The Effects of Large Amounts of Data in Math Problems on the Reasoning of Students in the End of Cycle 2 (Grade 6)

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Abstract

In order to study the effect of unnecessary data in the problem, we made an experiment with students in grade 6. We proposed one math exercise in two different forms: the first containing a large number of data, and the second containing only the necessary data in an organized way. The solution in both problems is the same and is relatively easy once the necessary data is selected. Our results show that very few students were able to make a good selection and use of the data and give a correct answer. We have concluded from our study that 6th grade students are very easily disrupted when the amount of data given in the problem gets larger. They lack the main transversal competencies that allow them to read and understand the problem and the question, to organize and pick the useful data, as well as to formulate a comprehensible answer.

Keywords: Transversal competencies, Mathematics, Problem solving, Problem strategies, Elementary school

1. Introduction

Transversal competencies, such as reading a text, understanding and interpreting the information, form a crucial step in learning. In fact, those competencies should be learned, developed and used in all school disciplines, which will make their transfer easier to real-life situations.

We studied the transversal competencies related to text reading and understanding in math situation. In fact, solving a math problem requires many steps: students have to read, understand and interpret text and numbers, apply knowledge of mathematical concepts and procedures to answer, define and select the relevant information and finally solve the problem using the appropriate procedures and communicate the results. In these steps, reading and understanding the text and selecting the information are primary to problem solving, especially when the problem contains a large number of data.

In order to study the effect of these transversal competencies in problem solving, we made an experiment with students in grade 6 at a private school in Northern Lebanon. We separated the students in two groups and proposed one arithmetic problem in two different models, the first containing a large number of data, and the second containing only the necessary data. The solution in both models is the same. The problem contains two questions: while the first question requires a very simple use of multiplication which the students are very familiar with, the second requires a very good understanding of the problem and of the data presented.

We present hereafter the theoretical frame of our study, and the results we found after presenting the problem to 80 students in the 6th grade.

2. Transversal Competencies

Transversal or horizontal competencies are the competencies that cannot be developed by a single school discipline. They are essential to help the students adapt to various situations and to benefit from independent learning throughout their lives. Transversal competencies require to be developed in all school disciplines and activities.

Moser's taxonomy

Fig 1 Moser's Taxonomy (from Moser 2011, Our Translation)
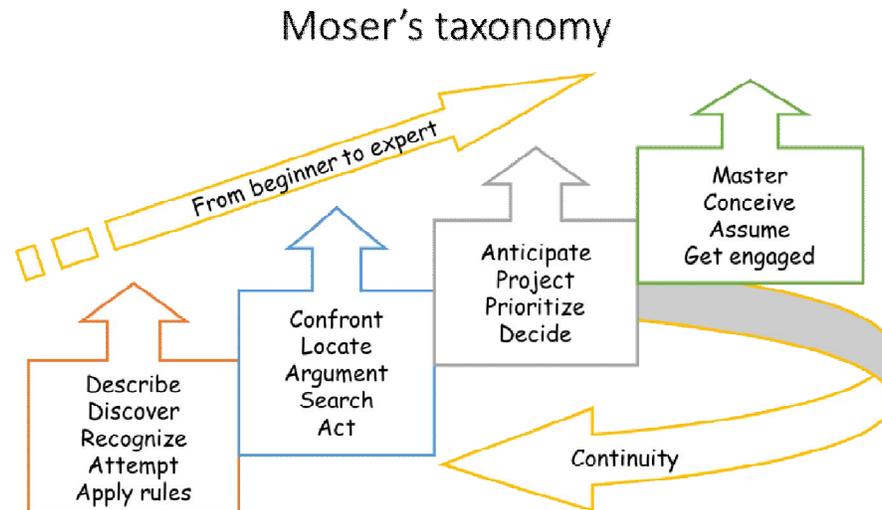
Moser (2011) established a taxonomy that regroups the transversal competencies required to attain a higher level in achievement. This taxonomy regroups four levels:

1. Describe, discover, recognize, attempt, apply rules;
2. Confront, locate, argument, search, act;
3. Anticipate, project, prioritize, decide;
4. Master, conceive, assume, get engaged.

These four levels describe the competencies a student should master during his schooling. These competencies cannot be taught in one discipline. They are used in all school disciplines and should therefore be taught in all of them. Once the student has acquired these transversal competencies, he will be able to use them in his daily life. Another classification of transversal competencies is based on their function. They are generally divided in four groups: Methodological competencies, cognitive competencies, linguistic competencies, and personal and social competencies. These competencies should be developed all through the student's schooling and in all disciplines. He should be aware of the benefits of those competencies in all disciplines and in his everyday life.

We will present hereafter the main transversal competencies that the student should learn by the end of his schooling (Rychen and Salganik, 2003).

- Methodological Competencies

Methodological competencies are the competencies that are developed in action. They include time, space, and writing management. The student will learn to work on his schedule, plan his work for the next day and for the week, as well as learning to finish the required work in a limited time. He will also learn to locate himself in his school, his neighborhood, and his city, to read maps and to search for countries and city in an Atlas. Finally, the student will learn to use a dictionary, to use multimedia tools to perform a research, and to read, formulate and understand questions and commands.

- Cognitive Competencies

To acquire the cognitive transversal competencies, the student will acquire the skills necessary to learn by asking questions about the lesson, to distinguish and explain different memorizing procedures. He will learn to organize the information and reformulate and explain the questions. Finally, he will learn to correct his own mistakes and to evaluate his own work (Tilman, 2006).

- Linguistic Competencies

The students who have acquired the linguistic transversal competencies will know how to take turn in speaking, to participate in a debate, to express his thoughts in an understandable way, formulate questions, ask for clarifications, as well as to use an appropriate lexicon.

- Social and Personal Competencies

The student will learn to participate in a debate, to respect others and accept their differences, to cooperate with others, work in groups and help those in need.

3. Steps to Solve a Problem

Solving a math problem may seem easy to the teachers, but it is not as smooth for the students. In fact, a student must follow many steps in order to solve a problem (Fite, 2002): Reading the problem, Listing and grouping the given data, Searching for the useful data and building a strategy of resolution based on the cognitive system.

Fig 2 Steps to Solve a Problem

3.1. Reading the Problem

Reading a problem is the first step to problem solving. Although it may seem easy, reading the problem is sometimes challenging to students. In fact, it requires linguistic and cognitive transversal competencies. The student should read the sentences and comprehend the text of the problem, he should identify the question that needs to be answered and know what type of information is being asked for. Reading a math problem requires symbol processing which involves the ability to derive meaning from symbols (equations, numbers, words, etc.). "If the student lacks the ability to process symbols, then he or she cannot read nor can they "do" math." (Fite, 2002).

3.2. Listing and Grouping the Given Data

After the student has read and understood the problem, he must list and group the given data. This involves picking the data from the text of the problem, and grouping them in different categories, depending on what they stand for. This step requires a good mastering of cognitive transversal competencies without which he will not be able to organize this data.

3.3. Searching for the Useful Data

Once the student has listed and grouped the data of the problem, he must search for the useful data, which will be relevant in solving the problem. In fact, most students are used to using all the given data, and face great difficulties when the amount of data is large. In order to search for the useful information, the student must have acquired the methodological transversal competencies.

3.4. Building a Strategy of Resolution Based on the Cognitive System

After picking the useful data among the given information, the student must create a link between them and build a strategy of resolution and follow it to get the solution. The strategy the student uses is based on the cognitive system. He uses perception (what we perceive from the external world through our senses), long term memory (the stock of what we have perceived), creativity (materiel created by joining elements we have stocked in long term memory) and readjustment (adjusting what we have stocked in long term memory and what we have created through creativity to what we perceive). This step requires mastering methodological and cognitive transversal competencies, which will allow him to follow the strategy or resolution then correct his own work and evaluate himself.

4. The Impact of Excessive Data

One of the most important steps of solving a problem is choosing the useful data. In fact, when teachers tend to give only the useful data in the problem, the students get used to using all the data given and get lost when the amount of data is large. To view the effect of large amounts of data on problem solving, we submitted the following problem to 24 students in grade 6.

4.1. The Problem

A dairyman receives his order of eggs in cartons. In a carton, there are 240 eggs. These eggs are in boxes of 6 and 12. A box of 6 weighs 20g empty. One egg weighs 50g. In a carton, there are 8 boxes of 12. The empty carton weighs 300g. Full, it weighs 13.2kg. The dairyman sells the box of 6 eggs at 1 Euro and the box of 12 at 1.90 Euros.
a- How many boxes of six eggs are there in a carton?
b- What is the weight of an empty box of 12 eggs*?*

Solving this problem may seem, at first sight, very difficult for 6th graders or even more advanced students. Nonetheless, if we follow the steps we described earlier in our article, solving the problem will become much easier.

4.2. Desired Way of Solving

Question a: How many boxes of six eggs are there in a carton?

Listing and grouping the given data

- One carton:
  - Contains 240 eggs;
  - Weighs 300g empty;
  - Weighs 13,2 kg full;
  - Contains 8 boxes of 12;
  - Contains …? boxes of 6.
- One egg:
  - Weighs 50g.

- One box of 6:
  - Contains 6 eggs;
  - Weighs 20g empty;
  - Costs 1€.
- One box of 12:
  - Contains 12 eggs;
  - Weighs …? g empty;
  - Costs 1€90.

Searching for the useful data

- One carton:
  - **Contains 240 eggs**;
  - Weighs 300g empty;
  - Weighs 13,2 kg full;
  - **Contains 8 boxes of 12**;
  - Contains…? boxes of 6.
- One egg:
  - Weighs 50g.

- One box of 6:
  - **Contains 6 eggs**;
  - Weighs 20g empty;
  - Costs 1€.
- One box of 12:
  - **Contains 12 eggs**;
  - Weighs …? g empty;
  - Costs 1€90.

Solution

- Number of eggs in 8 boxes of 12: **8*12= 96**
- Number of eggs in boxes of 6: *Total number of eggs in the carton – Number of eggs in 8 boxes of 12 = 240 – 96 = 144*
- Number of boxes of 6: **144 / 6= 24**
- There are **24 boxes of 6** in a carton.
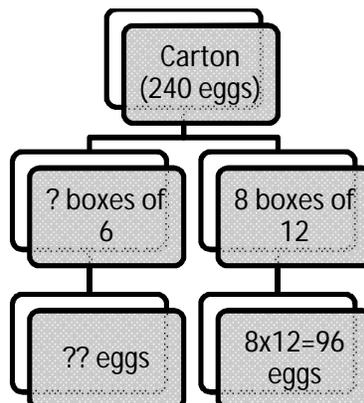
Question b: What is the Weight of an Empty Box of 12 Eggs?
Searching for the useful data

- One carton:
    - **Contains 240 eggs**;
    - **Weighs 300g empty**;
    - **Weighs 13,2 kg full**;
    - **Contains 8 boxes of 12**;
    - **Contains 24 boxes of 6**.
- One egg:
    - Weighs 50g.

- One box of 6:
    - Contains 6 eggs;
    - **Weighs 20g empty**;
    - Costs 1€.
- One box of 12:
    - Contains 12 eggs;
    - Weighs ...? g empty;
    - Costs 1€90.

Solution

- The carton weighs **13,2kg = 13 200g**
- The weight of the eggs is: **240*50 = 12 000g**
- The empty carton weighs **300g**
- The 24 boxes of 6 weigh: **24*20=480g**
- The 8 boxes of 12 weigh: Total weight of the full carton – (weight of the empty carton + weight of the 240 eggs + weight of the 24 boxes of 6) = **13 200 – (300 + 12 000 + 480) = 420g**
- One box of 12 weighs: **420 / 8 = 52.5g**
- **The weight of one box of 12 is 52.5g**
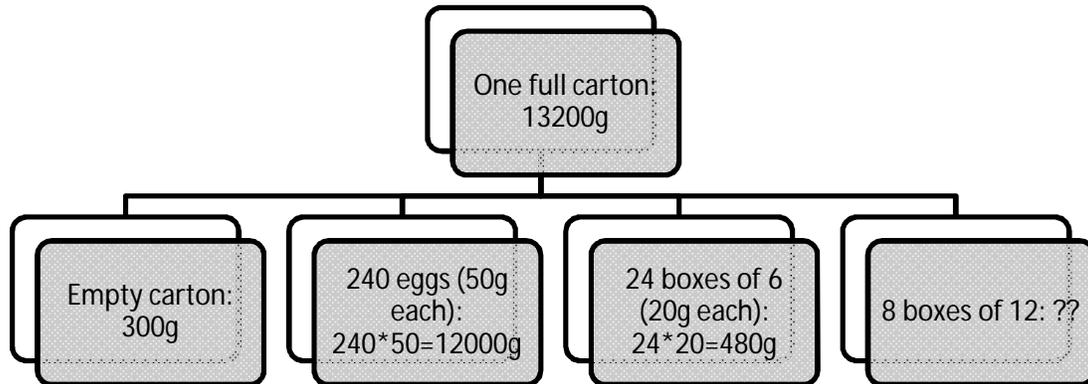
5. Pre-Experiment

Before applying our problems to students, we made a pre-experiment on 24 students of grade 6, to whom we presented the problem with excessive data. The goal of this pre-experiment was to show whether this data does in fact cause difficulties to students of this level or not. We chose to give this problem to students in grade 6 because this is the last grade in the primary cycle where students learn and acquire the basic mathematical operations required to solving the problem.

5.1. Methods used by Students

We present in the following section the methods that the students used to solve the two questions of the problem. We tried to interpret the solutions, whether they're correct or not, understand the methods the students used to give the answers, and group them in categories. We therefore got two different methods used to solve the first question, and three methods to solve the second question.

Question a
How many boxes of six eggs are there in a carton?

Table 1: Answers of students to Question a

	Question a
Correct answer	1
Proportionality	19
No answer	4
TOTAL	*24*

Correct Answer

As we notice in Table 1, only one student among the 24 answered correctly to question a. We can clearly see in *Fig. 3* below the distribution of the total number of eggs between those in boxes of 6 and those in boxes of 12. The student got the correct number of boxes of 6 by following the correct method: he/she deduced the number of eggs in boxes of 6 by multiplying 12 eggs by 8 boxes then subtracted this number from the total number of eggs to get the number of eggs in boxes of 6. He/she then divided that number by 6, deducing the correct number of boxes of 6.
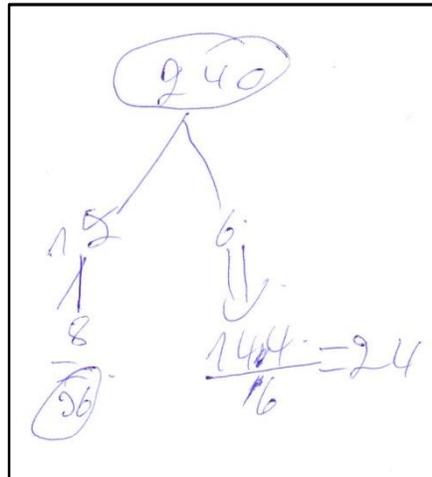

Fig 3: Correct but Incomplete Answer

Overall, this first method is correct; however, there aren't any units used with numbers, which makes us wonder about the signification of the each number. The operations done are not clear, so we can't know exactly where the student got each of the numbers from (26 and 144) or why any of the operations were done. Finally, even though the answer is correct, it is not presented in a clear way.

Proportionality

This method, used by 19 of the students, supposes that there is proportionality between the numbers. Although the students distributed correctly 240 eggs in boxes of 6 and 12, they assumed that because 6 is half of 12, then the number of boxes of 6 should be half the number of boxes of 12 (Fig. 4).

The students who used this method made a connection between the numbers without understanding the meaning of each of the numbers, or the relation that links them.
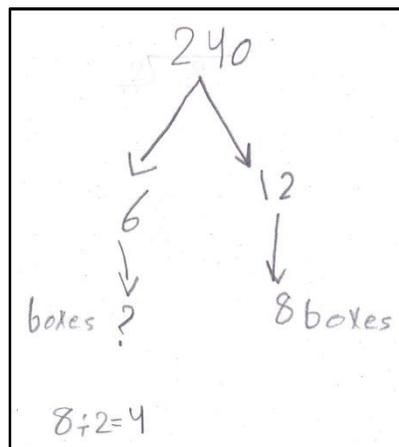

Fig 4: Proportionality

No answer

Four of the students did not give any answer to this question.

Question b

What is the weight of an empty box of 12 eggs?

Table 2: Answers of Students to Question b

	Question b
Correct answer	0
Misunderstood question	15
Misunderstood data	1
Misunderstood terms	1
No answer	7
TOTAL	*24*

Misunderstood Question

In the first method, used by 15 students, the question is not understood correctly. The students look for the weight of the eggs contained in one box of 12, not taking into consideration the weight of the empty box, which is the original question.

The use of this method indicates the lack of understanding of the question, and the difficult categorization of the data.

We encountered three variables of this method: in the first one, students don't use any units;

Fig 5: Misunderstood Question (1)

In the second, they don't use units in the operation but give one for the answer. We note here that the students using this variable gave the answer in kilograms, while the data is in grams.

Fig 6: Misunderstood Question (2)

In the third variable, students add the unit "eggs" to the answer.

Fig 7 Misunderstood Questions (3)

Misunderstood Data

Fig 8: Misunderstood Data

In this second method, used by one student, the number of eggs contained in a box of 12 is multiplied by the number of eggs contained in a box of 6. We notice the unit "weight" that the student affiliated to the result.

This method also clearly shows the lack of understanding of the question and of the data.

Misunderstood Terms
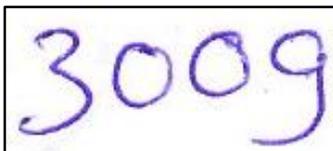
Fig 9: Misunderstood Terms

In this third method, used by one student, the lack of understanding of the terms used in the question is very clear: the student gave the weight of the empty carton instead of giving the weight of an empty box of 12. This answer shows an error in the first step of solving the problem, which is reading and understanding it.

Other Answers

Seven of the students did not answer this question, or gave an incomprehensible answer that we couldn't analyze (Fig. 10).
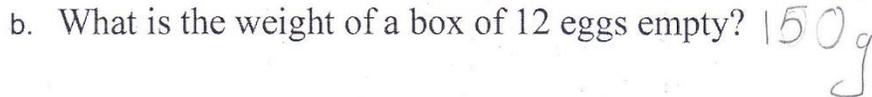

Fig 10: Unclear Answer

5.2. Conclusion of the Pre-Experiment

After studying the results of this experiment, we can clearly see the difficulties the students have in the first steps of problem solving: reading and understanding the problem. In fact, as we can see in table 3, the answers of the students to *questions a* and*b* clearly show that only one of them read and understood the problem in *question a* and only one other student tried to search for the useful data (Fig. 11).
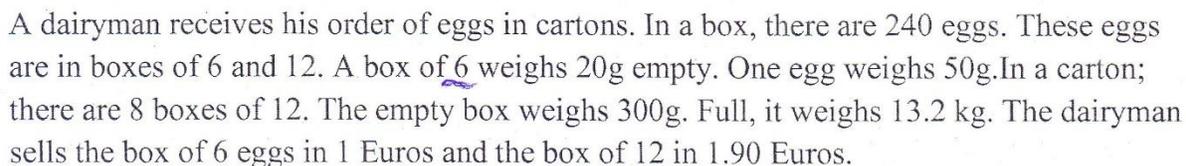
Fig 11: Search for Useful Information

On the other hand, most of the students built a strategy of resolution and followed it until they got an answer. However, these strategies are not correct since the previous steps of solving the problem are not followed. The students have therefore misunderstood the problems, the questions and/or terms used but felt obliged to give an answer, which made them use an erroneous strategy.

Table 3: Steps to Solve a Problem

	Question a	*Question b*
Reading and understanding the problem	1	0
Listing and grouping the given data	0	0
Searching for the useful data	1	0
Building a strategy of resolution	20	19

The results of this experiment where only one student gave a correct answer to one of the questions, we decided to make further studies in order to understand the real cause of the difficulties encountered. In fact, the students clearly can't solve a complex situation derived from daily life. They are missing the basic transversal competencies that will allow them to deal with such situations.

In view of the results, we can wonder where the real difficulty comes from: is the problem in itself difficult to students in grade 6 or is the presentation of the data causing this major difficulty? Or are the students really lacking basic transversal competencies that allow them to solve a complex problem? In order to complete this study, we created a new problem which requires the same solving procedures but where only the necessary data is given.

6. The Experiment

As stated previously, we aim in this part of our study to compare the methods used by students to solving the same problem presented in two different ways. In the first variant, which wecalled problem I or basic problem, we presented the same problem used in the pre-experiment. In the second variant, called problem II or simplified problem, we organized the data and gave only the necessary information to solving the problem. We present hereafter the problems I and II

Problem I – Basic problem

A dairyman receives his order of eggs in cartons. In a carton, there are 240 eggs. These eggs are in boxes of 6 and 12. A box of 6 weighs 20g empty. One egg weighs 50g. In a carton, there are 8 boxes of 12. The empty carton weighs 300g. Full, it weighs 13.2kg. The dairyman sells the box of 6 eggs at 1 Euro and the box of 12 at 1.90 Euros.

a- How many boxes of six eggs are there in a carton?
b- What is the weight of a box of 12 eggs empty?

Problem II – Simplified problem

A dairyman receives his order of eggs in cartons. In a carton, there are 240 eggs. These eggs are in boxes of 6 and 12. There are 8 boxes of 12.

a- How many boxes of six eggs are there in a carton?

A box of 6 weighs 20g empty. One egg weighs 50g. The empty carton weighs 300g. Full, it weighs 13.2kg.

b- What is the weight of a box of 12 eggs empty?

As we notice in this second problem, we eliminated the unnecessary information to keep only what is essential. The information given in the first question should be all used to solve it. We only give the information necessary for the second question afterwards. This will tell the students that the extra information given after the first question should only be used in the second question.

We presented students in grade 6 in a private school with these problems. Forty students solved problem I and forty others solved problem II. We present hereafter the results we obtained.

7. Results

We will present in this section the results of the students to both problems I and II. We will first present the results of question *a*of the problems, then those of question *b*. We find it necessary at this point to remind that the problem I (basic problem) and problem II (or simplified problem) are the same and solving them requires the same strategy and mathematical competencies. The only difference is the amount of data and the way it is presented in these problems. In other words, problem II has grouped and organized data, and only the useful data is presented (steps 2 and 3 in solving a problem). This allows the student to skip these steps, going from reading and understanding the problem to building a strategy of resolution. The understanding of the problem is also made easier by the way the problem is presented.

7.1. Question a

How many boxes of six eggs are there in a carton?

In order to solve this problem, students have to calculate the total number of eggs contained in boxes of six, then divide the obtained number by six:

- Number of eggs in 8 boxes of 12: ***8*12= 96***
- Number of eggs in boxes of 6: *Total number of eggs in the carton – Number of eggs in 8 boxes of 12 =* ***240 – 96 = 144***
- Number of boxes of 6: ***144 / 6= 24***

- There are **24 boxes of 6** in a carton.

For this question, the students' answers were as showed in table 4.

Table 4: Answers to Question A

	Problem I	Problem II
Correct answer	4	15
Correct answer with calculation error	0	2
Correct but incomplete strategy	2	1
Proportionality	1	1
Incomprehensible strategy	13	10
Use of all numbers in the problem	0	3
Misunderstood data and question	20	8
TOTAL	*40*	*40*

As we can see in *table 4*, eighteen students used the correct strategy in problem II – among which fifteen gave a correct answer (Fig. 12, 13 and 14) – while only six did in problem I – among which four gave the correct answer. These numbers show that students tend to pick the correct strategies when the data is presented in an organized and easy way whereas they find more difficulties when the data is excessive and is not presented in an organized way.

Fig 1 Correct answer

Fig 2 Correct but incomplete strategy

Fig 3 Correct but incomplete strategy

We can also notice that, among the forty students, twenty gave an answer that shows that they misunderstood the question and/or the data (Fig. 15) in problem I whereas only eight gave such an answer in problem II. This clearly shows that the presentation of the data and the presence of unnecessary data affected the understanding of the problem and the choice of the strategy.

Fig 15: Misunderstood Data

Finally, we notice that three of the students who solved problem II used a strategy that included all numbers present in the question (Fig. 16). This shows the tendency of the students to use all the numbers given in the problem as well as their incapacity for organizing the data. Of course, this difficulty cannot be seen in problem I, since a very large number of data is given before *question a*.

Fig 16: Answer Including All Numbers Present in the Question

7.2. Question B

What is the weight of a box of 12 eggs empty?

In order to solve this question, students have to use a simple yet long strategy that combines the answer of the first question as well as a large number of data. We remind here that the data necessary for this question is given directly before the question in problem II, while they are given among the data before *question a* in problem I.

- The carton weighs *13,2kg = 13 200g*
- The weight of the eggs is: *240*50 = 12 000g*
- The empty carton weighs *300g*
- The 24 boxes of 6 weigh: *24*20=480g*
- The 8 boxes of 12 weigh: *Total weight of the full carton – (weight of the empty carton + weight of the 240 eggs + weight of the 24 boxes of 6) = 13 200 – (300 + 12 000 + 480) = 420g*
- One box of 12 weighs: *420 / 8 = 52.5g*
- **The weight of one box of 12 is 52.5g**

Table 5: Answers to Question b

	Problem I	Problem II
Correct strategy and/or answer	0	0
Correct but incomplete strategy	2	6
Proportionality	16	18
Incomprehensible strategy	7	4
Misunderstood data and question	14	12
No answer	1	0
TOTAL	*40*	*40*

This question is obviously more difficult to students than question a. Although the strategy that should be used to solve this problem is well known to the students, we can clearly see that none of them had a correct answer, whether they were solving problem I or problem II. The answers given by the students are the same in both problems. In fact, only eight among eighty students started a correct strategy, where they deduced the weight of eggs and boxes from the total weight of the full carton, but none of them completed the strategy and deduced all the needed weights (Fig. 17). This difficulty is clearly the result of the large amount of data that should be used to solve the question as well as the incapacity of the students to organize the data and understand it fully. This is also shown in the answers of twenty-six among the eighty students, where the misunderstanding of the question and/or the given data is clear (Fig. 18).

Fig 4 Correct but incomplete strategy

Fig 5 Misunderstood data and/or question

7.3. Conclusion

We can see from analyzing the answers the students gave that they have much more difficulties in problem I than in problem II. In fact, the strategies they used and the answers they gave clearly showed that they have difficulties in the transversal competencies used to group and organize the data and to find the useful data for the question. In fact, none of the students listed and grouped the data and only one copy showed an attempt of searching for the useful data (Table 6 and Fig. 19). As for reading and understanding the problem, we cannot be sure of the number of students who performed this step, so we only assume that those who started building a correct strategy have indeed read and understood the problem. Finally, almost all students built a strategy of resolution and followed it until they got an answer, but only few built a *correct* strategy.

Table 6: Steps to Solve a Problem

	Problem I – Basic problem		*Problem II – Simplified problem*	
	Question a	*Question b*	*Question a*	*Question b*
Reading the problem	6	2	18	6
Listing and grouping the given data	0	0	0	0
Searching for the useful data	1	0	0	0
Building a strategy of resolution	40	39	40	40

A dairyman receives his order of eggs in cartons. In a carton, there are 240 eggs. These eggs are in boxes of 6 and 12. A box of 6 weighs 20g empty. One egg weighs 50g. In a carton, there are 8 boxes of 12. The empty carton weighs 300g. Full, it weighs 13.2kg. The dairyman sells the box of 6 eggs at 1 Euro and the box of 12 at 1.90 Euros.

Fig 19 Searching for the Useful Data

8. Conclusion and Interpretation

This study clearly shows the difficulties the students have in solving complex problems. In fact, they are missing the basic transversal reading competencies that will allow them to read and understand the problem and the question, the methodological transversal competencies that will allow them to organize and pick the useful data before choosing a strategy for resolution, as well as the linguistic transversal competencies that will allow them to formulate a comprehensible answer. The problem we presented the students with is in fact relatively easy for them to solve, which is shown by the amount of correct answers to its simplified version. The difficulties the students have are therefore mainly due to the lack of transversal competencies and the incapacity to follow the steps required to solve a problem.

One of the most important results this study showed is that, when faced with a complex problem, 6th grade students have major difficulties in all four steps of problem solving:

- Reading and understanding the problem seem to be problematic; the answers the students gave show the difficulties they have identifying the question that needs to be answered and knowing what type of information is being asked for.
- Listing and grouping the data is inexistent; in such a problem with large amount of data, groupingis primary. It helps the understanding of the problem and makes finding the solution much easier. However, we don't find any trace of such grouping in any of the students' answer sheets.
- Searching for the useful information is also a primary step in solving problems with large amounts of data. We can clearly see the attempt to such process in the students' answers.
- As for building a strategy of a resolution and following it until the result is found, we can see that most of the students performed this step. However, none of them verified if their method is correct. Since the previous steps are not achieved, we cannot know for sure if the students are actually capable of performing this step correctly.

In conclusion, we believe that if we teach the students transversal competencies as well as the steps to solve a problem, they will be able to solve not only complex problems we submit to them in school but also problems they encounter in their daily life.

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