Osmosis with Red Blood Cell:
a Scratch-based Learning Unit

Course of Methods in Computer Science Education: Analysis

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Introduction

The objective of this report is to provide a comprehensive overview of the creation process for a Learning Unit employing *Scratch*. The primary goal of this unit is to facilitate the understanding of the osmosis phenomenon within eukaryotic cells, with a specific focus on utilizing red blood cells as an illustrative example. The Learning Unit has been developed with the intention of being an educational resource aimed at students. The pedagogical approach has been designed to cater to the needs of students, providing meaningful learning experiences.

Prerequisites and Class

This Learning unit is aimed at a class of high school students during natural science lessons. More precisely, in a third year of scientific high school (ind. "scienze applicate").
As a result of ministerial programs, students in the natural sciences classes will have to learn the discipline knowledge and methodologies typical of earth sciences, chemistry and biology.
In fact, for this unit of learning will be necessary knowledge of chemistry and biology as it will focus on the phenomenon of osmosis in eukaryotic cells.
The primary focus of the learning unit will revolve around the measurement of osmotic pressure. Therefore, it is essential to have a solid foundation in certain chemistry topics.

The **chemistry topics** required to effectively conduct the experiment include:

- the concept of the mole as a fundamental unit in chemistry;
- understanding the practical application of molar mass in various contexts;
- knowledge of compound formulas and composition, with an emphasis on percentage composition and determining the minimum formula of a compound;
- comprehension of solutions, distinguishing between solute and solvent components;
- understanding the concept of molarity as a measure of concentration in a solution;
- familiarity with molality and its importance in certain chemical calculations.

Regarding the **biology topics** required to develop the learning unit, the following concepts are essential:

- cell definition, encompassing the fundamental understanding of cellular structures and functions;
- the structure of cell membranes, emphasizing the key components and their roles in cellular processes;
- mechanisms by which cells execute the transport of substances, both in terms of entry and exit processes.

In terms of **computer science prerequisites**, students should have a solid understanding of the following concepts:

- loop functions, including their purpose and implementation;
- if-then-else constructions, exploring conditional statements for decision-making in programming;
- variables, with an emphasis on their role in storing and manipulating data.
- assigning variables, ensuring participants are proficient in setting and updating variable values in a program.

Learning Objectives and Motivations

Through the learning unit, students will gain basic knowledge of Scratch, the block-based programming style, the concept of events, messages passed through parallel calculation, and the structure of a program.

On the biology side, they will understand that living beings follow the same physical and chemical laws governing the inanimate world. They will also learn about the phenomenon of osmosis, which is the diffusion of water molecules from a region with higher water potential to a region with lower water potential through partially permeable membranes.

From a chemical perspective, students will understand and analyze osmotic pressure and the effects that cells undergo as the relationships of solute and solvent change. They will also comprehend the concept of osmotic pressure in the biological-medical field.

The guidelines given to students are as follows:

> *"Using the Scratch system studied during the course, simulate the phenomenon of osmosis in a eukaryotic cell, specifically red blood cells. The first step is to create an isotonic saline solution with respect to the fluid present in the cell (i.e., a physiological saline solution with a concentration of 0.9% NaCl, i.e., 9 g/L). Finally, to demonstrate the effects of osmosis on the cell, calculate the osmotic pressure of the solution as the amount of solvent and solute varies."*

Formulas and data given:

1. **Osmotic Pressure:**

$$\pi = RTMi$$

Where:

- R is the ideal gas constant $(0.821\,(\mathrm{L}\cdot\mathrm{atm})/(\mathrm{mol}\cdot\mathrm{K}))$
- i is the van't Hoff index (For NaCl, $i = 2$)
- M is the molar concentration of the solute
- T is the temperature in Kelvin (Convert Celsius to Kelvin: $K =^{\circ} C + 273.15$)

2. **Molar Concentration:**

$$M = \frac{n}{v}$$

Where:

- n is the moles of the solute
- v is the liters of the solution

3. **Moles of Solute:**

$$n_{\text{moles}} = \frac{\text{mass}}{Mm}$$

Where:

- mass is the mass of the solute (in grams)
- Mm is the molar mass of the solute (For NaCl, Mm = $58.44\,\mathrm{g/mol}$)

Note: All calculations are based on a temperature of 37°C, and the Celsius to Kelvin conversion is applied using $K =^{\circ} C + 273.15$.

Structure of the Lectures

The learning unit will be delivered during the last month of the third year. In fact, students at the end of the year will have acquired the necessary skills in both computer science, chemistry, and biology to carry out the project.

Three lessons will be needed to explain the Scratch environment and in the 4th lesson the students will be given the project assignment that they will have to carry out during school hours. In total there are 8 lessons scheduled for the entire Learning Unit.

During the sixth lesson the students will be asked to show the work done to receive feedback. The last lesson will be needed to show the project and make the final revision and give them the marks.

Evaluation Grid

Criteria	Well Done	Good	Sufficient	Insufficient
Scratch and programming skills	Student demonstrates a high level of proficiency in using Scratch, effectively utilizing loops, if-then-else constructions, and variable assignments.	Student shows good understanding and application of Scratch features, with minor errors or inefficiencies.	Student demonstrates basic Scratch skills but struggles with advanced features, resulting in notable errors.	Student has difficulty navigating and using Scratch, leading to significant errors in the program.
Understanding of Osmosis	Student thoroughly understands the osmosis phenomenon and accurately simulates it in the Scratch program.	Student demonstrates a good understanding of osmosis, with minor inaccuracies in the simulation.	Student has a basic grasp of osmosis but struggles to accurately simulate the phenomenon in Scratch.	Student lacks a clear understanding of osmosis, leading to significant errors in the simulation.
Integration of Biology Concepts	The Scratch program integrates biological concepts effectively, showcasing a clear connection between osmosis and cellular processes.	The biological concepts are well-incorporated into the Scratch program, though some connections may be vague or unclear.	The Scratch program includes basic biological concepts, but the connection to osmosis is not well-established.	The integration of biology concepts in the Scratch program is minimal or missing.
Integration of Chemistry Concepts	The Scratch program effectively incorporates chemistry concepts, especially in calculating osmotic pressure. Osmotic pressure calculations are accurate and follow the given formulas correctly.	Chemistry concepts are present in the Scratch program, but there are minor errors or omissions in the application. Osmotic pressure calculations are mostly accurate, with minor errors in the application of formulas.	The Scratch program includes basic chemistry concepts, but there are significant errors in applying them to calculate osmotic pressure that contain significant errors or inaccuracies.	Chemistry concepts are poorly integrated into the Scratch program. Osmotic pressure calculations are entirely incorrect or missing.
Project Guidelines	The Scratch program aligns closely with the project guidelines, addressing all specified requirements.	The Scratch program meets most of the project guidelines but may have minor deviations or omissions.	The Scratch program partially meets the project guidelines, with significant deviations or omissions.	The Scratch program deviates substantially from the project guidelines.
Overall Performance	The student excels in all aspects, showcasing a comprehensive understanding of both Scratch and osmosis concepts.	The student performs well, with a good understanding of Scratch and osmosis, though there may be minor areas for improvement.	The student meets basic expectations but requires improvement in both Scratch and osmosis understanding.	The student struggles significantly, indicating a need for substantial improvement in both Scratch and osmosis understanding.

Table 1: Grading Criteria

Development

Optimal Solution

In the optimal solution, the student wrote a Scratch project with a particular emphasis on modularity and clarity. The codebase is both modular and extensively commented, which ensures a clear comprehension of the logic and functionality for anyone reviewing it.

Effective message passing and event handling between sprites is a notable strength. It also includes the consideration of isotonic, hypertonic, and hypotonic solutions, which reflects an understanding of cellular processes.

The student's ability to apply theoretical knowledge to practical programming challenges was demonstrated through the implementation of each scenario. The subject matter was comprehended by the student, who correctly implemented the osmosis effect on the cell as the osmotic pressure changed.

A feature of the optimal solution is the accurate representation of osmosis effects on the cell as osmotic pressure varies. The implementation is not only correct but also visually compelling, effectively conveying the scientific principles to the end user.

The following images show the functionalities of the code:

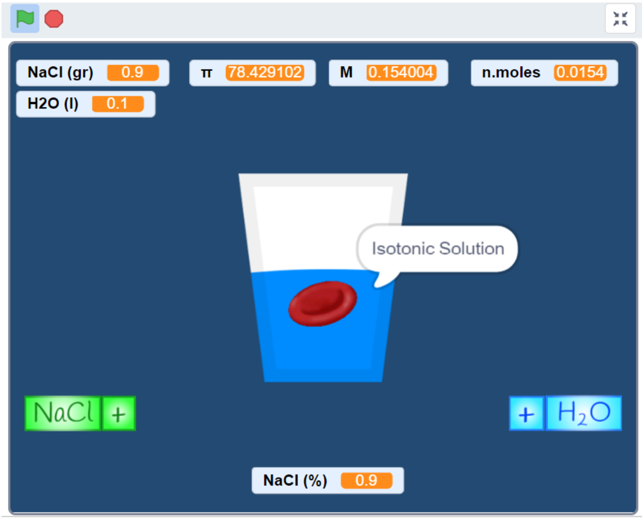

Figure 1: Isotonic solution

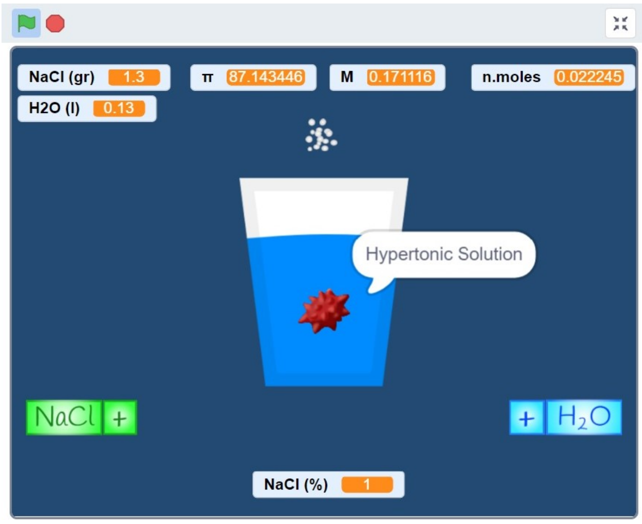

Figure 2: Hypertonic solution

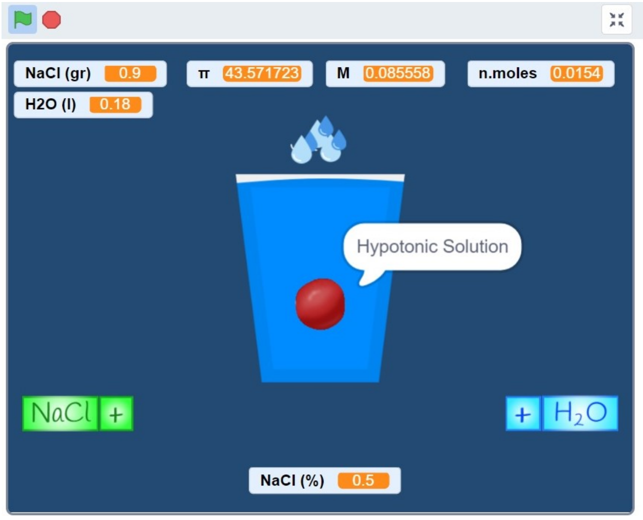

Figure 3: Hypotonic solution

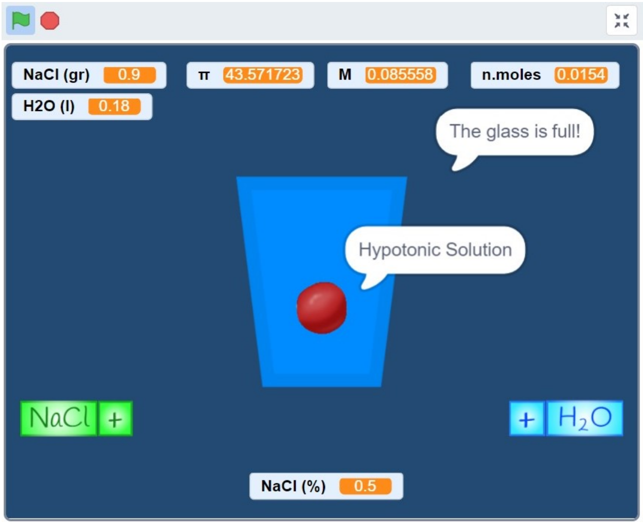

Figure 4: Case: The glass is full

- The isotonic solution image illustrates equilibrium with equal solute concentrations inside and outside a cell.
- In the hypertonic solution, higher external solute concentration causes water efflux, potentially shrinking the cell.
- The hypotonic solution image depicts lower external solute concentration, leading to water influx and potential cell swelling.
- The full glass scenario represents the case where the glass is filled with water.

Sufficient Solution

In the sufficient solution, the student demonstrated a basic understanding of Scratch programming, although certain aspects fell short of the optimal level. The code structure, while functional, lacks the modularity observed in the optimal solution. Comments are present but may be insufficient to fully explain the code logic.

One notable limitation is the absence of message passing between sprites, particularly regarding the addition of NaCl and H2O to the solution. The student's approach, while functional, may lead to a less cohesive and less interactive simulation compared to the optimal solution.

The osmosis effect on the cell was not adequately considered in this solution. The absence of a representation of osmotic pressure variations suggests a limited grasp of the underlying biological concepts.

In terms of formula implementation, the student exhibited a basic understanding. However, some formulas were either partially correct or lacked accuracy. This could be due to a misunderstanding of certain mathematical or chemical concepts. A more thorough application of the provided formulas would have enhanced the scientific accuracy of the simulation.

Finally, the following images show the sufficient solution:

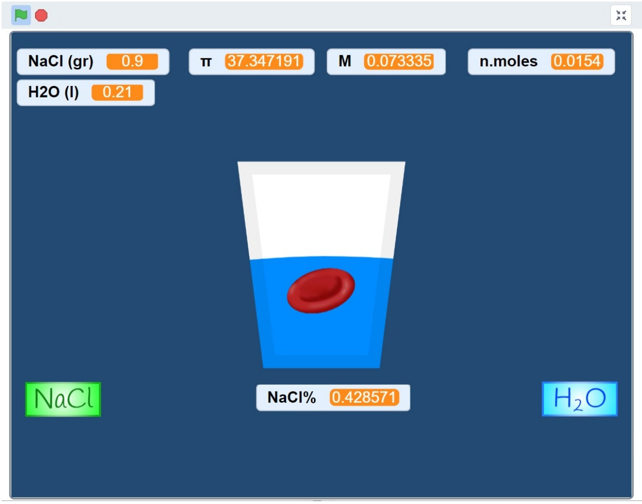

Figure 5: Hypotonic solution

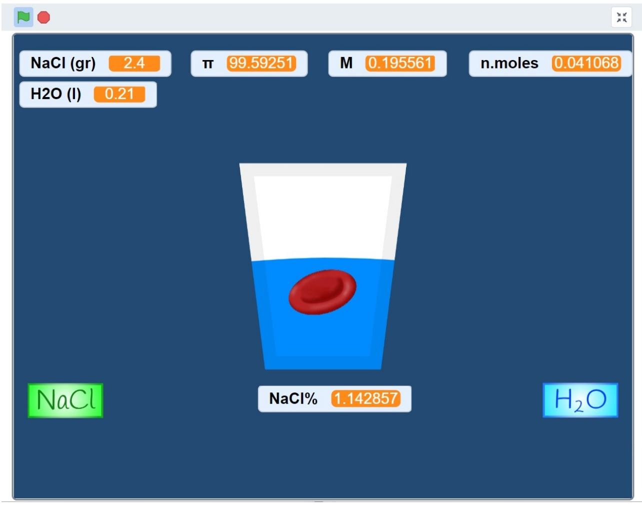

Figure 6: Hypertonic solution

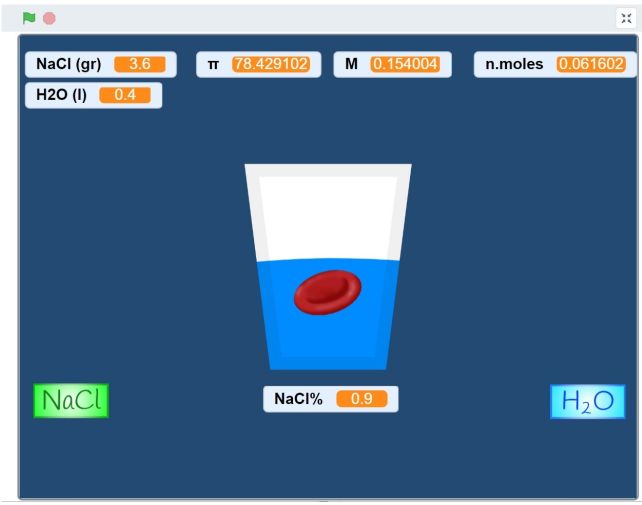

Figure 7: Isotonic solution