ISSN: 2184-7436

Revista APEduC Journal

Investigação e Práticas em Educação em Ciências, Matemática e Tecnologia

Research and Practices in Science, Mathematics and Technology Education

Section 1: *Research in Science, Mathematics and Technology Education*
Secção 1: *Investigação em Educação em Ciências, Matemática e Tecnologia*

STORYTELLING BASED ON THE HISTORY OF SCIENCE AS AN EFFECTIVE EDUCATIONAL TOOL – APPLICATION IN REAL CLASSROOM SETTINGS

CONTAR HISTÓRIAS COM BASE NA HISTÓRIA DA CIÊNCIA COMO UMA FERRAMENTA EDUCATIVA EFICAZ - APLICAÇÃO EM AMBIENTES DE SALA DE AULA REAIS

LA NARRACIÓN BASADA EN LA HISTORIA DE LA CIENCIA COMO HERRAMIENTA EDUCATIVA EFICAZ - APLICACIÓN EN AULA REAL

Nausica Kapsala & Evangelia Mavrikaki
National and Kapodistrian University of Athens, Greece
nkapsala@gmail.com

ABSTRACT | Telling stories derived from the History of Science (HOS) is an educational tool that can be used in science teaching to achieve multiple learning goals. In this research we examine the effectiveness of storytelling as an educational approach in secondary education biology teaching. We designed storytelling interventions about the transmission of diseases (grades: 8, 9, 12) and DNA structure (grade 9). We developed stories from the HOS and adapted them to the relevant curriculum. To evaluate the effectiveness of these interventions we used cognitive questionnaires, interviewed teachers and students in focus groups and used non-participatory observation of the approaches. HOS storytelling was effective in achieving cognitive goals, increasing students' engagement, improving classroom climate, bringing up NOS and sociocultural discussions, while both students and teachers enjoyed it and longed for more. Storytelling affects the classroom dynamics and the relationships among teachers and students cultivating the conditions for meaningful learning.

KEYWORDS: Storytelling, History of Science, Students' engagement, Classroom climate, Nature of Science.

RESUMO | Contar histórias provenientes da História da Ciência (HOS) é uma ferramenta educacional que pode ser utilizada no ensino das ciências para atingir múltiplos objetivos de aprendizagem. Nesta investigação, examinamos a eficácia da narração de histórias como uma abordagem educacional no ensino de biologia do ensino secundário. Concebemos intervenções de narração sobre a transmissão de doenças (8º, 9º, 12º anos) e estrutura do ADN (9º ano). Desenvolvemos histórias a partir da HOS e adaptámo-las ao currículo relevante. Para avaliar a eficácia destas intervenções, utilizámos questionários cognitivos, entrevistamos professores e alunos em grupos focais e utilizámos a observação não participativa das abordagens. A narração de histórias da HOS foi eficaz para alcançar os objetivos cognitivos, aumentando o envolvimento dos estudantes, melhorando o clima da sala de aula, trazendo à tona Natureza da Ciência e discussões socioculturais, enquanto que tanto estudantes como professores apreciaram e desejaram mais. A narração de histórias afeta a dinâmica da sala de aula e as relações entre professores e alunos, cultivando as condições para uma aprendizagem significativa.

PALAVRAS-CHAVE: Contar histórias, História da Ciência, Envolvimento dos alunos, Clima da sala de aula, Natureza da Ciência.

RESUMEN | La narración de la Historia de la Ciencia (HOS) es una herramienta educativa que puede utilizarse en la enseñanza de las ciencias para alcanzar múltiples objetivos de aprendizaje. En esta investigación, examinamos la eficacia de la narración de cuentos como enfoque educativo en la enseñanza de la biología en la escuela secundaria. Diseñamos intervenciones de cuentos sobre la transmisión de enfermedades (grados 8, 9, 12) y la estructura del ADN (grado 9). Desarrollamos las historias de la HOS y las adaptamos al plan de estudios correspondiente. Para evaluar la eficacia de estas intervenciones, se utilizaron cuestionarios cognitivos, se entrevistó a profesores y alumnos en grupos de discusión y se recurrió a la observación no participante de los enfoques. La narración de HOS fue eficaz para alcanzar los objetivos cognitivos, aumentar el compromiso de los estudiantes, mejorar el clima de la clase, hacer surgir la Naturaleza de la Ciencia y los debates socioculturales, mientras que tanto los estudiantes como los profesores disfrutaron y quisieron más. La narración de historias afecta a la dinámica del aula y a las relaciones entre profesores y alumnos, cultivando las condiciones para un aprendizaje significativo.

PALABRAS CLAVE: Narración de cuentos, Historia de la Ciencia, Participación de los alumnos, Clima del aula, Naturaleza de la Ciencia.

1. INTRODUCTION

Storytelling has been a teaching method ever since humans existed (Egan, 1989), so we strongly believe that it can result in raising students' attention, and in improving the classroom climate, creating a feeling of coherence among teacher and students making everyone feel like they are part of a bonded team. Stories from the History of Science (HOS) could serve best, so in our research we will examine if such an educational approach is a good tool to achieve the educational goals set by the curriculum, (biology content knowledge and Nature of Science (NOS)) and if it provides any other advantages to the learning process. We will follow a mixed method research approach and data triangulation. HOS storytelling will be designed and applied in real classroom settings gathering data to support or reject the effectiveness of the educational approach.

The contribution of our research is that it will provide evidence that promotion of HOS in biology teaching can be done without neglecting the content knowledge. Of course, further advantages or disadvantages will be examined.

2. LITERATURE REVIEW

Storytelling is a core human characteristic that describes the way we think, dream, construct our knowledge of the world, communicate, and learn (Bruner, 2003; Egan, 1989). Neurobiological and biochemical findings (Cheetham et al., 2014; Zak, 2015) support the notion that storytelling is an evolutionary characteristic of our species (Gottschall, 2012). Ever since humanity existed storytelling has been a crucial educational method, which allows learning from the experience of others from a distance and with safety (Gottschall, 2012).

The story-structure reflects the way our brains work (Egan, 1989). Stories work as a strong mnemonic tool; due to their form as well as the fact that they provoke feelings, their incorporated information can pass to the long-term memory (Bruner, 2003; Egan, 1989; Klassen, 2010). Not everything is a story though. We agree with the definition of Haven (2007) that a story is "a detailed narrative of a character's efforts to overcome obstacles and achieve an important goal" (p. 79). Haven (2007) also identified five narrative elements (central character / hero, intention, actions, efforts and obstacles, details) which are essential for the reader's or listener's brain to connect, understand, and decide to pay attention to a story.

In educational contexts it has been proposed that storytelling can reinforce class cohesion, and students' and teacher's relationships (Abrahamson, 1998; Wills, 1992). The mean of storytelling, orality, serves those purposes, as in oral communication the transmitter is simultaneously also a receiver (Ong, 2013). Functional Magnetic Resonance Imaging data show that while listening to a story, listeners exhibit similar brain activity (Wilson et al. 2008) and the brains of the speaker and his listeners display common, temporarily identified patterns of response (Stephens et al. 2010). The story told is being formed by the storyteller / teacher as well as by the listeners / students, whose reactions to the story affect it. During storytelling teacher and students share a common experience of co-creation that enforces their relationships. Moreover, due to dopamine released in the brain while listening to a story they experience feelings of contentment (Zak, 2015).

In science and in biology teaching, storytelling may be used to facilitate the introduction of history of science (HOS). HOS puts science in context, and science gets connected to more personal, moral, cultural, and political worries (Matthews, 1994); it gets humanized, and students get inspired and motivated (Kokkotas et al., 2010). HOS can also serve to introduce Nature of Science (NOS) aspects (Kapsala & Mavrikaki, 2020; McComas & Kampourakis, 2015), which are an essential part of scientific literacy (NSTA, 2020). HOS can facilitate students' conceptual change, helping them to collide their own alternative ideas. Through HOS, students get the opportunity to connect with science, to become familiar with scientific topics and to acquire positive attitudes towards science (Kokkotas, et al., 2010).

HOS storytelling in secondary education has been investigated in Physics and Chemistry courses with positive results concerning cognitive goals, students' engagement (Hadzigeorgiou et al., 2012; Kokkotas et al., 2010; Koliopoulos et al., 2010), and NOS instruction (Hansson et al., 2019). In biology courses, storytelling, as an educational tool, has been investigated mainly in college settings. Research shows that storytelling is as effective as "traditional" (teacher-centered) teaching in conceptual understanding of tricky concepts and in critical thinking development (Csikar & Stefaniak, 2018; Mavrikaki & Kapsala, 2014) and on some occasions it results in a greater extend of revision of alternative ideas (Cross, 2017). Moreover, students consider storytelling as helpful for understanding and remembering scientific concepts (Cross, 2017; Moitra, 2014; Frisch and Saunders, 2008). Students also find that stories help them to connect with their teachers, to keep engaged to the teaching process, and to associate the concepts with real life (Moitra, 2014; Frisch and Saunders, 2008).

However, there is not much research regarding storytelling as an educational tool in biology teaching and in secondary education settings. Therefore, in the present study we will investigate whether

1) HOS storytelling will be effective for achieving cognitive goals in biology in secondary education;
2) How do teachers and students evaluate storytelling as a teaching method;
3) How will HOS storytelling affect students' engagement and classroom climate;
4) If HOS storytelling could provoke discussions in the classroom about NOS and sociocultural aspects.

3. METHODOLOGY

The research was carried out both in a private school (grades: 8 and 9) and in a "tutoring center", where the teacher was a volunteer who taught 12th grade biology students of low-income families to prepare them for the national exams that would allow them to follow university studies. Though it was a convenience sampling (Bryman, 2016) in both cases, the fact that the students came from different social classes is expected to provide us stronger results that are not restricted to students of a given social class.

We followed both qualitative and quantitative approaches and data triangulation.

3.1 Sample

The sample of the research and its distribution to experimental groups, the number of students, the topics of the unit(s) and the story told in each case are presented in Table 1. In the social tutoring center, as there were only 10 students in each group, we decided to apply the approach in both groups and not use one of the groups as a control.

Table 1- *Description of the sample.*

Setting	**social tutoring** center (*pro bono)*	private school			
Grade	12	9		8	
Groups (E/C*)	2 E	1 E	1 C	1 E	1 C
Teachers	1	1			
Students	20	15	16	12	14
Girls / Boys	13/7	8/7	11/5	4/8	8/6
Focus Groups	4	3	-	3	-
Topic(s) of the Unit(s)	Transmission of diseases	Transmission of diseases / DNA structure	Transmission of diseases / DNA structure	Transmission of diseases	Transmission of diseases
Story	Typhoid Mary	John Snow / The Double Helix	John Snow / The Double Helix	John Snow	John Snow

* *E: Experimental / C: Control*

3.2 Method

3.2.1 The interventions' design

All interventions were implemented in all groups by the biology teacher of the school and the social tutor, respectively, so that students were familiar with the teacher.

The following lesson plan was implemented in all experimental groups:

A) Questions to connect with previous knowledge.

B) Introduction of new knowledge via HOS storytelling.

C) Application: Collaborative activity in which students are asked to answer questions in groups drawing elements: a) from the story they just heard, b) the textbook, and (c) in some cases other extracurricular material.

D) Assessment: Class discussion on the questions answered by the students in groups.

The stories that were told were developed by us, according to the story structure proposed by Bruner (2003) and to the story characteristics that Haven (2007) suggested. The stories were given to the teachers, along with storytelling tips (Kapsala & Mavrikaki, 2020). Teachers were asked to read them and then tell them in their own words to their students.

There were two different stories about the diseases' transmission and one story about the double helix:

- "John Snow" for grades 8 and 9 was based on Brody, Rip, Vinten-Johansen, Paneth and Rachman (2000) and Snow (1855).
- As "Typhoid Mary" is included in the 8th grade students' workbook and we wanted to evaluate the results of the oral narration of a story not familiar to the students we chose this story for grade 12 as more appropriate, where AIDS is also taught, as the story includes the concept "asymptomatic carrier". The story was developed based on Brooks (1996) and Soper (1939).
- The story about the double helix was based on Crick (1988) and Watson (2012).

Short versions of these stories are included in the work of Kapsala and Mavrikaki (2020).

The introduction of new knowledge in the control groups was done following a teacher-centered approach accompanied by a power point presentation. The application and the assessment were the same as in the experimental groups.

3.2.2 Research Tools

a. Observation Key

All interventions (experimental and control) were observed by a non-participatory observant who was using an observation key (pro-forma) (Walshe et al., 2012) part of which is shown in Table 2.

***Table 2**- Observation Key*

Time since the beginning of the lesson	No of students who participate	Comments
5		
10		
…		
45		

b. Teachers' reports

Right after each intervention each teacher reported and commented her experience concerning how she felt after the storytelling intervention and how she evaluated her students' engagement and participation.

c. Students' questionnaire regarding the cognitive content

Before the interventions and one month after the interventions, the students of all groups completed a short evaluation sheet with closed-ended questions about knowledge concerning disease transmission (all groups) and open-ended questions about DNA structure (grade 9 students only) (Appendix I).

Students' answers to the open-ended questions were graded according to the scale: 0 = irrelevant answer to the question, 1 = completely wrong answer, 2 = relatively wrong answer but right reasoning, 3 = correct but very incomplete answer, 4 = correct but incomplete answer, 5 = correct and complete answer. Question 4 was rated separately on a scale of: 1 = very incomplete, 2 = incomplete, 3 = moderate, 4 = relatively complete, 5 = complete.

Data collected from these questionnaires would help us assess the effectiveness of the approach regarding the knowledge gain of the students. Each student gets a score according to his/her answers (0 to 5 for the DNA test and 0 to 10 for the disease transmission test).

d. Students' interviews in focus groups

One month after the interventions, the students of the experimental groups participated in focus groups to record their opinions about the approach. Students could discuss certain topics more if they wished or raise new topics for discussion. Each focus group consisted of four to five students. The interviews' axes were the following: Do you remember what happened in your classroom during the lesson about the transmission of pathogenic microorganisms? / What was different that day? / How did you feel about that lesson? / Which part of the lesson did you enjoy the most? / How did you feel listening to the story? / Do you think the story helped you in any way, at that time or during your study at home? / Did you notice anything different about your teacher that day? / Would you be willing to attend more lessons taught like that?

3.3 Analysis of the data

To analyze students' answers to the questionnaires we followed descriptive and inductive statistics (averages, one-tailed paired t-test for pre-post tests, one-tailed independent t-test for differences between the control and experimental groups) using IBM SPSS 24. Students' and teachers' answers to the open-ended questions and the interviews were analyzed following thematic analysis (Braun and Clarke, 2012), with the unit of analysis being "the meaning unit" (Ratner, 2002); themes emerged from the analysed material, students' answers were coded and analyzed accordingly (frequencies of codes, etc.).

4. RESULTS

4.1 Contribution of the teaching approach to students' knowledge

Both teaching methods (storytelling and teacher-centered) proved to be equally effective in achieving cognitive goals (Table 3).

Table 3- *Students' performance at the disease transmission tests before and after the interventions*

Group	Score before	Score after	one-tailed paired t-test
12th grade E*	3,46	3,69	p=0,3>0,05
9th grade E	6,3	8,1	p=0,004<0,005
9th grade C	7,25	8,5	p=0,003<0,005
8th grade E	7,6	8,6	p=0,009<0,005
8th grade C	7,3	9	p=0,002<0,005

**The score could range from 0 to 6 for this group. For the rest of the groups the score could range from 0 to 10.*

No statistically significant differences (one-tailed independent t-test) were observed between the experimental and the control groups after the interventions (grade 8: p=0,46>0,05, grade 9: p=0,36>0,05).

For the 9th grade's students, their answers to the open-ended questions concerning DNA structure were improved in both groups. However, experimental group's students' answers revealed knowledge that was included in the story but not in their school textbook.

For example, the third question about the significance of the DNA structure (see APENDIX I) concerns a key teaching objective as it is important for students to understand the connection between the structure of DNA and the flow of genetic information (storage, preservation, transmission, expression). Prior to teaching, many students in both groups avoided answering the question, and those who answered focused on the fact that DNA structure determines the organism's characteristics. After the teaching, the students of both groups answered that the structure is important because it helps to store genetic information, and because it helps with the process of copying, transcription and translation, processes in which the two chains are separated. However, only students of the experimental group continued their thinking that thanks to the replication of DNA that is allowed due to its structure, new cells and new organisms are created and genetic traits are passed on to their offspring. This connection is not included in the text of the book (Mavrikaki et al., 2008). This information could be imprinted to them from the end of the story where Francis Crick excitedly goes crazy and explains the importance of the structure of DNA for the continuation of life and the transmission of characters from generation to generation.

As for question 4, about what it takes to make a scientific discovery, the answer contains information about the scientific method, which is part of the curriculum and was taught to students in both classes at the beginning of the school year. The elements mentioned in the textbook (observation, information gathering, hypothesis, test - experiment, verification, repetition, conclusion) (Mavrikaki, et al., 2008) were mentioned equally in the answers of the students of both classes, both before and after teaching. Some concepts though, were mentioned after teaching only by students of the experimental group. For example, that the discovery should be accepted by peers (a matter that concerns both stories they heard), or that it requires research and study, but also luck and taking risks. The reference to these facts could stem from the fact that these students have heard the story of "the double helix" and John Snow.

4.2 Teachers' views about the approach and the way their students perceived it

Both teachers were pleased with the method: *"Well, I really like it! I had a great time!", "Okay it was nice, and I think in the end I enjoyed the narration"*, and they reported that they wished to continue telling stories in their lessons.

The impression of both along with the feedback they received from their students was that students enjoyed it *"at the end of the lesson, two students approached me and told me that the lesson was very nice today." "One was very excited, and said it was a very fun way to learn something, and that they liked it very much."*

Regarding the involvement and participation of their students during the lesson, they both noted that in the lesson with the storytelling there participated *"more students than usual", "two little girls who are usually very hesitant, today participated more", "for the first time they were all so quiet. And in their participation, I saw a difference, they were activated, they showed interest and students who usually remain silent unless they are making a fuss about irrelevant issues, also participated. This time they also showed interest, and took the floor, asked, commented and that was a very pleasant surprise for me!".*

Teachers reported that they considered that HOS storytelling gives a good opportunity to discuss NOS and sociocultural aspects: *"It is an opportunity to discuss issues that otherwise I do not know how else I could approach". "It is easier to approach such issues in the context of the story, and make students think a little more about them outside the school curriculum"*.

Teachers also referred to a) difficulties they encountered with one of the stories ("The double helix") because it contained difficult scientific information, and b) a feeling of "stage fright" while telling the story. Nevertheless, their holistic impression was positive.

4.3 Observer's results

There were differences regarding students' behavior between the experimental and the control groups. In the experimental groups, the students' response to the stories was strongly positive; in some classes they even applauded at the end of the story. According to the observation key results, in the experimental groups the students stayed focused to the lesson for longer time than in the control groups. According to the observant's notes students' interruptions during the storytelling were about the story. Students' attention during the storytelling was high and they enthusiastically participated in the rest of the lesson. On the other hand, the students in the control groups were more distracted, especially during the frontal teaching, and discussed more about irrelevant staff during the rest of the lesson. The teacher was stricter in the control group. On the contrary, in the experimental group the teacher was calmer.

Moreover, the students in the experimental groups participated more fruitfully to the discussion in the end of the interventions as they could comment on some epistemological issues using the story they had heard. In the control groups the students could not respond to such a discussion as well, and to answer some questions they needed more guidance from their teacher and did not form their own point of view.

As an example, we provide some of the notes kept during the DNA structure interventions: Experimental group: the teacher asks a few questions about the Second World War and begins the narration. All students watch the teacher with their eyes, often commenting on the story,

asking questions about it and laughing. When the story is over, they applaud. Everyone participates in the following teamwork activity. The importance of the structure of DNA was discussed at the end of the discussion. The teacher asked them what impressed them about the story, and they answered: "that one complemented the other's theory". There was a discussion about how Watson and Crick relied heavily on the experiments of others, and the teacher explained who finally won the Nobel and why.

Control group: the lesson begins with some with questions to connect with prior knowledge. The teacher begins a slide show. There is a fuss, five students are talking to each other about irrelevant staff. The teacher is forced to make a remark. She tries to involve them in the lesson by asking them questions. Two other play with their pens making noise, the rest class observes the teacher and the slides. In the middle of the lesson all the students pay attention, some ask about heredity. A video is shown about the structure of the genetic material that causes positive reactions from the students. The teacher makes a fifth remark requesting silence and concludes about Watson and Crick. Overall, she has given more information about the structure of DNA in terms of the content of knowledge but not about the context, i.e. how the discovery was made, etc. The teamwork activity begins. About half of the students participate. After the 6th remark, there is silence in the classroom. Students have difficulty with the last questions of the activity. The teacher tries to guide them to find the answers by asking simpler questions.

4.4 Students' views recorded during the focus groups

The students enjoyed the storytelling and the stories, their interest was provoked, and they found the stories helpful to understand and learn scientific concepts. The discussion in the focus groups of all classes moved on the same axes, despite the age differences. The identified differences concerned the different stories' content (e.g., cholera, water, hands).

The codes and themes that came up from the thematic analysis and their frequencies are presented in Table 4. In the focus groups the students collectively answered the questions completing each other. A few examples of the students' statements about each code are presented in Table 5. Each statement may correspond to more than one themes, that perhaps belong to different codes.

Table 4- *Codes and themes identified in the focus groups (N=10) by the students*

Codes	Themes	Frequency	grades
Storytelling as a teaching method	Orality	2	8
	Imagination	1	9
	Vivid / creating mental images	7	8,9,12
	Creativity	1	12
	Outside the book	4	8,9,12
	It allows interaction with the teacher	4	8, 9, 12
	Time consuming	2	8
Cognitive goals	Easy to follow	5	8,9,12
	Facilitates understanding	10	8,9,12
	Facilitates learning	3	12
	Helps to remember	10	8,9,12

Codes	Themes	Frequency	grades
	Consolidation	2	12
	Acted as an example	5	8,9,12
	Helpful	8	8,9,12
	They recalled the whole told story	10	8,9,12
	Helped them during homework	7	8,9,12
	Practical	2	9
Students' engagement	Interesting	10	8,9,12
	Participatory	4	8,9
	Held their attention	2	9
	Satisfactory / wanted	10	8,9,12
	Quiet	1	8
	Nice	8	8,9,12
	Entertaining	3	8, 12
	Interactive	3	8,9,12
	Boring	1	12
Classroom climate	Relaxed classroom climate	3	8,9,12
	Difference in teacher's attitude	4	9, 12
	Provoked feelings	2	8,12
NOS - sociocultural	Knowledge does not easily get accepted by Peers and society	1	8
	Creativity is part of the scientific process	2	8,9
	Reasons why a person may not trust officials	2	12
	Knowledge in context	7	8,9,12

Table 5*- Examples of students' statements and the themes they were attributed.*

Examples	*Themes*
"Basically, even if she gave us the story in script, I would not have read it much. That is, I remember what our teacher said, and I remember it well."	*Orality, Helps to remember*
"Story… is like the difference between an encyclopedia and a documentary. The encyclopedia who sits to read it, while a documentary about nature okay, you will sit down to listen to it, it is like a story."	*Vivid / creating mental images*
"The lesson is even more practical, that is, it is like the equivalent of the experiment, something like that. In an experiment let's say it stays in your mind and gives you to understand it better, and in the story, it actually takes place a little in your head"	*Vivid / creating mental images, Practical*
"We imagined it [the story]"	*Imagination*
"We created our own story in our minds"	*Vivid / creating mental images*
"In the story, you form it in your mind, and depending on how you shape it, you usually remember it better"	*Vivid / creating mental images, Helps to remember*
"I remember the story, because it is your teacher who tells you, she makes it practical, and whatever question you want to ask, you can ask it at that moment"	*Orality, It allows interaction with the teacher*
"When they tell you something with a story, you understand it better and you also remember it."	*Facilitates understanding, Helps to remember*

Examples	*Themes*
"When I studied about diseases later, I used this story as an example in my mind, and it was more understandable to me."	*Acted as an example, Facilitates understanding, Helped them during homework*
"We memorized several things faster, without saying too many definitions and tedious… say… examples and terminology, yes. With the story we understood more"	*Helps to remember, Facilitates understanding*
"You bare it in mind, without need to study"	*Helps to remember*
"The fact that we started with a story, basically made us interested and then we paid attention to the whole lesson"	*Interesting, Held their attention*
"We participated more to this lesson than other times"	*Participatory*
"The lesson was given in a way that grabbed our attention"	*Held their attention*
"I think it was one of the most interesting lessons we have done in biology"	*Interesting*
"I think it was the most fun lesson we have ever done."	*Entertaining*
"It was more relaxed, and we participated as well, it was more… interactive"	*Relaxed classroom climate, Participatory,* Interactive
"Yes, there was a more relaxed atmosphere, and it was more relaxed, and we, in general… was… clearly the lesson was much nicer… we were all focused"	*Relaxed classroom climate, Nice, Held their attention*
"Basically [the teacher was] more relaxed, easier to do the lesson. Not like the other times that she keeps making remarks, nothing like that"	*Difference in teacher's attitude*
"-Basically, we saw the other side of the teacher, that, how to say that… -Like she enjoyed the story lesson more? -yes, she seemed immediate to me, more open, as if we were having a friendly chat, I can say"	*Difference in teacher's attitude, Relaxed classroom climate*
"And it was that is, it escapes a little bit from theory you saw it a little more practically, because it really happened. Not just the theory and that's it, but also what and how it happened."	*Knowledge in context, Practical*
"Because it was a story, an event that has happened, well, we understood it better than something general and vague that may never happen to us"	*Knowledge in context*
"- I think it was hard for people to believe what John Snow was saying. -yes, they believed that with the winds. -Basically, I did not expect them not to believe so much what he was saying"	*Knowledge does not easily get accepted by peers and society*
"I was impressed by the fact that he thought about all this."	*Creativity is part of the scientific process*
"With this story we saw that biology also happens in everyday life, that is, how can I explain it? it is everywhere in our daily lives"	*Knowledge in context*
"it made us think a little, to think about the seriousness of the situation in some issues"	*Knowledge in context*

5. DISCUSSION

5.1 HOS storytelling effectiveness concerning cognitive goals

Storytelling based on the HOS in our approach was as effective in achieving cognitive goals as the traditional teaching method. This is in accordance with the literature (Hadzigeorgiou et al., 2012; Kokkotas et al., 2010; Koliopoulos et al., 2010; Mavrikaki & Kapsala, 2014; Csikar &

Stefaniak, 2018). However, through the HOS-storytelling intervention students embedded extra information besides the textbook's content, probably because through the story the teacher finds an opportunity to say "something more" to the students which is not included in the educational material. It is impressive that students remembered the extra information (i.e. the meaning of the DNA structure), although they did not have the opportunity to refer to it. Perhaps it is due to the medium, the story that facilitates memorization (Bruner, 2003; Egan, 1989; Klassen, 2010).

5.2 Teachers' views towards HOS storytelling

The teachers were contented by the implementation of the method and by the response of their students. Tigner's (1993) findings about storytelling leaving teacher and students with a feeling of satisfaction were confirmed by our results. Both teachers claimed that they wished to implement more HOS-storytelling in their teaching in the future.

5.3 Students' views towards HOS-storytelling

The students enjoyed the HOS-storytelling lesson. They declared that they found the process pleasant, and they felt contented. This is important as satisfaction relates to how easily someone learns (Guolla, 1999). All students (but one) expressed the desire for more HOS-storytelling lessons. One student (8th grade) characteristically said: *"Biology without stories: no, biology with stories: yes!"*.

Students parallelized HOS-storytelling with performing an experiment and characterized it as participatory and practical (see Table 5). This may seem like a paradox but according to neurobiological findings listening to a story is a very active action for the brain, as mirror neurons get activated in motor, aesthetic, and other areas, and the listener experiences the story as if they are living it (Cheetham et al., 2014). Listening to a story is an active process of collecting facts, forming hypotheses, testing them, and correlating new information to the already existing, that can lead to active learning (Kokkotas et al., 2010).

In 7 (out of 10) focus groups it was mentioned that through storytelling the story gets "played" in their mind, and that, as they listen, they create mental images. This is the goal of storytelling – the teller describes what he sees in mind to make listeners create their own pictures in their minds. Students appreciated the given freedom to shape the story in their mind instead of watching a video. During storytelling each listener crates their own personal mental images and through those they connect new information to the existing one (Hadzigeorgiou et al., 2012).

In 4 focus groups students appreciated the live, oral storytelling and the deep connection and communication that direct oral speech can offer (Ong, 2013; Stephens et al., 2010). While students in 4 focus groups underlined the fact that during storytelling they could directly interact with their teacher.

5.4 Students' views regarding the achievement of cognitive goals through the HOS-storytelling approach

In all (10) focus groups the students collectively recalled and retold the story they had heard, something that impressed even themselves, and they attributed it to the story: *"we still remember it! basically this stays in your mind even more because... yes now we somehow remember it, while... the theory after a while, we forget it"*.

In 7 (out of 10) focus groups students underlined that the story helped them while studying at home and that they brought it in mind as an example to comprehend what they studied. This was also noted in previous research with biology majors (Frisch & Saunders, 2008). Moreover, they said that with the story they learned everything without needing to study, and that the story helped them understand and memorize scientific information, which is in accordance with the findings of other researchers (Cross, 2017; Mavrikaki & Kapsala, 2014; Moitra, 2014; Frisch & Saunders, 2008).

Some students of the 9th grade said: *"Because it (the story) is directly related with the material we do now, (…)we knew some things so we could also discuss in class not just listen to the lesson, we could ask her (our teacher) about various diseases such as Ebola and cholera…"*. Students stated that through the story they had achieved the first two cognitive goals (according to Bloom), learning, and understanding, and so they were ready to conquer others (application, analysis, and evaluation) through discussion with their teacher (Anderson & Krathwohl, 2001).

5.5 HOS-storytelling influence on the students' engagement

All students off all groups were amused by the storytelling (except for one student of the 12th grade). They characterised the lesson as different, interesting, fantastic, fun, and pleasant (see Table 5). Students said that they participated more to this lesson, and that they paid attention. All this is confirmed by the teachers' reports and the observation key. Students' interest is a very important factor of learning as it is associated with the intrinsic motives for learning (Mavrikaki, et al., 2012).

Students from all grades were emotionally engaged with the stories and empathised with the heroes *"I can't describe how I felt, I was moved by this woman who was illiterate, and she didn't know…"*, *"had I been there I would be scared"*. It is important to provoke feelings, this way the lesson is enriched, plus information that gets connected with feelings, passes to the long-term memory more easily (Egan, 1989).

The student who had a negative opinion, said that he found the story boring and that he did not enjoy the fact that *"our teacher was the only one talking, we could not have an opinion"*. His classmates in the same focus group disagreed and told him that he could have interrupted if he had something to say. He replied *that "I don't like it, I was not inspired, and I don't have the interest to follow it"*. He was the only one in 47 students who did not find the method interesting. But he rings the bell that as teachers we should never relax in our vigilance and try to use different teaching methods and tools to assure that we do not exclude anyone from our teaching.

5.6 Influence of HOS-storytelling on the classroom climate

Data triangulation confirms that storytelling was beneficial for the classroom climate. The students were more cooperative, the teachers were calmer, and the classroom climate was more relaxed. There was a sense of partnership among teacher and students. This agrees with literature: through storytelling, both students and teachers get inspired and satisfied (Tigner, 1993), their relationship is enriched and strengthened (Abrahamson, 1998) as they get the feeling of "common creation" that enforces class cohesion, and they become part of the same bonded community (Wills, 1992).

Moreover, students found their teachers different, calmer, more approachable, and friendlier. Storytelling can contribute to the repositioning of teachers' and students' roles, making them collaborators and creating a friendly and trustful classroom climate that can contribute to fruitful, democratic, honest dialogues and that can sharpen their critical thinking and promote meaningful learning (Kapsala, Mpalampekou & Mavrikaki, 2017). Research in college settings has also shown that through storytelling students felt closer to their teachers (Moitra, 2014; Frisch and Saunders, 2008).

5.7 HOS-storytelling as an opportunity to introduce NOS and sociocultural issues

Some students commented positively that the story was real. They also claimed that the story helped them to connect biology with the real life and to realise that science is something they can find everywhere in their everyday life. Even about the transmission of diseases, a very practical issue, one 12th grade student claimed that it was the typhoid's Mary story that helped him realise that microbes are spread in easy, everyday life ways. In literature it has also been found that storytelling helps students to connect science with everyday life (Moitra, 2014; Frisch and Saunders, 2008).

During the students' interviews in 7 out of 10 focus groups, students commented that they appreciated how through the story, the taught material was put in context, e.g., *"through the story we can understand the time and the condition that was then dominant…"*. While other students (see Table 5) noted that through the storytelling they escaped the "plain" theory (that as they say they do not always understand and they easily forget) and they got the opportunity to learn exactly what happened and how it happened and find out about all the procedures that led to the scientific discovery and not just the results, what Dolphin et al. (2018) names as "ready science". HOS gives the opportunity for students to experience science as it is produced (Dolphin et al., 2018).

Moreover, during the interviews students of all grades commented that through the stories, in a way, they "entered" the historical context of the time and they saw the heroes and the scientists of the stories as humans and not superheroes, which is one of the goals of NOS instruction (NSTA, 2020). They also developed some thoughts about other NOS aspects, like the tentative nature of scientific knowledge, and some sociocultural issues confirming the literature about the appropriateness of HOS to introduce NOS (McComas & Kampourakis, 2015; Matthews, 1994)

The above was also confirmed by the teachers who recognised that the HOS-storytelling gave them the opportunity to discuss such issues. The observation results showed as well that the students - from the experimental groups - who had heard a story were in a better position to discuss about NOS and sociocultural issues, compared to the students of the control groups. Hansson's (2019) findings in secondary education physics courses agree with ours.

5.8 Limitations of the results

The presented research concerns a limited sample. Although our results are supported by the literature, it is important to repeat the process in a larger sample to be able to generalize our findings.

6. CONCLUSIONS

HOS storytelling is an effective educational tool in achieving cognitive goals. Teachers and students enjoy it and appreciate it as helpful and amusing. Students claim that the story helps them understand and remember scientific data, and that they use it as an example in their minds to understand theory. They characterize it as an active process during which their imagination is provoked, and they create mental images. They also underline the importance of the fact that the story was orally delivered by the teacher instead of a script, and they attribute part of the improved classroom climate to this live deep communication.

Data triangulation confirms that HOS-storytelling raises students' attention, participation, and engagement, and that it results in a better classroom climate where teacher and students are co-players. Through HOS-storytelling students get emotionally engaged to the story and see their teachers as more approachable. The students spontaneously confirmed a lot that has been theoretically written about storytelling as a teaching method, as well as other researchers' findings.

The contribution of our research is that we propose an easy and pleasant way (for both students and teachers) to introduce HOS in science teaching, offering teachers a tool to attract their students' interest and achieve cognitive and epistemic goals. There is a lot more though, as the method we propose creates a different educational situation. Oral storytelling affects students and teachers as persons, affects their relationships, affects the classroom climate and the classroom dynamic. The conditions it creates cultivate trust and they are ideal for fruitful and truthful conversations concerning sociocultural topics and for meaningful learning.

7. IMPLICATIONS

Our study sheds light on the effects of HOS-storytelling in biology teaching in secondary education students. HOS-storytelling is found to be effective in achieving cognitive goals, rising students' engagement, and making the classroom climate relaxed and friendly. It would be interesting to investigate whether HOS-storytelling is indeed beneficial in other school settings such as in public schools. Also, although students and teachers in our research have declared that they came in touch with NOS concepts, it still needs to be researched whether this is done in an effective way.

REFERENCES

Abrahamson, C. E. (1998). Storytelling as a pedagogical tool in higher education. *Education*, *118*(3), 440-451.

Anderson, L. W., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. London: Longman. ISBN: 080131903X

Braun, V., & Clarke, V. (2012). Thematic analysis. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf, & K. J. Sher (Eds.), APA handbook of research methods in psychology, Vol. 2. Research designs: Quantitative, qualitative, neuropsychological, and biological (pp. 57–71). Washington, DC: American Psychological Association. https://doi.org/10.1037/13620-004

Brody, H., Rip, M. R., Vinten-Johansen, P., Paneth, N., & Rachman, S. (2000). Map-making and myth-making in Broad Street: the London cholera epidemic, 1854. *The Lancet, 356*(9223), 64–68. doi:10.1016/S0140-6736(00)02442-9

Brooks, J. (1996). The sad and tragic life of Typhoid Mary. *Canadian Medical Association Journal, 154*(6), 915–916.

Bruner, J. S. (2003). *Making stories: Law, literature, life*. London: Harvard University Press

Bryman, A. (2016). *Social research methods*. Oxford: Oxford university press.

Cheetham, M., Hänggi, J., & Jancke, L. (2014). Identifying with fictive characters: Structural brain correlates of the personality trait "fantasy." *Social Cognitive and Affective Neuroscience*, *9*(11), 1836–1844. http://doi.org/10.1093/scan/nst179

Crick, F. (1988). *What Mad Pursuit : a Personal View of Scientific Discovery*. New York NY: Basic Books.

Cross, C. J. (2017). An Analysis of Storytelling on Student Content Acquisition. *The American Biology Teacher, 79*(8), 628–634. doi: https://doi.org/10.1525/abt.2017.79.8.628

Csikar, E., & Stefaniak, J. E. (2018). The utility of storytelling strategies in the biology classroom. *Contemporary Educational Technology, 9*(1), 42-60. https://digitalcommons.odu.edu/stemps_fac_pubs/56

Dolphin, G., Benoit, W., Burylo, J., Hurst, E., Petryshen, W., & Wiebe, S. (2018). Braiding history, inquiry, and model-based learning: A collection of open-source historical case studies for teaching both geology content and the nature of science. *Journal of Geoscience Education,* 66(3), 205-220, doi: 10.1080/10899995.2018.1475821

Egan, K. (1989). Memory, imagination, and learning: Connected by the story. *Phi Delta Kappan, 70*, 455-459.

Frisch, J. K., & Saunders, G. (2008). Using stories in an introductory college biology course. *Journal of Biological Education*, *42*(4), 164-169.

Gottschall, J. (2012). *The Storytelling Animal: How Stories Make Us Human*. Boston, NY: Houghton Mifflin Harcourt.

Guolla, M. (1999). Assessing the teaching quality to student satisfaction relationship: Applied customer satisfaction research in the classroom. *Journal of marketing theory and practice*, *7*(3), 87-97.

Hadzigeorgiou, Y., Klassen, S., & Klassen, C. F. (2012). Encouraging a "romantic understanding" of science: The effect of the Nikola Tesla story. *Science & Education*, *21*(8), 1111-1138.

Hansson, L., Arvidsson, A., Heering, P., Pendrill, A.M. (2019). Rutherford visits middle school: a case study on how teachers direct attention to the nature of science through a storytelling approach. *Physics Education. 54*, 045002.

Haven, K. (2007). *Story Proof: the science behind the startling power of story*. Westport, CT: Libraries Unlimited.

Kapsala, N., & Mavrikaki, E. (2020). Storytelling as a Pedagogical Tool in Nature of Science Instruction. In McComas W. F. (ed.), *Nature of Science in Science Instruction*, 485-512, Springer, Cham.

Kapsala N., Mpalampekou, M. & Mavrikaki, E. (2017). Repositioning Science Teacher's Role in The Context of Critical Education with History of Science Storytelling. In Gounari, P., Liambas, A., Drenoyianni, H., & Pavlidis, P. (Eds) (2019). *"Rethinking Alternatives to Neoliberalism in Education". Proceedings of the lx International Conference on Critical Education.* ISBN: 978-960-243-712-4, Volume I, pp. 125-143. http://www.eled.auth.gr/, date accessed 10/04/2020.

Klassen, S. (2010). The Relation of Story Structure to a Model of Conceptual Change in Science Learning. *Science & Education, 19*(3), 305–317.

Kokkotas, P., Rizaki, A., & Malamitsa, K. (2010). Storytelling as a strategy for understanding concepts of electricity and electromagnetism. *Interchange, 41*(4), 379-405.

Koliopoulos, D., Dosis, S., & Kanderakis, N. (2010). The attitudes of students toward the introduction of case histories inspired from the History of Science in the teaching of Science. In HIPST International Conference, Kaiserslautern, Germany, 11-14/3, Kaiserslautern: http://www.hipst.uni-hamburg.de/archive%20of%20papers.html

Matthews, M. (1994). *Science Teaching: The Role of History and Philosophy of Science.* New York: Routledge.

Mavrikaki, E. & Kapsala, N. (2014). Teaching biology by storytelling. In G. Katsiampoura (ed.), *Scientific Cosmopolitanism and Local Cultures: Religions, Ideologies, Societies, Proceedings of the 5th International Conference of the European Society for the History of Science* (pp. 612-617). Athens. ISBN 978-960-98199-3-0.

Mavrikaki, E., Koumparou, H., Kyriakoudi, M., Papacharalampous, I., & Trimandili, M. (2012). Greek Secondary School Students' Views about Biology. *International Journal of Environmental and Science Education*, *7*(2), 217-232.

McComas, W. F., & Kampourakis, K. (2015). Using the History of Biology, Chemistry, Geology, and Physics to Illustrate General Aspects of Nature of Science. *Review of Science, Mathematics and ICT Education, 9*(1), 47–76.

Moitra, K. (2014). Storytelling as an active learning tool to engage students in a genetics classroom. *Journal of microbiology & biology education*, *15*(2), 332-334. https://doi.org/10.1128/jmbe.v15i2.815

Ratner, C. (2002). Subjectivity and Objectivity in Qualitative Methodology [29 paragraphs]. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 3*(3), Art. 16, http://nbn- resolving.de/urn:nbn:de:0114-fqs0203160.

NSTA Board of Directors. (2020). *Nature of Science | NSTA*. [online] Available at: <https://www.nsta.org/nstas-official-positions/nature-science> [Accessed 3 March 2021].

Ong, W. J. (1997). *Προφορικότητα και εγγραμματοσύνη: Η εκτεχνολόγηση του λόγου*. (Κ. Χατζηκυριάκος, Μτφρ.) Ηράκλειο: Πανεπιστημιακές Εκδόσεις Κρήτης.

Snow, J. (1855). *On the Mode of Communication of Cholera*, Second Edition. London: John Churchill.

Soper, G. A. (1939). The Curious Career of Typhoid Mary. *Bulletin of the New York Academy of Medicine, 15*(10), 698–712.

Stephens, G. J., Silbert, L. J., & Hasson, U. (2010). Speaker – listener neural coupling underlies successful communication. *Proceedings of the National Academy of Sciences of the USA, 107*(32): 14425-14430. doi:10.1073/pnas.1008662107

Tigner, S. S. (1993). Homer, teacher of teachers. *Journal of Education, 175*, 43-63.

Walshe, C., Ewing, G., & Griffiths, J. (2012). Using observation as a data collection method to help understand patient and professional roles and actions in palliative care settings. *Palliative medicine*, *26*(8), 1048-1054.

Watson, J. (2012). *The Double Helix.* London: Hachette UK.

Wills, J. E. (1992). Lives and Other Stories: Neglected Aspects of the Teacher's Art. *The History Teacher, 26*(1), 33-49. http://doi.org/10.2307/494084

Wilson, S. M., Molnar-Szakacs, I., & Iacoboni, M. (2008). Beyond superior temporal cortex: Intersubject correlations in narrative speech comprehension. *Cerebral Cortex, 18*(1), 230–242. http://doi.org/10.1093/cercor/bhm049

Zak, P. J. (2015). Why Inspiring Stories Make Us React : The Neuroscience of Narrative. *Cerebrum*, (February), 1–13.

APPENDIX I

A. The closed-ended questions concerning disease transmission that were included in the evaluation sheet that all students filled in before and one month after the interventions.

1) Disease-causing microorganisms are characterized as (choose the correct answer): a. pathogens b. harmful c. beneficial d. bacteria

2) When an organism is infected by a pathogenic microorganism, we mean that (choose the correct answer): a. this microorganism is generally pathogenic b. this microorganism exists in the environment of the specific organism c. the microorganism has entered within that organism d. the microorganism is harmless

3) The diseases that are characterized as infectious are those that (choose the correct answer): a. can be transmitted from air to humans b. can be transmitted from person-to-person c. are inherited diseases d. are diseases due to environmental factors

4) Pathogens can be transported over long distances by dust and insects (True or False)

5) In a plate of food there may "sit" microorganisms from cough droplets or sneezing, with dust or from flies (True or False)

6) Pathogens cannot be transmitted via sexual contact (True or False)

7) Deadly diseases such as Ebola and cholera cannot be transmitted via a handshake. (True or False)

8) The quality of the sewer system does not affect the outbreak of epidemics. (True or False)

9) A pandemic definitely has more cases than an epidemic. (True or False)

10) The symptoms of a disease appear as soon as we get infected by a microorganism. (True or False)

B. The open-ended questions concerning DNA structure that were included in the evaluation sheet that 9th grade students filled in before and one month after the interventions.

1) Where is the genetic information inside the cell?

2) What is the structure of DNA?

3) What is the significance of the DNA structure? (Its implications)

4) What does it take to make a scientific discovery?