Universidad Zaragoza 1542

International Conference New Perspectives in Science Education

Universidad Rey Juan Carlos

STEM in the classroom through problem solving on bacteria and drugs

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INTRODUCTION

Since 2000, the OECD has been conducting triennial studies on the skills that 15-year-old students must acquire in three areas, reading comprehension, Mathematics and Science, leading to the PISA. These tests allow reflection on the international learning situation and the exchange of experiences to improve some educational indicators in all participating countries (Vilches & Gil, 2010).

They aim to determine whether students are able to apply what they have learned in the classroom in different situations.

In our context, Spanish students scored below the OECD average in both Mathematics and Science in PISA 2018 (INEE, 2019).

INTRODUCTION

Despite these results, the Spanish curriculum (BOE, 2015) includes objectives related to the development of various scientific practices: posing problems, formulating hypotheses, proposing models, designing strategies for solving them, analysing the results, etc.

INTRODUCTION

In order to understand and promote the interaction between the disciplines of Science, Technology, Engineering and Mathematics, as well as the associated vocations, in the 1990s the term STEM. In the STEM framework, apart from understanding concepts about Science, Mathematics or Technology, it is of utmost importance to solve real-world problems by "thinking like" mathematicians, scientists and engineers, and being aware of the interconnections between these disciplines (Domènech-Casal, Lope & Mora, 2019).

OBJECTIVE

To analyse the obstacles faced by students when tackling a contextualised problem with a task which integrates knowledge from Science, Mathematics or Technology areas.

METHOD

- This research follows a qualitative design to explore how Secondary Education students approach the resolution of a problem contextualised in Science and Technology and in which a variety of mathematical concepts and procedures are involved.
- 16–17-year-old students from a technological high school in Spain were selected.

METHOD

We proposed the following problem to the students:

On January 1st (Monday) at 0.00 am, one million people were infected with a certain bacterium. Two pharmaceutical companies are trying to combat a situation that could trigger a humanitarian disaster. The first pharmaceutical company has manufactured a drug that reduces the number of bacteria by 62.5% each time it is given; and can be injected every six hours. The second pharmaceutical company has made a drug that reduces the number of bacteria by 72% and can be injected every 24 hours. On the other hand, a laboratory has started to study the reproduction of these bacteria. It has found that at a temperature of 36.5°C (human body temperature), the number of bacteria doubles every 6 hours. Medical research has shown that, if people have more than one million bacteria in their body, they die, but if they are able to keep the number of bacteria bellow that quantity for 10 days, they survive and are immunised for life. What drug would you use to alleviate this infection? Justify your answer.

METHOD

To facilitate problem solving, a set of questions were proposed to allow students to structure the problem in steps or stages. These questions were linked in four blocks:

- I.Reproduction of bacteria (drug-free)
- II.Drug-free life time
- III.Drug introduction
- IV. Survival

METHOD

Block I – Reproduction of bacteria (drug-free).

1. A person who has not been treated pharmacologically, how many bacteria will he/she have in his/her body 6 hours after becoming infected?
2. A person who has not been treated pharmacologically, how many bacteria will he/she have in his/her body 18 hours after becoming infected?
3. A person who has not been treated pharmacologically, how many bacteria will he have in his body 22 hours after becoming infected?
4. Express algebraically the number of bacteria that a person would have in his or her body at any time if there were no risk of death.
5. How many bacteria would a person have in his or her body in the long term if there were no risk of death?

METHOD

Block	Mathematics content	Science content	Technology content
I.Reproduction of bacteria (drug-free)	- Numerical sequences - Arithmetic calculations - Exponential functions - Algebraic expressions - Limit of sequences /functions	- Characteristics of living things and levels of organisation. (Biology and Geology) - Bioelements and biomolecules. (Biology and Geology) - Research project. (Physics and Chemistry)	

METHOD

Block II – Drug-free life time

6. A person dies if they have more than one million bacteria in their body. How long does it take before they die? What day do they die? What time?
7. A person dies if they have more than one million bacteria in their body, how many bacteria did they have shortly before they died?
8. Graphically represent, with pencil and paper, the evolution of the infection using the variables: elapsed time (independent) and number of bacteria (dependent).
9. Graphically represent, with Geogebra, the evolution of the infection using the variables: time elapsed (independent) and number of bacteria (dependent).

METHOD

Block	Mathematics content	Science content	Technology content
II.Drug-free life time	- Logarithmic and exponential equations. - Arithmetic calculations - Graphical representation of sequences/functions	- Research project. (Physics and Chemistry)	- Using GeoGebra

METHOD

Block III – Drug introduction

10. A person was infected by bacteria 18 hours ago, and is injected with drug A. How many bacteria will remain immediately afterwards?
11. A person was infected by a bacterium 18 hours ago, and is injected with drug B. How many bacteria will remain immediately afterwards?
12. A person was infected by bacteria 24 hours ago, and is now injected with drug B. How many bacteria will remain after three doses of the drug?

METHOD

Block III – Drug introduction

13. Express algebraically the number of bacteria a person will have in his or her body in the long term if he or she was injected with drug B after 24 hours of infection. Express the same for drug A.

14. Graphically represent, with pencil and paper, the evolution of the infection with each of the drugs, using the previous section and the variables: time elapsed (independent) and number of bacteria (dependent).

15. Express algebraically the number of bacteria a person will have in his or her body in the long term if he or she was injected with drug A after a certain number of hours of infection.

METHOD

Block	Mathematics content	Science content	Technology content
III.Drug introduction	- Percentages - Arithmetic calculations - Algebraic expressions - Graphical representation of sequences/functions	- Research project. (Physics and Chemistry)	

METHOD

Block IV - Survival

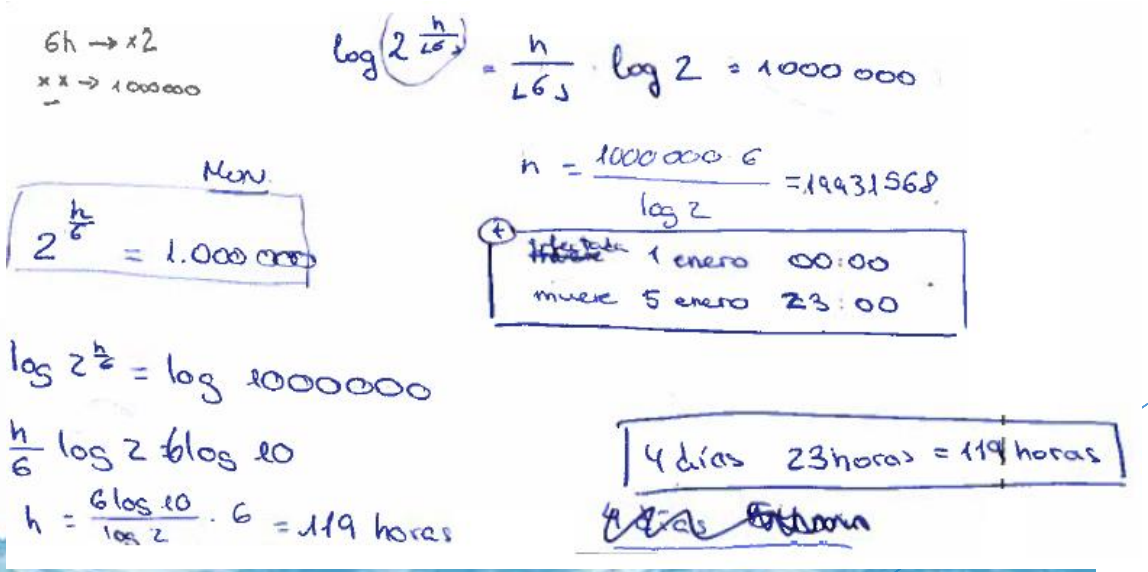
16. Does the patient survive if he/she has started treatment with drug A within 24 hours of infection? And using B?
17. At what point should drug A be injected for the first time, at the latest, in order to ensure the person's survival?
18. At what point should drug B be injected for the first time, at the latest, in order to ensure the person's survival?
19. What drug would you use to alleviate this infection?

METHOD

Block	Mathematics content	Science content	Technology content
IV. Survival	- Arithmetic calculations	- Characteristics of living things and levels of organisation. (Biology and Geology) - Bioelements and biomolecules. (Biology and Geology) - Research project. (Physics and Chemistry)	

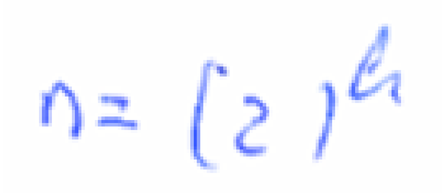
RESULTS

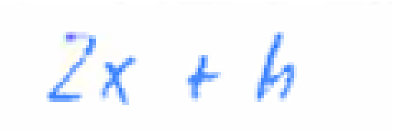
Students show a good resolution of the numerical calculations that appear during the problem and a good approach to percentages. Both mathematical notions were already acquired in previous years. In addition, they correctly pose and solve logarithmic equations. In all three cases, these are tasks that require the acquisition of different processes and skills, but not a particular reflection on the reflection on the problem posed.



RESULTS

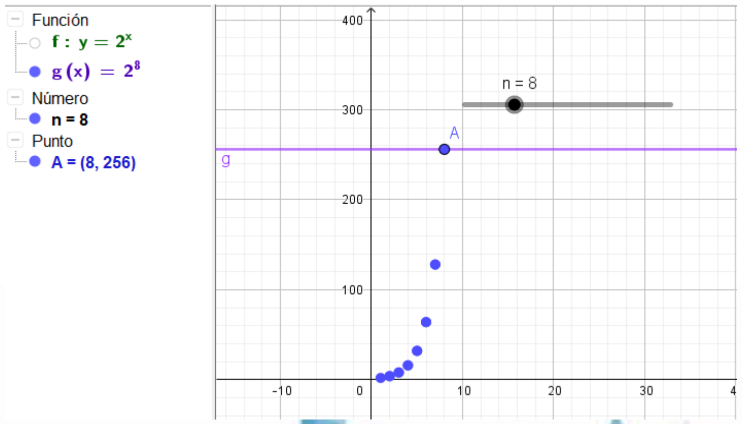
Despite being part of a multitude of tasks that pupils of this age have to solve at school, algebraic expressions are not tackled with the rigour they require. Moreover, a great number of difficulties are detected in their interpretation; for example, some pupils incorporate the same number of bacteria in each step of growth and add them to the previous ones, instead of doubling the number of bacteria in each step of growth, e.g., $2x + h$ instead of 2^h

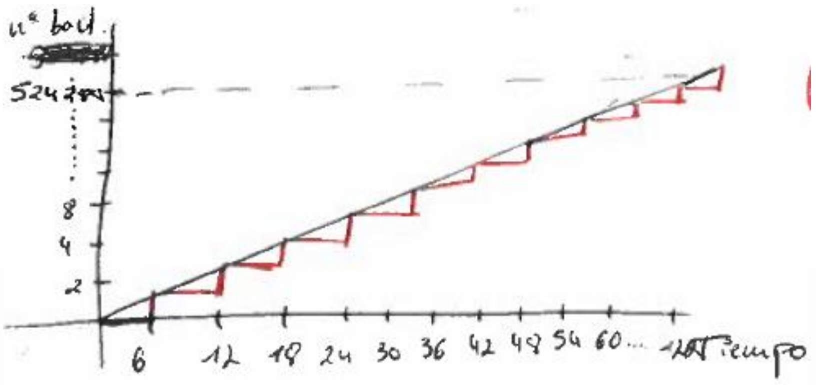




RESULTS

The greatest difficulties arose when dealing with the notion of limits and, above all, in the graphical representation and interpretation of the results reached in each of the questions posed. Regarding the graphical representation, the students had the opportunity to use the educational software GeoGebra. However, they decided to use paper and pencil instead.





RESULTS

The students barely alluded to the concepts associated with Science (Biology), even though they were implied in the context of the problem. They only used the word bacteria to determine the units of the numerical quantities.

CONCLUSIONS

- We can affirm that the students involved in the task were not able to apply what they learn in the classroom to a specific situation that demands reasoning instead of a previously established procedure.
- Among these obstacles, we highlight those related to the graphic representation and interpretation of the results achieved, and the absence of the specific vocabulary of Sciences that provided context to the problem.
- Moreover, despite the suggestion to use GeoGebra, the students declined this option and preferred to carry out traditional graphical representations.

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