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PROPOSING A METHOD TO CREATE METACOGNITIVE SCHOOL EXAMS

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Abstract:
Metacognition is defined as the capacity of the persons to monitor, to regulate and to construct knowledge about their inner processes. Theoretically, this construct is relevant to Education and correlated areas, since the process of learning and knowledge construction involves metacognition. Besides, there are evidences that certain metacognitive components are predictors of academic achievement of the students. Regarding these aspects, this paper proposes a methodology that permits educators to elaborate metacognitive school exams, which are capable of measuring both the students' knowledge of an educational domain (i.e., concepts pertaining to biology, chemistry, history, mathematics, physics, and so on), and the following metacognitive abilities: feeling-of-knowing, monitoring (detection of errors), self-management, and judgment. In this paper, we present the methodology stressing on the steps that enable the teacher to elaborate a school exam capable of measuring a target educational domain, as well as the stated metacognitive abilities. Concomitantly, we apply this methodology, showing the construction of the Metacognitive School Exam in Electrostatics.

Keywords: metacognition; educational assessment; methodology; school exams.

1. Introduction

Metacognition is defined as the capacity of the persons to monitor, to regulate and to construct knowledge about their inner processes (Flavell, 1979; Nelson & Narens, 1996; Sternberg, 2000). In a general sense, metacognition is the cognition about one's own cognition (Flavell, 1979).

Theoretically, this construct is relevant to Education and its related areas, since it has a preponderant participation in the process of learning and knowledge construction

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(Garrett, Alman, Gardner & Born, 2007). For example, certain abilities of metacognition are responsible for the capacity of the students to define *what* strategies should be applied when they are performing a specific academic task, and also, *when* to use these strategies. Not by chance, metacognition enables students to have control, to a certain degree, about their own resources (Brown, 1987; Busnello, Jou & Sperb, 2012; Flavell, 1979). Since metacognition regulates the inner processes related to learning and to academic achievement, the metacognitive abilities promote a better performance and are related to a better confidence of the students in their academic capability (Andretta et al., 2010; Dreher, 2012; Veenman & Verhei, 2003; Veenman, Wilhelm & Beishuizen, 2004).

There is evidence that certain metacognitive abilities are substantial predictors of students' academic achievement (Costa, 2013; Faria, 2015; Gomes, Golino & Menezes, 2014). Studies show that students who have higher levels of metacognition have a higher probability to retain and retrieve new information (Dunning, Johnson, Ehrlinger & Kruger, 2003; Thiede & Anderson, 2003). A relevant aspect of metacognition concerning education is that a great deal of metacognitive abilities can be trained. To a certain extent, the school promotes the development of metacognition, since the metacognitive abilities are critical components for the development of higher processes of abstraction, reasoning, problem-solving, and so on (Schraw, 1998; Schneider, 2010; Stewart, Cooper, Moulding, 2007).

Although there are many psychological instruments that measure metacognition, the vast majority of them are self-report questionnaires or metacognitive tasks that follow the guidelines of the think aloud protocol (Gonçalves & Martins, 2013; LaMarca, 2014). Besides, there are many standardized metacognitive tests for the abilities of feeling-of-knowing and judgment (in some cases named as monitoring), since these abilities encompass exclusively the opinion of the respondents about their performance, *a priori* or *a posteriori* (e. g. Metacognitive Monitoring Instrument" in Tanikawa & Boruchovitch, 2016). On the other hand, we noticed the existence of only one metacognitive test, the Reading Monitoring Test (Gomes, Golino & Menezes, 2014; Gomes & Golino, 2014), measuring the metacognitive ability of error detection through performance, which is neither a self-report questionnaire nor a metacognitive task guided by think aloud protocol nor a test based in the opinion of the respondents about their performance, like feeling-of-knowing and judgment. Examining the literature, we did not find a metacognition test assessing many metacognitive abilities. However, we advocate that it is possible to produce a school exam that measures a broad set of metacognitive abilities inserting in this exam specific adaptations.

Taking into account the stated arguments, this article proposes a methodology that enables the educators to create metacognitive school exams capable of measuring both the students' knowledge of an educational domain (i.e., concepts related to biology, chemistry, history, mathematics, physics, and so on), and the following metacognitive abilities: feeling-of-knowing, monitoring (detection of errors), self-management, and judgment. So, in this paper, we present this methodology, stressing on the steps that permit the educator to elaborate a metacognitive school exam. We apply this methodology, showing the construction of a Metacognitive School Exam in Electrostatics.

2. Presenting the Methodology to Create Metacognitive School Exams

2.1 Defining the Target Metacognitive Abilities

Although there are many models describing metacognition, there is certain consensus that this construct is formed by two broad domains: knowledge of cognition and regulation of cognition (Schraw, 1997). Table 1 shows these two broad domains, and it presents some examples of abilities into these broad domains.

Table 1: The Metacognitive Broad Domains and Examples of Metacognitive Abilities into the Metacognitive Broad Domains

Domain	Abilities	Description
Knowledge of cognition (metacognitive knowledge)	Declarative Knowledge	Knowledge about himself/herself and about the variables that affect his/ her achievement.
	Procedural Knowledge	Knowledge about his/her own strategies and procedural abilities.
	Conditional Knowledge	Knowledge about when and why to use certain actions and strategies.
Regulation of cognition (metacognitive regulation)	Planning	Regarding the anticipation and the organization of the actions before they occur.
	Monitoring	Concerning the detection of errors at the moment of the task execution.
	Judgment	Judging of the task after it is completed.

The knowledge of cognition, also called metacognitive knowledge, involves the knowledge that individuals possess about their inner processes. This knowledge is stored in long-term memory and can be retrieved when someone performs a task. (Flavell 1976; Lai, 2011). People who think that they are good at mathematics, for example, think it because they have knowledge about their capability to perform tasks on mathematics. This declarative knowledge (see Table 1) is stored in the long-term memory making it available to the individual, permitting one to see oneself as good at mathematics.

Otherwise, the regulation of cognition, or metacognitive regulation, concerns the "online" processes that manage and regulate the own inner processes at the moment that someone executes a task (Flavell, 1979; Lai, 2011; Schraw, Crippen & Hartley 2006; Veenman, 2011). One example of ability pertained to the regulation of cognition is the capacity of the persons to detect an error in their performance when they are trying to perform a task (monitoring ability; see Table 1)

Concerning our methodology, it involves specifically the measurement of four metacognitive abilities into the broad domain of the regulation of cognition: feeling-of-knowing, self-management, monitoring, and judgment. Since these metacognitive abilities are main components of the proposed methodology, we will present its definitions, as well as, briefly, the literature on metacognition that sustains these constructs.

The feeling-of-knowing was one of the first metacognitive judgments systematically studied, being already investigated experimentally in the 1960s by Joseph Hart (Metcalfe & Dunlosky, 2008; Nelson & Narens, 1980). This ability, coined too, as a prospective judgment, is defined as a feeling, a first glance at a particular task, that generates a fast first impression that permits persons to make a quick judgment, before performing the task, if they are capable to perform the task (Hart, 1965, 1967; Hertzog, Dunlosky & Sinclair, 2010; Busnello, Jou & Sperb, 2012; Nelson & Narens, 1980). Studies have investigated the underlying mechanisms capable of explaining the predictive reliability of the prospective judgment produced by the feeling-of-knowing (Metcalfe, 1986). Some related mechanisms are the previous knowledge about the task, as well as the difficulty of the task itself (Metcalfe, Schwartz & Joaquim, 1993; Thomas, Bulevich & Dubois, 2012).

Self-management is the ability to control the motivation and to maintain the focus on the task (Paris & Winograd, 1990; Wixson, 1983). This ability regulates the motivation and the attention to perform the task, managing the task engagement (Roebers, Krebs & Roderer, 2014). Moreover, self-management protects the individual against internal and external noise stimuli that could disturb the task resolution (Lawanto, 2010).

In its turn, monitoring is the ability to detect errors at the moment of the task resolution (Busnello, Jou & Sperb, 2012; Yeung & Summerfield, 2012). According to Yeung and Summerfield (2012), this ability is crucial for the development of the adaptive behavior.

Finally, judgment is the ability to evaluate the task performance after its completion. It involves an estimate about how much the task was correctly performed (Schraw, 2008). Furthermore, this is named as retrospective judgment (Efklides, 2006; Nelson & Narens, 1994; Fleming, Massoni, Gajdos & Vergnaud, 2016).

2.2 Defining the Fundamental Properties of the Methodology

Having exposed these four metacognitive abilities, we will now present the methodology proposal that allows teachers to elaborate metacognitive school exams. Our methodology defines three properties that a school exam must have to be a metacognitive school exam. The first property defines some fundamental characteristics that a school exam must possess to measure the target educational domains. These characteristics are crucial to the validity and reliability of any school exam. Further explanation about the reasons regarding these properties can be found in Pires and Gomes (2017). On the other hand, the second and the third properties show strategies to integrate the metacognitive abilities into the school exam.

2.3 Property 1: Minimal Conditions for the School Exam Validity

According to the latent variable theory (Borsboom, 2008; Loehlin, 2004), all the educational domain (such as electricity, magnetism or mechanics, concepts pertaining to the physics area) are theoretical constructs (latent variables), that is, they cannot be directly observable by perception. Since they cannot be directly observable, they need to be linked to a set of observable variables to be estimated. The observable variables, in the case of tests or school exams are the items or questions, and the target educational domains intended to be measured by this exam are the latent variables. (Yong & Pearce, 2013).

To estimate each latent variable, they should be connected by a set of questions, since the estimation method of the latent variables demands it. This estimation is currently performed by quantitative methods such as item factor analysis (Baghaei & Yazdi, 2016; Fox, Marsman, Mulder & Verhagen, 2016; Gomes, Almeida & Núñez, 2017). The process of estimating the latent variables and connecting them to observable variables is just the process of inspecting the validity of the school exam. The validity, in general terms, is the capacity of the test (or school exam, as in the case of our article) to measure the latent variable which is intended to be measured (Heale & Twycross, 2015; Hood, 2009). The reader can learn about the process of validation, through many didactical books, for example Urbina (2014).

Taking into account these stated conditions, property 1 of this methodology assumes that it is mandatory that any school exam defines its target constructs (latent variables), as well as determines what set of questions (observable variables) are theoretically related to each target construct. The first step involves the precise definition of the target construct and how to properly measure it. Since the target educational domain is structured by a set of contents that expresses its properties, its measurement demands items capable of covering these contents. For example, if electrostatics is the target construct to be measured by the school exam and this construct has the contents of electric charge, electric field, and electric potential, then it is mandatory that the school exam has items capable of covering all of these contents. The second step involves defining previously the maximum number of questions that the exam could contain. Most of the times, this number is dependent on two variables: (i) the duration of the examination and (ii) the presumed average time interval necessary to the resolution of one typical question of the content. There is a lot of suggested time/question relation and it is required that the teacher who is elaborating the exam chooses the most appropriate proportion to use, because it may be different from one exam to another. In a school exam, the more questions related to a specific construct, the better its estimation, concerning validity and reliability of the exam (Byrne, 1999; Yong & Pearce, 2013).

Later, as it will be shown, that set of the elaborated questions will be divided into two groups, one to assess the educational domain, and another aiming at the measurement of monitoring. So, we suggest a minimum of six questions for each educational domain, since half of them will be used, in fact, for the measurement of the educational domain, and the other half part will be used for the measurement of monitoring metacognitive ability.

It is important to emphasize that, if the proposed measurement model for an exam aims to assess only one construct, it is possible, in case of existence of complementary concepts to this construct, that they could be measured too, by this exam. This measurement is a consequence of the fact that a good exam is elaborated with a reasonably large number of questions related to the target construct and its complementary concepts. The item factor analysis is the statistical technique that allows validity investigations in order to confirm if the exam is able to measure the focused content, as well as whether the exam measures some of the complementary contents. Besides, this technique is used to verify whether the exam is capable of measuring the intended metacognitive abilities. If the reader expects his/her metacognitive exam to present characteristics of validity, then he/she should learn how to use the technique of item factor analysis, aiming to assess empirically if the items elaborated converge toward the measurement of the target school dimensions.

Following correctly property 1 of this methodology, the school exam will present a well-defined linkage between the questions of the exam and the educational domains that it intends to measure. This condition permits the school exam to be evaluated, in terms of its validity and reliability. It is not the purpose of this methodology to teach the use of the item factor analysis, however, the reader can search for details of this technique and how it supports the investigation of validity, through the works of Beaujean (2013), Hirschfeld and von Brachel (2014), Yong and Pearce (2013), Wirth and Edwards (2007) among others. Even if the teacher does not know how to perform an item factor analysis, property 1 of this methodology permits this analysis to be carried out afterwards, since it demands the definition of a set of specific questions for each content of the exam. In other words, our methodology prepares the way for a school exam to go through the process of validity.

2.4 Property 2: Embedding the Metacognitive Abilities into the School Exam through Testlets

Our methodology proposes to integrate into a school exam the evaluation of both school domains and metacognitive abilities. This integration can be performed through the construction of questions that have a testlet structure, since a testlet, basically, is a condition where in the same question there are different items that allow the measurement of different constructs. In this way, property 2 proposes that the questions of the metacognitive school exam are testlets because they aim exactly to measure the intended school domains, as well as the four metacognitive abilities. For a better understanding of a testlet and its structure, see Frey, Seitz and Brandt (2016), Lee, Brennan and Frisbie (2001) and Wainer and Kiely (1987).

So, we propose, through property 2, a structure for the school exam, where each question must have 4 items: item 1 for the measurement of feeling-of-knowing, item 2 for the measurement of the target school domain or the metacognitive ability of monitoring, item 3 for the measurement of judgment, and item 4 for the measurement of self-management.

Property 2 also defines that each question has 10 blocks or pieces of information. Eight of the 10 blocks are commands that allow the measurement of the intended constructs (see Figure 1). The blocks, except 2 and 10, contain commands to assess the student's metacognitive abilities and the educational domains. Block 2 shows the statement, or stem, of the question, in terms of the basic information for the problem-solving. Block 10 is only an order for the student not to go to the next question without finishing the previous one. Next, we will describe the blocks in function of their contribution to each item of the question. The commands within blocks 1 and 3 compose the item 1 for the measurement of feeling-of-knowing. The commands in blocks 4, 5, 6 and 7 compose item 2, which are for the measurement of the educational domain or, in certain cases that will be explained later, monitoring. The command in block 8 composes item 3 for the measurement of judgment, and the command in block 9 composes item 4, intended to measure self-management. The contents of blocks 2 and 5 will vary from one question to another because they depend on the content of the proposed problem in the question, while the contents of the other blocks will be the same in all questions.

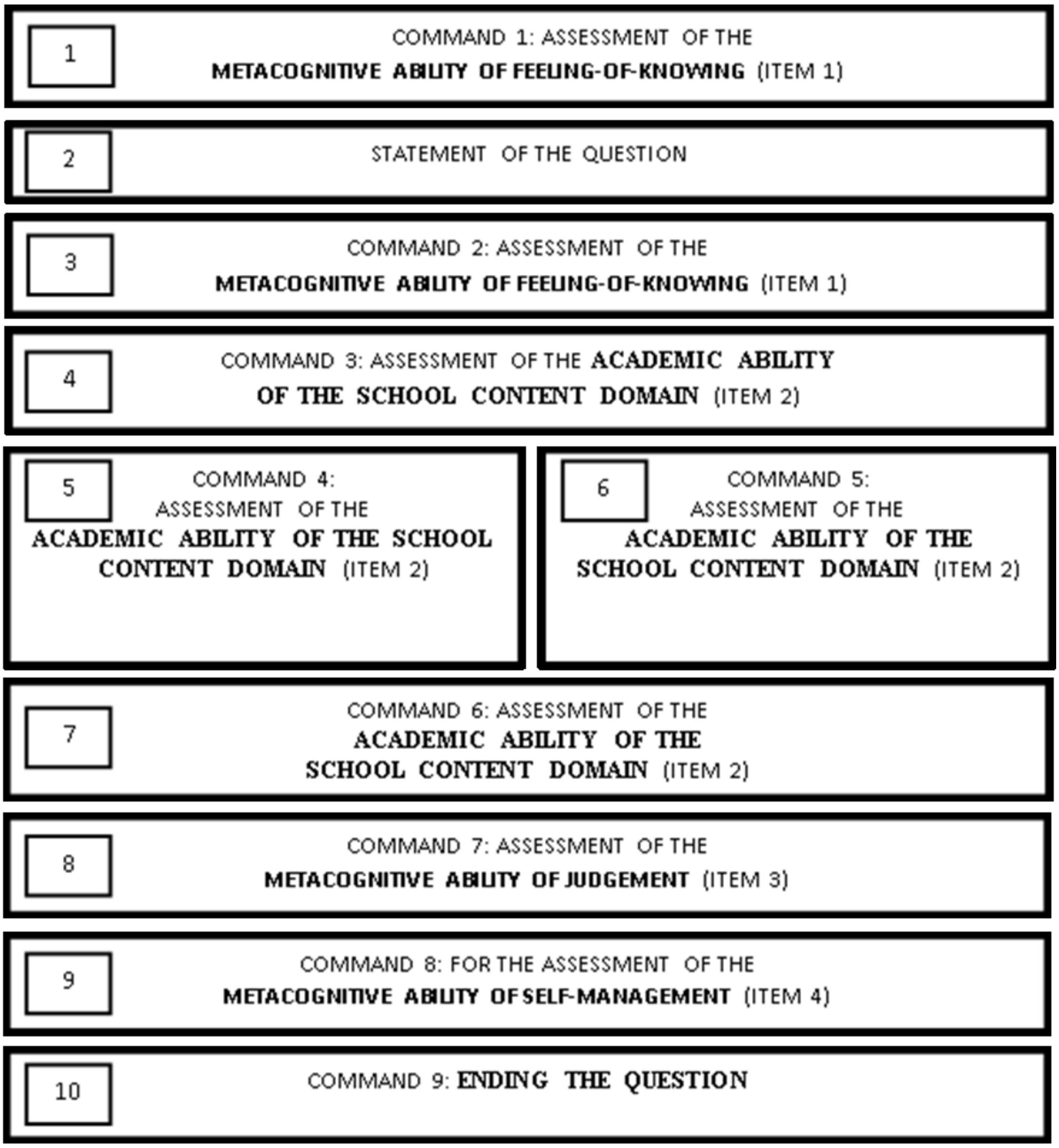
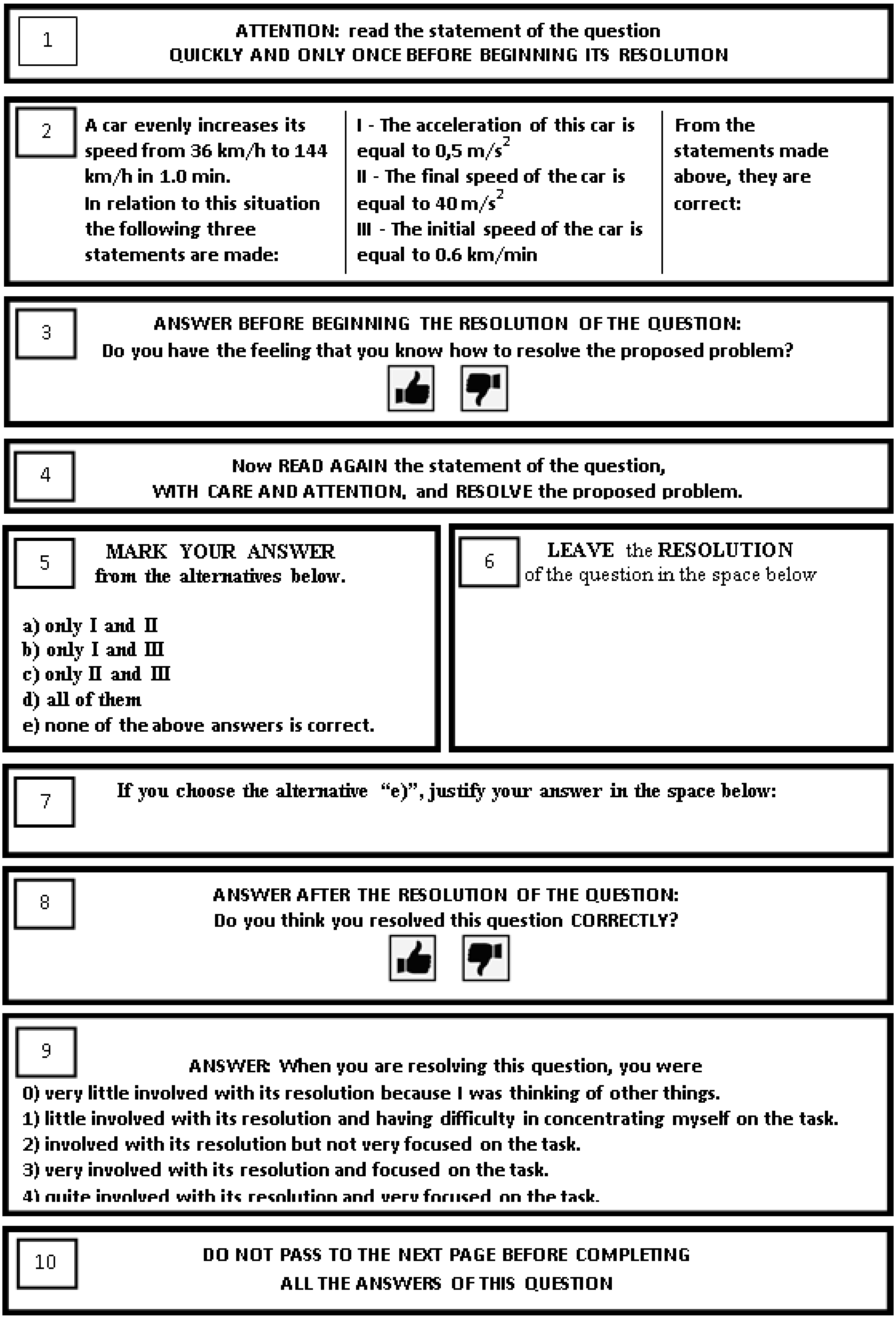


Figure 1: Set of commands of a question of a metacognitive school exam

2.5 Property 3: Defining the Commands of the Items and the Errors for the Measurement of Monitoring



1 — ATTENTION: read the statement of the question
QUICKLY AND ONLY ONCE BEFORE BEGINNING ITS RESOLUTION

2 — A car evenly increases its speed from 36 km/h to 144 km/h in 1.0 min.
In relation to this situation the following three statements are made:

I - The acceleration of this car is equal to 0,5 m/s^2
II - The final speed of the car is equal to 40 m/s^2
III - The initial speed of the car is equal to 0.6 km/min

From the statements made above, they are correct:

3 — ANSWER BEFORE BEGINNING THE RESOLUTION OF THE QUESTION:
Do you have the feeling that you know how to resolve the proposed problem?

4 — Now READ AGAIN the statement of the question,
WITH CARE AND ATTENTION, and RESOLVE the proposed problem.

5 — MARK YOUR ANSWER
from the alternatives below.

a) only I and II
b) only I and III
c) only II and III
d) all of them
e) none of the above answers is correct.

6 — LEAVE the RESOLUTION
of the question in the space below

7 — If you choose the alternative "e)", justify your answer in the space below:

8 — ANSWER AFTER THE RESOLUTION OF THE QUESTION:
Do you think you resolved this question CORRECTLY?

9 — ANSWER: When you are resolving this question, you were
0) very little involved with its resolution because I was thinking of other things.
1) little involved with its resolution and having difficulty in concentrating myself on the task.
2) involved with its resolution but not very focused on the task.
3) very involved with its resolution and focused on the task.
4) quite involved with its resolution and very focused on the task.

10 — DO NOT PASS TO THE NEXT PAGE BEFORE COMPLETING
ALL THE ANSWERS OF THIS QUESTION

Figure 2: Example of a question of a metacognitive school exam

While property 2 defines that the questions of a metacognitive school exam should have a structure of a test let composed of a set of commands aiming at the assessment of educational domains and metacognitive abilities simultaneously, property 3 establishes what the content of each of these commands should be. In order to show the content of each of the commands and explain their functions within the structure of the question, we present in Figure 2 an example of a typical question of a metacognitive school exam. This question involves a kinematic content, part of the domain of physics, called mechanics.

In block 2 of the Figure 2, we have a stem of the question with three sets of basic information necessary for the problem-solving. The first part shows that the speed of a car has grown in a certain interval of time, the second part is made up of three statements related to the values of the speed of the car, while the third part is the problem proposed.

To allow the measurement of the students' ability of the feeling-of-knowing, the first item of the question, we have a set of two commands, one in block 1, another in block 3. The command of block 1, "ATTENTION: read the statement of the question QUICKLY AND ONLY ONCE BEFORE BEGINNING ITS RESOLUTION", is necessary because of the nature of the feeling-of-knowing: the student must read the statement only superficially insofar this ability is a first and quick impression that allows individuals to make a fast judgment about their ability to perform a task. After this, according to the command in block 3, "ANSWER BEFORE BEGINNING THE RESOLUTION OF THE QUESTION: Do you have the feeling that you know how to resolve the proposed problem?", the student should indicate whether his/her feeling is that he/she knows how to resolve the proposed problem or not. If his/her feeling is that he/she thinks he/she knows how to resolve the proposed problem, then the student should mark the hand with the thumb up. Otherwise, if his/her feeling is that he/she thinks he/she does not know how to resolve the proposed problem, then the student should mark the hand figure with the thumb down. For each item of feeling-of-knowing, the score is 0, if the student marks, in the third block, the figure of the hand with the thumb down, or 1, if the student marks the figure of the hand with the thumb up.

We have a set of commands located in blocks 4, 5, 6 and 7 for the measurement of the educational domains or monitoring. In the example of Figure 2 these blocks regard the measurement of an educational domain, not the monitoring. Afterward, we will show how blocks 4, 5, 6 and 7 measure monitoring. The content of block 4, the first command, "Now READ AGAIN the statement of the question, WITH CARE AND ATTENTION, and RESOLVE the proposed problem", has exactly the objective of stressing the rhythm of reading of the student, warning that he/she must read again the statement of the question, now carefully. Now the student is expected to read the statement carefully, differently from the previous case, because his/her next action of is the resolution of the proposed problem, in order to assess the educational domain. After this has been done, the student should mark, among the alternatives presented in block 5, his/her response to the proposed problem. Completing the assessment of the educational domain, there is also a command in block 6, asking the student to leave there his/her resolution of the question. It may happen that the student may not find his/her answer to the proposed problem among the first four alternatives available in block 5. In that case, the student should mark the alternative "e) none of the above questions is correct." If this happens, according to the command in block 7 "If you choose the alternative "e)", justify your answer in the space below", the student must justify his/her response, in order to allow its analysis, comparing his/her mark with their resolution. In the case of this item regarding the measurement of the target educational domain, the score is 0, if the student marks the wrong response to the proposed problem, or 1, if the student marks the right answer to it.

In order to allow the assessment of the metacognitive ability of judgement, we have the command in block 8, "ANSWER AFTER THE RESOLUTION OF THE QUESTION: Do you think you resolved this question CORRECTLY?". If the student judges he/she answered correctly the proposed problem, the student has to mark the figure of the hand with thumb up. If he/she thinks that he/she answered incorrectly the problem, the student has to mark the figure with thumb down. In this case, the score is 0, if the student marks in the eighth block, the figure of the hand with the thumb down, or 1, if the student marks the figure of the hand with the thumb up.

To permit the assessment of the metacognitive ability of self-management, the last item, we have the command in block 9. This command is composed of five alternatives indicating, in ascending order, states of engagement-involvement with the resolution of the proposed problem. So, for this item, the score varies from the value 0, in which the student considers that he/she was very little engaged in the process of resolving the proposed problem, to the value 4, where the student affirms that he/she thinks he/she was very involved with the resolution of the proposed problem.

In its turn, the metacognitive ability of monitoring is assessed through the students' capability of error detection (see Gomes, Golino & Menezes, 2014). The way to do that is to introduce, intentionally, an error in the stem or in the set of alternatives of answer to the question. Thus, some questions are intentionally modified by introducing an error in them. The introduction of this error, as a consequence, breaks the structure of those questions and, therefore, they no longer have correct answer, but alternative "e". It is important to note, in this way, that the simultaneous measurement of the monitoring and the educational domain in the same question is not possible.

As stated, the measurement of monitoring involves blocks 4, 5, 6, and 7. The questions that are intended to measure educational domains will always have a correct answer among the first four response alternatives ("a", "b", "c" and "d"), while the correct answer to the monitoring questions always involves selecting the "e) none of the above answers is correct" option in block 5 in addition to the necessary justification of this choice that should be made in block 7 (see Figure 2). In this sense, it is mandatory that all questions of the metacognitive school exam have the option "e".

As stated, the questions to assess the monitoring ability involve the presence of an error intentionally introduced in their stems or in the set of their answer alternatives. Property 3 defines that these errors must belong to one of the following three categories:

(i) absence of correct answer, (ii) conceptual error and (iii) data gap, as shown in Table 2.

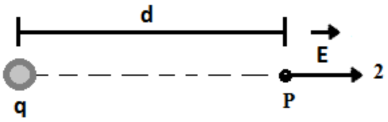
In the example number 1 of Table 2, the introduced error in the question belongs to the first category, the absence of correct answer. There is not any kind of error in the statement of this question that can prevent its resolution and, doing appropriate calculations, the student finds the value of 0.2m as its correct answer. However, the set of alternatives of answers does not bring this value, because the alternative with the right answer was simply replaced by a wrong one.

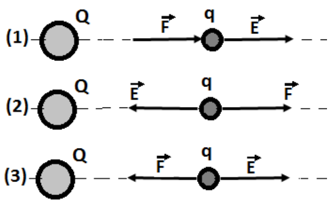
The second example in Table 2 shows a question in which the introduced error belongs to the second category, the conceptual error. This error, introduced in the statement of the question, consists of the assertions that the electric field vector generated by an electric charge points outside of it, if the charge is negative, and to its inside, if it is positive. Those assertions are incorrect, since the electric field theories state that the electric field vector points to the inside of a negative charge and points to the outside of a positive charge. A non-proficient student may think that there is a correct answer to this question, that is, the letter “c” alternative, since this option is the logical conclusion from the incorrect assertions of the question. However, this is an incorrect answer according to the theories of the electric field. It is important to emphasize that, especially in the case of those questions in which the category of conceptual error was introduced, it is necessary the elimination of the original correct answer from the set of alternatives in order to avoid that the student, not realizing the presence of this error, marks this alternative, precisely because it is correct according to the theory. All the questions featuring the second category of error must be constructed through this approach.

The third example of Table 2 shows a situation involving the third category of errors, the data gap. There are two conducting spheres A and B and the information given about sphere A - its radius, the electric potential on its surface, and the number of electrons lost by it to reach that electric potential - are useful only for the student to verify that these values are respectively correct. Concerning sphere B, the value of its radius has not been given, without which the number of electrons that it must lose to reach half of the electric potential of sphere A cannot be calculated. If the student uses the data of the sphere A as a reference for the sphere B, he/she can conclude that the sphere B must lose half the number of electrons that the A sphere has lost, since it must reach half the electric potential value of the sphere A, corresponding to the alternative "d". However, it has not been stated that there is any relationship between the two spheres, so it is not correct to use this relationship.

In the monitoring questions, if the student detects the existence of the errors, he/she must mark the alternative "e", and, as a complement, he/she should use block 7 to justify his/her marking, showing what the correct answer would be in the questions with error of the first category, or the incoherence of the proposed problem, in case of the questions with the second or third category of errors. The student's justification for his/her answers is the way to check if he/she actually detected the presence of the error in the question, because simply ticking the "e" option does not guarantee this. Once again, it is important to note that the assessment of the ability of monitoring is made by detecting the presence of the error introduced in the question, as shown.

Table 2: Definition and examples of each of the three types of errors of the monitoring questions

<table>
<tr><th colspan="3">Examples of errors introduced in monitoring questions</th></tr>
<tr><td colspan="3">1. Absence of correct answer: The alternative with the correct answer has been deleted and replaced by an incorrect alternative.</td></tr>
<tr><td>Through electrification process by contact, a small conducting sphere is electrified with an electric charge Q = 4 pC. The electric field created by it at a point P located at a distance d of the center of the sphere has an intensity equal to $9x10^{-1}$ N / C.
($k_0 = 9 \times 10^9 Nm^2/C^2$)</td><td>

Calculate the value of that distance d between the center of the electrified sphere and the point P.</td><td>a) 0,06 m
b) 0,02 m
c) 0,6 m
d) 0,4 m
e) none of the above answers is correct.</td></tr>
<tr><td colspan="3">2. Conceptual error: Introduction of a conceptual error in the statement of the question which provides an INCORRECT solution of the proposed problem, according to the theory involved in it. This result is not among the answer alternatives of the question.</td></tr>
<tr><td>The electric field generated by positive electric charges is represented at points close to them by vectors pointing to them, whereas the electric field generated by negative electric charges is represented at points close to them by vectors pointing outside them. It is also known that the electric field vector E generated by an electric charge Q always has the same direction as the electric force vector F that it applies on a charge q. If the charge q is positive, these two vectors point to the same side and, if this charge q is negative, these two vectors point to opposite sides.</td><td>Consider the three situations below where Q is a charge generating the electric field E and q is the charge that receives the action of the electric force F applied by E:

</td><td>The following statements are made regarding the situation

I. In situation 1: Q> 0 and q> 0
II. In situation 2: Q <0 and q> 0
III. In situation 3: Q <0 and q <0
IV. In all the situations: q> 0

Based on theories of physics:

a) all statements are true.
b) only statement II is true.
c) only statement III is true.
d) only statements I and IV are true.
e) none of the above answers is correct.</td></tr>
<tr><td colspan="3">3. Error data gap: In the statement of the issue are present situations that are not related to each other and / or do not have enough data to solve the problem proposed.</td></tr>
<tr><td colspan="2">In order to electrify with positive electric charge an aluminum sphere A, radius 0,20m, in the air, until it reaches on its surface an electric potential of 120V is necessary that it lose a number N of electrons equal at $1.7x10^{10}$. In order to electrify a second conducting sphere, B, also of aluminum until it reaches only half the electric potential on the surface of the sphere A, does it need that it lose how many electrons?</td><td>a) $1,7 x10^{10}$ electrons
b) $8,5x10^{10}$ electrons
c) $1,7x10^9$ electrons
d) $8,5x10^9$ electrons
e) none of the above answers is correct.</td></tr>
</table>

In order to avoid students identifying which of the two types of question they are doing, whether it is the question to assess the educational domain, or the question to assess the monitoring, all the questions have the same alternative "e". It is important to stress again, that these items, which possess the errors shown above, do not participate in the score of the educational domain, since they are markers of monitoring.

It is necessary to draw the attention to a very important aspect. Students are used to resolving only traditional questions in which the purpose is to assess an educational domain. So, it is imperative for students to be given an example of how to resolve a typical question of a metacognitive school exam, whose format, a testlet, they do not know yet. Another characteristic that is new, too, to the students is a question whose goal is to assess the metacognitive ability of monitoring. For this reason, it is mandatory the presence of a front page in the metacognitive school exam. This front page, as shown in Figure 3, alerts the students of how to perform the exam, as well as, stresses the existence of questions with intended errors. Attention: The teacher, before the students begin the exam, should read aloud the contents of the first page, verifying if they understood the example exposed in it.

As we stated, the front page presents, basically, the instruction of how to perform the exam. Figure 3 shows this instruction in the context of an exam of physics. As aforementioned, this instruction needs to be shown by the teacher to the students before they start to perform the exam. The first rectangle of the Figure 3 provides information about the exam and the student (discipline, content, class, teacher, student and score). In the second rectangle there is a set of information, in which one of them intends to alert the students about the existence of questions which may contain one among three types of errors (absence of correct answer, conceptual error and data gap) and a brief description of each one. After this, the instruction presents a resolved question and some comments on each of its commands, aiming to show the students how to correctly respond to every command of the exam, as well as how to understand what the logic of the questions with errors is and how to respond them. The statement brings a question about kinematics which, according to theories of physics, has no correct answer among the set of alternatives. It then shows that the student should, in the case of this type of question without correct answer, mark the alternative "e)" and justify this answer, as in the justification shown below the answer alternatives. Finally, this instruction shows to the student how he/she should respond to the judgement and the self-management items.

3. Application of the Methodology

We presented, in the previous sections, the three fundamental properties of the methodology. Now we are going to apply the proposed methodology in an elaboration of a metacognitive school exam, as an example to show how this methodology can be used.

According to the first property, Minimum Conditions for School Exams Validity, when a school exam is to be prepared, the teachers' first step should be to think deeply about the educational domain that they want to evaluate and then define very well and objectively the target constructs and what contents compose these constructs. Then, only after this definition, they will be able to select or elaborate a set of questions that will evaluate these constructs.

METACOGNITIVE SCHOOL EXAM OFPHYSICS - CONTENT: ELECTROSTATICS	
CLASS:	TEACHER:
STUDENT:	SOCORE:

ATENTION
→ This exam is composed of 18 questions of multiple choice, each one composed for 4 (four) items.
→ All the questions are composed by one or more commands that are intended to show how you should proceed for their resolution.
→ In some questions were intentionally introduced one of the three following types of errors: "absence of correct answer" (the correct answer is not included in the alternatives set), "conceptual error (use of conceptually incorrect assumptions in the statement)," or "data gap" (giving insufficient information), so they do not have correct answer. In that case, the option to be marked must be "e) none of the above answers is correct."
→ There is no identification that differentiate for you the questions with or without errors.

SEE CAREFULY THE FOLLOWING EXAMPLE (THE COMMENTS ONLY APPEAR IN THIS EXAMPLE, NOT IN THE QUESTIONS):

ATTENTION: read the statement of the question QUICKLY AND ONLY ONCE BEFORE BEGINNING ITS RESOLUTION

⇒ ***As the command above, you should ONLY make a QUICK reading of the following question statement. Do not read it more than one time.***

A car which moves in a uniform linear motion, evenly increases its speed from 36 km/h to 144 km/h in 1.0 min. In relation to this situation, three statements are made:	**I - The acceleration of this car is equal to 0,5 m/s^2 II - The final speed of the car is equal to 40 m/s^2 III - The initial speed of the car is equal to 0.6 km/min**	**From the statements made above, they are correct:**

ANSWER BEFORE BEGINNING THE RESOLUTION OF THE QUESTION: Do you have the feeling that you know how to solve the proposed problem?

⇒ ***According to the above command, after reading the statement of the question, in case you judge you can resolve the proposed problem, you should make an "X" in the figure with the thumb up, or, if you judge you do not know how to resolve it, you should make an "X" in the figure with the thumb down. Do not mark both of them.***

Now READ AGAIN the statement of the question, WITH CARE AND ATTENTION, and RESOLVE the proposed problem.

According to the above command, you should read the question again, with care and attention, and resolve it as organized as possible in the space bellow.

MARK YOUR ANSWER from the alternatives below.
a) only I and II
b) only I and III
c) only II and III
d) all of them
X none of the above answers is correct.

LEAVE the RESOLUTION of the question in the space below
V_1 = (36 km/h)/3,6 = 10m/s
V_2 = (144km/h)/3,6 = 40m/s
Δt = 1,0min = 60s
a = Δv/Δt = (40 - 10)/60 = 0,5m/s²
V_1 = (36 km/h)/60min
V_1 = 0,6 km/min

If you choose the alternative "e)", justify your answer in the space below:
If I consider only the numerical data of the proposed problem, only the affirmations I and III are correct, according to the calculations above. However, if the car moves in uniform linear motion, as affirmed, its speed cannot vary. So, all the statements are incorrect.

ANSWER AFTER THE RESOLUTION OF THE QUESTION: Do you think you resolved this question CORRECTLY?

⇒ ***If you judge you have the right answer, according to the above command, you should make an "X" in the figure with the thumb up, and if you judge you did not get it right, you should make an "X" in the figure with the thumb down.***

ANSWER: When you are solving this question, you were
0) very little involved with its resolution because I was thinking of other things.
1) little involved with its resolution and having difficulty in concentrating myself on the task.
2) involved with its resolution but not very focused on the task.
3) very involved with its resolution and focused on the task.
X quite involved with its resolution and very focused on the task.

⇒ ***According to the above command, you should choose ONLY ONE of the options above to indicate how much you judge you were involved with the resolution of the question.***

DO NOT PASS TO THE NEXT PAGE BEFORE COMPLETING ALL THE ANSWERS OF THIS QUESTION

⇒ ***According to the above command, you should not move to the next one before resolving the proposed problem of this question.***

Figure 3: Front page of a metacognitive school exam of physics

In our example, the school content of the exam is a physics domain called electrostatics, a set of concepts related to physical phenomena involving electric charges at rest. It is commonly addressed in the third year of high school in most Brazilian schools. Luz and Álvares (2011), authors of one of the most widely adopted textbooks of physics in Brazilian schools, developed this content in three different chapters in the third volume of their work, Physics Course: Electric Charge (chapter 1), Electric Field (Chapter 2) and Electric Potential (Chapter 3). Although this domain is taught in three parts in physics classes, this is only a strategy of didactic organization. In this context, electric charge, electric field and electric potential are the contents that compose electrostatics. Thus, the elaboration of a school exam with the objective of measuring the concept of electrostatics involves the elaboration of an exam with questions encompassing the electrostatics contents, that is, electric charge, electric field and electric potential. It is important to stress that even using questions from these three contents, we do not intend to measure them. They are used because a good measurement of electrostatics requires to cover these contents.

Still according to the first property, the next step corresponds to the selection or elaboration of a set of questions to assess the target content. However, it is necessary to define beforehand the maximum number of questions the exam may have. This number is a function of two variables, the length of time of the examination and a presumed average time interval for the resolution of one question. Assuming that the time available for students to resolve the exam is 60 minutes and supposing too, that due to the complexity of the content each question could be resolved in about 3 minutes, the exam will be able to have a maximum of 20 questions. Discounting about 5 minutes of loss related to the process of handing out the exam papers to the students and also for them to fill out the answer sheet and return their copies of the exam, we have 55 minutes for the students to actually use in resolving the questions. For this time interval, the exam can have a maximum of 18 questions.

Suppose, then, that six questions related to the specific content of the electric charge, six related to the electric field and six questions related to electric potential must be elaborated aiming to assess the construct of electrostatics - in this context, it may be either the creation of inedited questions, or it may be the selection or adaptation of some that already exist in banks of questions available in books or on the internet. In fact, this distribution does not have to be equanimous in this way, since any question of these contents was aimed at measuring the same electrostatics construct in our model.

So far, the application of the methodology has dealt specifically with the part concerning the evaluation of the target educational domain. From this point on, we will approach the aspects that involve the integration of the educational domain to the evaluation of the metacognitive abilities. As we stated, the second property, "Embedding the Metacognitive Abilities into the School Exam through Testlets", determines how this integration is made. This integration is achieved by elaborating questions using the testlet structure, that is, questions composed by a set of commands that enable the desired integrated assessment of these abilities simultaneously. On the other hand, the third property, "Defining the Commands of the Items and the Errors for the Measurement of Monitoring", determines what the content of each command should be.

In the case of our application, as stated, we intend to construct a metacognitive school exam of electrostatics. As it is reported, it is impossible to measure, in the same question, the target educational domain and the monitoring ability. So, if we decide that our metacognitive school exam of electrostatics has 18 questions, then the next step involves deciding how many questions will measure the educational domain and how many questions will measure the monitoring. As we intend to have a robust set of items for each ability of the exam, we chose nine questions for each of them. In order to do so, we organized randomly into two groups of nine questions, three electric charge questions, three electric field questions and three questions of electric potential. In the group of the nine monitoring questions, one of the questions of electric charge receives the introduction of the error of absence of correct answer, in another one it is introduced the conceptual error and, in the last one, it is introduced the error of data gap. The same type of errors and their frequencies are present in the three questions of the electric field and in the three questions of electric potential.

Aforementioned, Table 2 shows modifications we made in the 3 questions chosen to assess the monitoring. Observe that the examples of Table 2 regard the measurement of electrostatics. Nonetheless, the reader is expected to understand that a similar procedure was used in the other 6 questions related to the assessment of the monitoring.

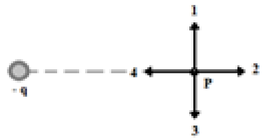
In the next step, the 18 exam questions were transformed into the testlet structures outlined by property 2, as well as the commands necessary for the evaluation of the metacognitive abilities, as defined by property 3, were inserted in them. In order to help the reader to understand in depth this process of integrating target school content with metacognitive abilities, we will present an example question in Figure 4, describing in detail the procedure.

As already said, Figure 4 shows an example of one question that measures the target educational domain, electrostatics, elaborated in accordance with the principles of the second and third property of the methodology. This question refers to the electric field content and brings the following basic information to the students: the stating that the electric field is created in the space around the electric charges and the asking to identify the correct representation of an electric field vector at a point close to an electric charge positively charged. After a first and quick reading of the stem of the question and before resolving the problem proposed in it, as it has been said, the student is asked to indicate if his/her feeling is that he/she knows how to resolve the problem proposed. As mentioned before, the score for this item is 0 if the student judges he/she does not know how to resolve the proposed problem, or 1 if he/she judges he/she knows how to resolve it. So, considering that the exam has 18 questions, this implies that this exam also has 18 items of feeling-of-knowing, and that the maximum score of this ability is 18 points.

Therefore, if a student's feeling-of-knowing score is 6/18 in this exam, it means that this student judged that he/she could pass about 33% of the exam items. The scores related to the other abilities should be calculated in the same way as done in the feeling-of-knowing case.

ATTENTION: read the statement of the question QUICKLY AND ONLY ONCE BEFORE BEGINNING ITS RESOLUTION

Electric charges generate in the space around them a "modification" called electric field, vector quantity associated with the application of electric force over other electric charges, among other properties. The electric field vector at a point in space is characterized by the electric force acting on a test charge placed at that point:



Thus, the electric field vector generated at point P by the negative charge - q is best represented by the "arrow"

ANSWER BEFORE BEGINNING THE RESOLUTION OF THE QUESTION:
Do you have the feeling that you know how to solve the proposed problem?

Now READ AGAIN the statement of the question WITH CARE AND ATTENTION and RESOLVE the proposed problem.

MARK YOUR ANSWER between the alternatives below.

a) 1 or 2
b) 3 or 4
c) only 2
d) only 4
e) none of the above answers are correct.

LEAVE the RESOLUTION of the question in the space below

If you choose the alternative "e)", justify your answer in the space below:

ANSWER AFTER THE RESOLUTION OF THE QUESTION: Do you think you resolved this question CORRECTLY?

ANSWER: When you are resolving this question, you were

0) very little involved with its resolution because I was thinking of other things.
1) little involved with its resolution and having difficulty in concentrating myself on the task.
2) involved with its resolution but not very focused on the task.
3) very involved with its resolution and focused on the task.
4) quite involved with its resolution and very focused on the task.

DO NOT PASS TO THE NEXT PAGE BEFORE COMPLETING ALL THE ANSWERS OF THIS QUESTION

Figure 4: Example of content domain question of a school metacognitive test

After resolving the problem proposed in the question, it is informed that the student should mark his/her answer in the response alternatives (see Figure 4). In the questions assessing educational domain, the score is 0, if this answer is wrong, or 1, if it is a right answer. This score is used to assess the student's academic performance, that is, if the student marks the correct answer to the proposed problem, the value assigned to the question will be added to his/her score. As we have 9 questions assessing the target school domain, we have, too, 9 items to assess this domain and the maximum score of this exam involving this dimension will be 9 points. It is important to emphasize that only nine of the 18 questions in the exam measure educational domain, while the other 9 assess the student's ability of monitoring. If a student answers four items correctly, then his/her performance will be 4/9.

After this, Figure 4 shows that the student has to answer if he/she judges if his/her answer is correct or not, and so the student`s judgment ability can be assessed. As shown, the score is 0, if the student's judgment is that his/her answer is wrong, or 1, if the student's judgment is that his/her answer is right. As the item for the evaluation of the judgement is present in all the questions, if we have 18 questions, and also have 18 judgment items, then the maximum score of this item is 18 points.

Finally, the student should indicate how much he/she thinks he/she was involved in resolving the problem proposed in the question. The assessment of this self-management ability of student is made in the ninth block by indicating, on a scale with five alternatives in ascending order of intensity, how the student judges that he/she was involved in the problem-solving. Since the student marks within a range of 5 alternatives with values from 0 to 4, his/her score for each item of self-management goes from 0 to 4 points. In the case of our exam, featuring 18 questions, due to the 18 items of self-management, the minimum score is 0 point and the maximum 72 points.

As in the questions assessing educational domain, the score for monitoring questions is 0, if the students mark, in the fifth block, an alternative different from the "e" option, or 1 if the students detect the presence of the error and mark the "e" option. However, it is necessary that they correctly justify their option for the alternative "e", as said. So, for example, if a student answers six items correctly then his/her performance in this ability will be 6/9.

4. Final considerations

This article has presented a methodological proposal that enables educators to elaborate a metacognitive school exam, an instrument that allows to assess, simultaneously, educational domains and also some metacognitive abilities: feeling-of-knowing, judgment, self-management and monitoring. The proposed methodology defines three basic properties to guide the correct elaboration of a metacognitive school exam. The first property, "Minimal Conditions for the School Exam Validity" states that any school exam must have defined its target constructs, as well as an elaborate set of questions (observable variables) that are theoretically related to a specific target construct (latent variables), allowing the estimation and measurement of the target constructs by quantitative methods. As a metacognitive school exam merges the assessment of school domain and some metacognitive abilities simultaneously, the second property defines what the architecture of the question, which is the basic element of the examination, should be. This second property, "Embedding the Metacognitive Abilities into the School Exam through Testlets," establishes that a question must have a testlet structure. The third property, "Defining the Commands of the Items and the Errors for the Measurement of Monitoring", determines the content of each command of the testlet structure, as well as defines three categories of errors that can be used in the monitoring questions.

Although we have used the educational domain of physics, electrostatics, as a background to show the applicability of the proposed methodology, a metacognitive school exam can be applied to all other educational domains and also to all school grades, not only to the discipline of physics. Finally, an important point to be observed is that our methodology aims to prepare the school exams so that they can pass through validity verification processes.

The wide applicability of the methodology proposed in this article and its originality are fundamental aspects of its relevance to the educational process. We hope that the educators may largely use this methodology to construct school exams or metacognitive school exams.

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