematically infinite number".

In the follow-up phase, when I told students this story, they weren't surprised by that answer. Very likely, they didn't understand well enough limitations of the concept of "mass point", physics textbook used carelessly. So, I decided to show them mathematically that normal-size bird could hardly make more than 15 flights before its flying would become impossible. My message was that in applied physics, good physicists don't count flights of a dead bird.

Four Penguins

"Figure 5-48 shows 4 penguins that are being playfully are pulled along a very slippery (frictionless) ice sheet by a curator. The masses of three penguins and the tension in two of the cords are m_1 = 12 kg, m_3 = 15 kg, m_4 = 20 kg, T_2 = 111 N, and T_4 = 222 N. Find the penguin mass m_2 that is not given." (Halliday, Resnick & Walker, 2008, Problem 50, p. 11)

Critical consideration (Event's implications) In this problem it is fun to pull 4 penguins and slide them on the ice, when in real life this would be taken as animal abuse to be punished, and more so with species such as penguins.

Critical consideration (Event's implications) To my consideration this problem has no relation to reality since it would be difficult to keep the penguins aligned and subject to a rope. Another issue is the fact that in the problem it is said that the curator did it as a play. Would a worker really play with the penguins that way? We must also add that there should be rules that prohibit such interaction.

Critical consideration (Event's implications) First, poor penguins! It is not possible that penguins like to be tied and then pulled, as the authors think. Also, if the problem is to find the weight, they could have weighed it. Can it be that they don't have a scale? But even so, this problem is very cruel and unethical. It may cause laughter to someone, but not to me.

These considerations bring an important ethical and animal-right issue that should be taken seriously into account when end-of-chapter physics problems are formulated and revised by reviewers. In addition, in real life, a penguin's mass is found, not by a complicated "physics textbook approach" described above, but by a careful process of direct weighing. One possibility is to use a spring scale to hang a penguin and find its weight (Figure 1).

***Figure 1**. The weight of a penguin can be found by a spring scale.(https://www.youtube.com/watch?v=aBs-_2qPE0M)*

The other possibility is to "teach" penguins how to climb and stand on an electronic balance that would show their weight (Figure 2). In future studies of this type, students should be asked to use Internet searches to evaluate authenticity of supposed situations, processes and data in considered physics problems.

Figure 2. *Measuring weight of King penguins by an electronic balance.*
(https://www.youtube.com/watch?v=xVNSdMA71YA)

Sleeping Cat

"A cat dozes on a stationary merry-go-round, at a radius of 5.4 m from the center of the ride. Then the operator turns on the ride and brings it to its proper turning rate of one complete rotation every 6.0 s. What is the least coefficient of static friction between the cat and the merry-go-round that will allow the cat to stay in place, without slipping?" (Halliday, Resnick & Walker, 2008, Problem 43, p. 134)

Critical consideration (Event) Cats are nocturnal animals, they like to be in safe places, and not exposed. The situation in this particular problem is that the cat is dozing on the shore of a merry-go-round. So, in my opinion, at the time of operating the machinery, any cat would move right away, and leave the person who is doing the experiment disappointed, since he could not keep a cat quiet until it moved by the force of the merry-go-round. So, the realization of this experiment would be almost impossible. Instead of using a cat, one could use a toolbox forgotten by the merry-go-round operator.

Critical consideration (Authors) Do the authors have something against animals?

Critical consideration (Event) In this problem of the cat, we can say that it is a little illogical since the cats do not usually get on the merry-go-round.

It is important to mention that a student felt a need to imagine the supposed situation and to make a drawing of it (Figure 3).

Figure 3. *A Nice Student's Drawing of The Situation "A Cat on Merry-Go-Round".*

Asking students to draw how they imagine supposed problem situation may reveal conceptual and comprehension difficulties they have when they try to understand the problem text. Important differences between "pictorial" and "schematic" representations (or between "situation drawing" and "mathematical drawing") and their implications in students' problem solving performances were commonly studied in mathematics education (Hegarty & Kozhenikov, 1999; Rellensmann, Schukajlow & Leopold, 2017).

In physics education, such type of studies is missing, although transition between a "situation model" and "mathematical model" isn't a trivial one. In some physics textbooks, those models are mixed-up in the same drawing. That unnecessary mixing might be another obstacle for a proper student's understanding of the role and characteristics of mathematical modeling in physics.

A Slide-Loving Pig

"A slide-loving pig slides down a certain 35° slide in twice the time it would take to slide down another frictionless 35° slide. What is the coefficient of kinetic friction between the pig and the slide?" (Halliday, Resnick & Walker, 2008, Problem 6, p. 131)

Critical consideration (Event's implications) The first thing that comes to my mind about this problem is that the only situation in which a pig is going down a slide is that it goes straight to the slaughterhouse, given that what matters in this particular situation is the efficiency that has this slide to get the pigs in the shortest time possible down, either with friction or without friction. So, vegetarians or animal rights advocates would not see it well.

Critical consideration (Event) Let's analyze the information first. Why would a pig be on a slide? Let's forget the formulas for a moment. Would it really slide? What if it's too fat and it does not slide?

Critical consideration (Event + Question) I wonder who climbed the pig to the slide or the pig wants to have fun and climbed alone. It sounds quite illogical for someone to do something like that. On the other hand, is the fact: what's the use of getting the friction coefficient between the pig and the slide? I believe that the problem was made only to develop our skills to use formulas. Nevertheless, I can say this isn't physics.

A Kidnap Story

"You are kidnapped by political-science majors (who are upset because you told them political science is not a real science). Although you are blindfolded, you can indicate the speed of their car (by the whine of the engine), the time of travel (by mentally counting off seconds), and the direction of the travel (by turns along the rectangular of street system). From these clues, you know that are taken along the following course: 50 km/h for 2.0 min, turn of 90° to the right, 20 km/h for 4.0 min, turn of 90° to the right, 20 km/h for 60 s, turn of 90° to the left, 50 km/h for 60 s, turn 90° to the right, 20 km/h for 2.0 min, turn 90° to the left, 50 km/h for 30 s. At that point, a) how far are you from your starting point, and b) in what direction relative to your initial direction of travel are you?" (Halliday, Resnick & Walker, 2008, Problem 83, pp. 82 - 83)

Critical consideration (Event) This problem was to me too funny and exaggerated, because I do not think it is possible to accurately determine the speed of the car only with the ear. I understand that there are excellent machines that with the Doppler effect do a marvel by calculating the speed of a car. But to use the ear to calculate the speed, to keep the count in seconds as close as possible to a clock and to be concentrated in the turns, it seems to me like a Sherlock Holmes movie, and that without counting the fact why the kidnapping allegedly happened. Should I believe that the majors of the law school are so sensitive to be told something like that? Ha, ha, ha…

Critical consideration (Event + Question) In the first place, a person might not know who the kidnapper is. In case there is a kidnapping, maybe they are political science students, but they may also be from another career or maybe they are not even students. In second, maybe one can know what the engine speed is, but not exactly. At least personally, I couldn't know what the speed is but only if it accelerates or decelerates. On the other hand, time can be counted, but what good is that if it is related to the turns that the car gives? Maybe the place where the person is being taken is just a straight road or the city has not a rectangular system of streets. The problem does not make much sense, a person would panic in such a situation. In the remote case of remaining calm, in my opinion, I would first wait to know where I would be taken and from there I would plan the escape or something like that.

For both previous problems, students presented strong critical considerations of suggested events and asked questions. It is unlikely that they would have such a type of considerations if they were asked to solve the problems. In a sense, they "learn" to suspend their critical thinking about problem situations in order to be "successful" in learning how to find a numerical answer by playing with mathematical formulas.

The second problem show that the authors try to give a kind of "justification" about the way given numbers were obtained. It is good to know that, at least, some students don't accept that cheating approach to the origin of arbitrary invented numbers in an equally invented story!

A Penguin Led

"A loaded penguin sled weighing 80 N rests on a plane inclined at angle $\theta = 20°$ to the horizontal (Fig. 6-28). Between the sled and the plane, the coefficient of static friction is 0.25, and the coefficient of kinetic friction is 0.15.
(a) What is the least magnitude of the force F, parallel to the plane, that will prevent the sled from slipping down the plane?
(b) What is the minimum magnitude of F that will start the sled moving up the plane?
(c) What value of F is required move the sled up the plane at a constant velocity?" (Halliday, Resnick & Walker, 2008, Problem 20, p. 132)

Critical consideration (Event) The penguin does not have to be inside a box.

Critical consideration (Event + Question) This problem, I think, has no relation to reality and I wonder what is the meaning of studying and calculating what happens with a penguin on a sled. I think it would be neither common to see it in everyday life nor would it make sense to observe what happens with friction in the event that a sled contains a penguin. Also, it would be difficult to keep the penguin still while the sled moves to prevent it from leaving.

Scrambled Eggs in a Skillet

"The coefficient of static friction between the Teflon and scrambled eggs is about 0.04. What is the smallest angle from horizontal that will cause the eggs to slide across the bottom of a Teflon-coated skillet?" (Halliday, Resnick & Walker, 2008, Problem 15, p. 132)

Critical consideration (Question) Let's imagine this problem. It is, no doubt, extremely creative. Let's think that in the morning you want to have breakfast, you cook some eggs and you think at what angle would they slide to the bottom? It comes to my mind that only a physicist would think about that question.

Critical consideration (Question) I will only say: for what I would want to know how much to I have to incline the skillet? It is not that I am going to measure an inclination in the moment of cooking.

As a part of the follow-up phase, this problem was chosen for an optional home experiment. The task given to students was to check out if the angle given by the authors (2^0) corresponds, at least approximately, to the angle obtained in a real experiment. In other words, students were supposed to design and carry out a specific experiment to measure at which inclination angle of the skillet the scrambled eggs would start to slide down. Ten students accepted the challenge, although some of them didn't understand the task quite well (they derived the relationship between the coefficient of static friction and critical inclination angle).

One student, experimenting with an egg that wasn't fried, concluded that small angle given by authors was acceptable. Nevertheless, two students who fried eggs, find that critical angle is about 45^0, raising serious doubts about the authenticity of the given coefficient of static friction (Figure 4).

***Figure 4**. Scrambled Eggs Star to Slide Down When the Angle Is About 45^0^*

A Climbing Monkey

"A 10-kg monkey climbs a massless rope that runs over frictionless tree limb and back down to a 15-kg package on the ground (Fig. 5-54)."
(a) What is the magnitude of the least acceleration the monkey must have if it has to lift the package off the ground?
If, after the package has been lifted, the monkey stops its climb and holds onto the rope, what are the (b) the magnitude and (c) the direction of the monkey's acceleration and (d) the tension in the rope?" (Halliday, Resnick & Walker, 2008, Problem 57, p. 112)
Critical consideration (Question) In the first place, a monkey would not lift the box, he would break it if it contained food. Also, the monkey may not have the intelligence to do that. The main thing is: why would he do it? The monkey only looks for food and isn't interested in tension or acceleration.

A Dangerous Flight

"A pilot flies horizontally at 1300 km/h, at height h = 35 m above initially level ground. However, at time t = 0, the pilot begins to fly over ground sloping at angle $\theta = 4.3^0$ ... If the pilot does not change the airplane's heading, at what time t do the plane strike the ground?" (Halliday, Resnick & Walker, 2008, Problem 80, p. 35)
Critical consideration (Event) The inconvenient aspect of this problem is that the air traffic laws do not allow a plane to fly at such a low height. If it were in a city, it would have already collided. Although it is possible that it is possible, but it would involve a great risk for the pilots and the passengers.

Beside highly questionable situation, commented by a student, this problem shows how far from reality given numerical data in "physics problems" can be. Normal passenger jets need almost 30 minutes to reach their biggest cruising speed of 900 km/h at an altitude of about 10 kilometers (Torenbeek & Wittenber, 2009, p. ix). Only "physics textbook pilots" would fly at such an incredible speed of 1300 km/h, being only 35 meters above the ground.

A Very Dense Ball
"What is the terminal speed of a 6.00 kg spherical ball that has a radius of 3.00 cm and a drag coefficient of 1.60? The density of air through which the ball falls is 1.20 kg/m^3." (Halliday, Resnick & Walker, 2008, Problem 73, p. 137)
Critical consideration (Data) The weirdest thing is the dimension of the ball. It is too small to weigh so much, unless it is made of a very heavy or dense material.

This critical consideration is the most important particular result of this study. Here come my reasons. The volume of this spherical ball would be about 113 cm^3. Its density would be about 53 g/cm3. The densest material on Earth is the element osmium. Its density is 22.59 g/cm^3. So, supposed density of the spherical ball is more than twice bigger than the density of osmium.

For the first time, the problem was included in the seventh edition of the textbook (Halliday, Resnick & Walker, 2005, Problem 84, p, 138) and was kept with equal formulations in its ninth (Halliday, Resnick & Walker, 2011, Problem 77, p. 137) and tenth edition (Halliday, Resnick & Walker, 2014, Problem 77, p. 146), too. What does it mean?

It means that a Mexican physics freshman was able to detect an impossible density value, implicitly supposed in problem formulation. That detail was missed by many physics PhD holders who reviewed the textbook in its four editions or who used its three editions with their students!

If such a density error can stay unnoticed for so long time in the world's most popular physics textbook, then actual culture of physics teaching doesn't care too much about critical thinking.

Do Physics Problems with Questionable Authenticity Facilitate the Learning of Physics?

Students were also asked to consider if non-authentic problems facilitate physics learning. As whole analysis of students' is out of scope of the present article, here come only a few selected answers:

> *"I do not think they facilitate it. They mess it up, so to speak, since we are not referring to something that happens in our environment, in our real life. They maybe teach you to solve them with formulas, but I reaffirm that this would not be physics."*
>
> *"I do not think that focusing practically on violence and destruction facilitates the learning of physics and that focusing on that it takes away perspective and objectivity of true everyday use of physics. Although some problems pose situations that may come to happen, it is not what physics is all about. To be honest, these problems, at the time of reading them, puzzled me a lot because of the level of violence that most of them contain."*
>
> *"I think they don't, they are only pencil and paper activity. The true way of learning physics is to live the physics. For what will an exercise serve me if it is solved only by formulas that are already given to me. That is just repetition and learning does not work that way."*
>
> *"I doubt very much that with them we can learn physics, because physics is not being robots who are told a problem with given data and who apply formulas. Many of these formulas came out of experimentation. But there we have a contradiction, because during solving problems the experimental part never appears."*
>
> *"These types of problems don't help us reflect about what happen really in our environment. If we have to work only with real cases, what is the reason to know to solve fictitious problems."*

CONCLUSIONS

The results of this initial study show quite clearly that first-semester physics students are able to consider critically authenticity level of some textbook physics problems if they are given such a task without being "bothered" by the common task to solve them. Being so, one must ask a question: Why textbook reviewers (who know how to solve these problems) didn't apply similar critical considerations when they revised the textbook in question?

It is strange that today, when it is possible to find easily and gratis on Internet so many real physics data and quite numerous amazing real-world application of physics concepts, processes and laws, textbook authors still invent physics data and questionable contextualization to "help" students learn physics.

As a study dedicated to critical analysis of science textbooks already exists (Khine, 2013), it is a right moment to suggest a similar consideration of physics textbooks, at least, of the most popular that, in their original and translation editions, shape physics teaching and learning in whole world.

It is important to mention that wrong idea of "infinite number of flights", a bird allegedly can make between two trains in a crushing course, once eliminated from "Fundamentals of Physics", is still alive in many physics textbooks in India.

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REFERENCES

Adams, W. K., & Wieman, C. E. (2015). Analyzing the many skills involved in solving complex physics problems. *American Journal of Physics*, *83*(5), 459-467.

Davies, A., Fidler, D. & Gorbis, M. (2011). *Future Work Skills 2020*. Palo Alto, CA: Institute for the Future.

Evans, J. S. B. (2003). In two minds: dual-process accounts of reasoning. *Trends in cognitive sciences*, *7*(10), 454-459.

Fabby, C., & Koening, K. (2015). Examining the Relationship of Scientific Reasoning with Physics Problem Solving. *J. of STEM Education: Innovation and Research, 16*(4), 20-26.

Frederick, S. (2005). Cognitive reflection and decision making. *Journal of Economic Perspectives, 19*(4), 25–42.

Gok, T. (2015). An investigation of students' performance after peer instruction with stepwise problem solving strategies. *International Journal of Science & Mathematics Education, 13*(3), 561-582.

Halliday, D., & Resnick, R. (1970). *Fundamentals of Physics*. 1st Edition. New York: John Wiley & Sons.

Halliday, D., Resnick, R., & Walker, J. (2005). *Fundamentals of Physics*. 7th Edition. New York: John Wiley & Sons. Halliday, D., Resnick, R., & Walker, J. (2008). *Fundamentals of Physics*. 8th Edition. New York: John Wiley & Sons.

Halliday, D., Resnick, R., & Walker, J. (2009). *Fundamentos de Física*. Volumen 1, Octava edición. Ciudad de México: Grupo Editorial Patria.

Halliday, D., Resnick, R., & Walker, J. (2011). *Fundamentals of Physics*. 9th Edition. New York: John Wiley & Sons.

Halliday, D., Resnick, R., & Walker, J. (2014). *Fundamentals of Physics*. 10th Edition. New York: John Wiley & Sons.

Khine, M. (2013). *Critical analysis of science textbooks*. Dordrecht: Springer.

Hegarty, M., & Kozhevnikov, M. (1999). Types of visual–spatial representations and mathematical problem solving. *Journal of educational psychology*, *91*(4), 684-689.

McCormick, N. J., Clark, L. M., & Raines, J. M. (2015). Engaging students in critical thinking and problem solving: A brief review of the literature. *J. of Studies in Education*, *5*(4), 100-113.

Palm, T. (2006). Word problems as simulations of real-world situations: A proposed framework. *For the learning of mathematics*, *26*(1), 42-47.

Palm, T. (2008). Impact of Authenticity on Sense Making in Word Problem Solving. *Educational Studies in Mathematics, 67*(1), 37-58.

Palm, T. (2009). Theory of authentic task situations. In B. Greer, L. Verschaffel, W. Van Dooren, & S. Mukhopadhyay (editors.), *Word and worlds: Modelling verbal descriptions of situations*. Rotterdam: Sense Publishers.

Polya, G. (1973). *How to solve it. A new aspect of mathematical method*. Princeton and Oxford: Princeton University Press.

Reif, F., Larkin, J. H. & Brackett, G. C. (1976). Teaching general learning and problem-solving skills. *American Journal of Physics*, *44*(3), 212-217.

Rellensmann, J., Schukajlow, S., & Leopold, C. (2017). Make a drawing. Effects of strategic knowledge, drawing accuracy, and type of drawing on students' mathematical modelling performance. *Educational Studies in Mathematics*, *95*(1), 53-78.

Sliško, J. A. (2016). Improving teaching design of active physics learning by using potentially helpful knowledge from other science fields. *Inovacije u nastavi-časopis za savremenu nastavu*, *29*(2), 1-14.

Slisko, J. (2014). The Eiffel Tower as a Context for Word Problems in textbooks for School Mathematics and Physics: Why Authors Have a Licentia Poetica and What Are Possible Consequences for Students' learning and Beliefs? In *Conference on Mathematics Textbook Research and Development (ICMT-2014)* (p. 433).

Tobin, K. G., & Capie, W. (1981). The development and validation of a group test of logical thinking. *Educational and Psychological Measurement*, *41*(2), 413-423.

Teodorescu, R. E., Bennhold, C., Feldman, G., & Medsker, L. (2013). New approach to analyzing physics problems: A Taxonomy of Introductory Physics Problems. *Physical Review Special Topics-Physics Education Research*, *9*(1), 010103.

Torenbeek, E. & Wittenberg, H. (2009). Flight Physics: Essentials of Aeronautical Disciplines and Technology, with Historical Notes. New York: Springer.