

Supporting the Understanding and Memorization of Advanced Chemistry Concepts in Third-Year Junior High School Students through Narrative Techniques

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Abstract

The applications of Science Communication (SciComm) can support teaching by making it more productive by engaging the audience's interest. One tool of SciComm is the narrative technique, which has tangible results. If designed appropriately, it can assist in a fuller understanding of concepts and in their memorization. In this section of our research, we studied the effectiveness of four narrative approaches to advanced Chemistry concepts in twenty 3rd-year Junior High School students at Anavryta Model Junior High School. The students were divided into two groups. Subsequently, the techniques were alternately applied, and the results were compared regarding both the understanding of the thematic subject and the duration of the educational imprint. Statistically significant positive results were confirmed.

Keywords: Science Communication, narrative technique

Introduction

Science Communication (SciComm) is defined as the use of appropriate means and approaches for the interaction between scientists and the non-scientific public, aiming to promote scientific knowledge (Burns et al., 2003).

SciComm refers to the process and techniques by which scientific knowledge, ideas, and discoveries are communicated from scientists and research institutions to a less specialized audience. The goal of science communication is to inform, educate, and enhance public understanding and participation in the scientific process. The available means that can now be utilized for this purpose are numerous and include the internet, print media, radio, television, and museums.

During the phase of doctoral research, we studied the parameters of SciComm (Asimellis et al., 2020; 2021a; 2021b; 2022a) and the effectiveness of its educational parameter in both face-to-face applications (Asimellis et al., 2021c; 2021d) and online approaches (Asimellis et al., 2022b). In the context of our postdoctoral research focused on SciComm, we further explored the possibility of educating someone more effectively, faster, and with a more extended educational imprint through its applications. This part of our research focused on a specific audience observed over a long period. The aim of the research was to test the educational value of specific narratives as a tool for a fuller understanding of scientific concepts and as a supportive tool for the memorization of the taught material over a longer period. Our sample consisted of twenty 3rd-year middle Junior High School students from the

excellence, creativity and innovation group of the Model Junior High School of Anavryta. The students who participated in the group generally showed particular interest in the scientific field of Chemistry, achieved high performance, and adopted laboratory behavior consistent with safety rules. The application and investigation were carried out in the 2023-2024 academic year.

The teaching narrative, i.e., the inclusion of short stories in teaching, is a means of SciComm and has scientifically proven benefits in education, as it can enhance understanding, memorization, and knowledge transfer. The use of appropriate teaching narratives increases audience attention and concentration, enhances understanding, facilitates memorization (Haven, 2007), promotes critical thinking (Schank, 1995), strengthens emotional engagement (Green et al., 2003), creates multicultural sensitivity (Dahlstrom, 2014), and connects scientific knowledge with everyday life (McEwan & Egan, 1995). Narrative is a fundamental human process for understanding the world and organizing knowledge, making it particularly effective in the educational process (Bruner, 1991).

Methodology

In this research, short stories were used to help understand:

- *Catalyst Concept*: Understanding how a catalyst remains unchanged in quantity and quality during a chemical reaction.
- *Surface Area's Role in Reaction Rates*: The effect of surface area on the rate of reactions involving solids or pure liquids.
- *Energy Degeneration*: The concept of energy degeneration and the specific amount of energy required to excite an electron within an atom.
- *Appropriate Energy Amount for Exciting an Electron in an Atom*.

The technique used was as follows: the students of the group were divided into two equal groups, A and B, of ten individuals each. When Group A was taught the first thematic, the same worksheet based on guided inquiry technic was used as that of the other group, with the only difference being that the corresponding story was included in it. The same approach was used for the third thematic. In the second and fourth themes, the worksheet was again common for both groups, but the narrative technique was applied only to Group B. After completing each unit, there was a written individual examination with closed-type questions common to all students. Subsequently, the performances of the two groups were studied separately, and an analysis was conducted to see if statistically the average performance differed significantly between them when the specific story technique was utilized. Additionally, a corresponding written examination was repeated three months after the teaching to observe whether the taught material remained active in memory. The structure of each evaluation test was examined for content validity and internal validity, ensuring that the assessed elements are representative. Additionally, the reliability of internal consistency was tested using Cronbach's alpha as a criterion. The measured value in each case ranged between 0.868 and 0.886, leading to the conclusion that good internal consistency reliability was achieved. Statistical testing was conducted using an independent samples t-test with the SPSS software at a 95% confidence interval.

Results and Discussion

Catalyst Concept

Catalysis is a field of Chemistry with particular importance. The idea of a material involved in the reaction mechanism, making it faster—thereby solving the problem of the slow rate of its occurrence—while remaining qualitatively and quantitatively unchanged, is difficult for students to grasp. To better understand the regeneration of the catalyst after accelerating the reaction in which it was used, the following story from mathematics was used:

"Once upon a time, there was an Arab father who had three sons. When he died, he left his property, i.e. his 17 camels, to his children. The condition of the will was that the eldest

son would receive half of the herd, the second a third, and the third a ninth. Obviously, the problem arises because the number of 17 camels is not divisible by any of the numbers 2, 3, or 9. The children had fallen into despair until one day a friend of theirs, riding his camel, met them by chance. When the three sons told their friend what had happened, he replied, 'No problem! Take my camel!' Now the children had 18 camels. The first son took half of them, i.e., 9. The second took a third, corresponding to 6 camels. The third took a ninth, thus 2 camels. Therefore, the sum of the camels they divided was $9+6+2=17$. Subsequently, they returned the extra camel to their friend. Problem solved. Just as the friend's camel 'entered' the problem and was 'regenerated' qualitatively and quantitatively unchanged, so too can a catalyst engage in a reaction, modify the path the reactants take to become products, and ultimately regenerate after speeding up the reaction."

The results of the written examination obtained from the two groups were tested with an independent samples t-test using SPSS software to determine whether statistically the mean scores differed significantly at a 95% level. In each case, prior to the use of the t-test, the normality of the distributions was tested, and through the Kolmogorov – Smirnov test, it was determined that at a 95% significance level, they do not statistically significantly differ from a normal distribution. The average score of Group A was 18.0, while that of Group B was 14.4.

Table 1. Mean and Standard Deviation of Scores for the Two Groups

Group	N	Mean	Standard Deviation
A	10	18.0000	2.10819
B	10	14.4000	3.86437

Assuming the null hypothesis (H_0) that statistically there is no significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.009 < \alpha$. This means we reject the null hypothesis and conclude that the mean score of Group A is significantly higher than that of Group B at a 95% confidence level.

Table 2. t-test for Independent Samples

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
2.586	18	0.009	0.019	3.60000

The written examination was repeated—this time with different closed-type questions—on the same topic after three months. The results were tested to see if the mean score statistically differed significantly both between the different groups and between the individuals who were members of the same group. The first test aimed to check the effectiveness of incorporating the specific narrative into the teaching unit, and the second to assess the possibility of extending the memorization of knowledge over a more extended period.

The average score of Group A was 17.2, while that of Group B was 13.2.

Table 3. Mean Scores of the Two Groups After Three Months

Group	N	Mean	Standard Deviation
A	10	17.2000	2.69979
B	10	13.2000	2.69979

Assuming the null hypothesis (H_0) that statistically there is no significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.002 < \alpha$. This means we reject the null hypothesis and conclude that statistically the

mean score of Group A remained significantly higher than that of Group B at a 95% confidence level.

Table 4. t-test for Independent Samples After Three Months

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
3.313	18	0.002	0.004	4.00000

Additionally, we conducted a paired-samples t-test for each group separately at a 95% significance level to determine whether the mean score significantly decreased or not, to assess the improvement or otherwise of the long-term memorization of the taught material. For Group A, we obtained $p = 0.084 > \alpha$, while for Group B, we calculated $p = 0.041 < \alpha$.

Table 5. Paired-Samples t-test Separately for the Members of the Two Groups

	t	df	Significance	
			One-Sided p	Two-Sided p
Group A	1.500	9	0.084	0.168
Group B	1.964	9	0.041	0.081

This leads to the conclusion that in the case of Group A, the mean performance score did not significantly decrease, while in Group B, there was a significant decrease in the mean score. Thus, the educational significance of the specific narrative technique was confirmed both in terms of understanding the concept it concerned and for improving its memorization.

Surface Area

The reaction rate is a subject of study in chemical kinetics. One of the factors that affect the speed of a reaction is the surface area of the pure liquids or solids reacting with other reactants. However, this factor is often taught briefly without confirmed educational outcomes. To better understand how the reaction rate is affected by the surface area of the pure liquids or solids involved in the reaction, the following historical narrative was used:

"The Battle of Thermopylae took place in 480 BC between the Persians and the allied Greek army. The specific location was chosen due to the strategic importance of the narrow passage. Thermopylae was a narrow path between the mountains and the sea, limiting the movement of the numerous Persian troops. King Leonidas of Sparta and his 300 Spartan warriors, along with other Greek forces, chose to defend this passage to halt the advance of the Persians, giving the rest of Greece time to organize its defense (Pressfield, S. 1998)".

"The Battle of Salamis took place between the Persians and the Greeks in 480 BC. The Persian fleet had a clear numerical superiority. However, it was won by the Greeks mainly due to the clever strategy of Themistocles. The Greeks managed to lure the Persian fleet into the narrow straits of Salamis, where the numerically superior Persian fleet could not deploy its full strength. On one hand, the Persian ships were lined up in three rows, so they fought few at a time; on the other hand, the smaller and more agile Greek ships took advantage of the confined waters and successfully attacked, causing great confusion and destruction among the Persians, leading to their defeat (Strauss, B. 2004)".

These historical events were chosen to highlight the importance of the surface area between the "reactants." Specifically, we observe, that the Persian superiority did not help them because, ultimately, what played a crucial role was the interface area between the two fleets, which was small in the narrow straits of Salamis. Similarly, solid reactants interact only through the surface that comes into contact with the other reactants in the reaction. Therefore, breaking them down into smaller pieces increases the interface area and accelerates the reaction, as the internal portion of the solid is now exposed to the other reactant.

A written examination followed, and the results obtained from the two groups were tested with an independent samples t-test using SPSS software to determine whether the mean scores differed statistically at a 95% significance level. In each case, prior to the use of the t-test, the normality of the distributions was tested, and through the Kolmogorov – Smirnov test, it was determined that at a 95% significance level, they do not statistically significantly differ from a normal distribution. It should be noted that the narrative technique was applied to Group B. The average score of Group A was 16.0, while that of Group B was 18.0.

Table 6. Mean and Standard Deviation of Scores for the Two Groups

Group	N	Mean	Standard Deviation
A	10	16.0000	2.66667
B	10	18.0000	2.10819

Assuming the null hypothesis (H_0) that statistically there is no significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.040 < \alpha$. This means we reject the null hypothesis and conclude that statistically the mean score of Group B is significantly higher than that of Group A at a 95% confidence level.

Table 7. t-test for Independent Samples

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
-1.861	18	0.009	0.040	-2.00000

The written examination was repeated—with different closed-type questions—on the same thematic after three months. The results were tested to see if statistically the mean score differed significantly both between the different groups and between the individuals who were members of the same group. The first test aimed to check the effectiveness of incorporating the specific historical narrative into the teaching unit, and the second to assess the possibility of extending the memorization of knowledge over a more extended period.

The average score of Group A was 14.4, while that of Group B was 16.8.

Table 8. Mean Scores of the Two Groups After Three Months

Team	N	Mean	Standard Deviation
A	10	14.4000	2.79682
B	10	17.2000	3.29309

Assuming the null hypothesis (H_0) that statistically there is no significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.028 < \alpha$. This means we reject the null hypothesis and conclude that the mean score of Group B remained statistically significantly higher than that of Group A at a 95% confidence level.

Table 9. t-test for Independent Samples After Three Months

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
-2.049	18	0.028	0.055	-2.80000

Additionally, we conducted a paired-samples t-test for each group separately at a 95% significance level to determine whether the mean score significantly decreased or not, to assess the improvement or otherwise of the long-term memorization of the taught material. For Group A, we obtained $p = 0.041 < \alpha$, while for Group B, we calculated $p = 0.084 > \alpha$.

Table 10. Paired-Samples t-test Separately for the Members of the Two Groups

	t	df	Significance	
			One-Sided p	Two-Sided p
Group A	1.964	9	0.041	0.081
Group B	1.500	9	0.084	0.168

This leads to the conclusion that in the case of Group A, the mean performance score significantly decreased, while in Group B, there was no significant decrease in the mean score. Thus, the educational significance of the specific narrative technique was confirmed both in terms of understanding the concept it concerned and for improving its memorization.

Energy Degeneration

A significant part of the curriculum covered in the group concerned modern atomic theory. In the section on electronic structure, the concept of energy degeneration was taught. To make this concept more fully understood and retained for a longer period, the narrative technique was utilized.

"Two mathematician friends who had studied together in Thessaloniki meet by chance after many years. During the conversation, one mentions that he now has three sons. The other asks him about their ages.

'Look, we are mathematicians. I will answer you with a riddle.'

'I don't mind.'

'If you multiply the ages of my three sons, the product is 36. If you add their ages, the sum equals the number of the building where we lived in Thessaloniki when we were students.'

'That's nice, but it is not enough for me. I need one more piece of information.'

'Fine. My eldest son has blue eyes.'

How can we determine the ages of the children based on this information? We consider the ages of the children as natural numbers and list all the possible triplets that give a product of 36 (Table 11). Additionally, the last column of the table provides the corresponding sum of the ages.

Table 11. Combinations of Ages with a Product of 36

Age 1	Age 2	Age 3	Sum
1	1	36	38
1	2	18	21
1	3	12	16
1	4	9	14
1	6	6	13
2	2	9	13
2	3	6	11
3	3	4	10

If they lived in a building with the number 21 as students, the first two pieces of information would have been sufficient to determine the children's ages. Since a third piece of information was required, it means they lived in a building with the number 13, as it is the only sum that appears twice. Thus, two different situations lead degeneratively to a common characteristic. Two combinations of ages remain: 1, 6, 6, and 2, 2, 9. The correct choice is 2, 2, 9 because, in the other combination, there is no eldest son, as the two older children are twins!"

Just as two different combinations of ages led to a common characteristic—the same sum—degeneracy similarly involves different orbitals of the same subshell that have equal energy.

A written examination followed, and the results obtained from the two groups were tested with an independent samples t-test using SPSS software to determine whether the mean scores differed statistically significantly at a 95% significance level. In each case, prior to the use of the t-test, the normality of the distributions was tested, and through the Kolmogorov – Smirnov test, it was determined that at a 95% significance level, they do not statistically significantly differ from a normal distribution. It should be noted that the narrative technique was applied to Group A. The average score of Group A was 18.8, while that of Group B was 16.0.

Table 12. Mean and Standard Deviation of Scores for the Two Groups

Group	N	Mean	Standard Deviation
A	10	18.8000	1.93218
B	10	16.0000	3.26599

Assuming the null hypothesis (H_0) that statistically there is no significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.016 < \alpha$. This means we reject the null hypothesis and conclude that the mean score of Group A is statistically significantly higher than that of Group B at a 95% confidence level.

Table 13. t-test for Independent Samples

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
2.333	18	0.016	0.031	2.80000

The written examination was repeated—with different closed-type questions—on the same thematic after three months. The results were tested to see if the mean score differed statistically significantly both between the different groups and between the individuals who were members of the same group. The first test aimed to check the effectiveness of incorporating the specific historical narrative into the teaching unit, and the second to assess the possibility of extending the memorization of knowledge over a more extended period.

The average score of Group A was 14.4, while that of Group B was 16.8.

Table 14. Mean Scores of the Two Groups After Three Months

Group	N	Mean	Standard Deviation
A	10	14.4000	2.06559
B	10	16.8000	3.79473

Assuming the null hypothesis (H_0) that statistically there is no significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.008 < \alpha$. This means we reject the null hypothesis and conclude that the mean score of Group B remained statistically significantly higher than that of Group A at a 95% confidence level.

Table 15. t-test for Independent Samples After Three Months

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
2.635	18	0.008	0.017	3.60000

Additionally, we conducted a paired-samples t-test for each group separately at a 95% significance level to determine whether the mean score significantly decreased or not, to

assess the improvement or otherwise of the long-term memorization of the taught material. For Group A, we obtained $p = 0.172 > \alpha$, while for Group B, we calculated $p = 0.041 < \alpha$.

Table 16. Paired-Samples t-test Separately for the Members of the Two Groups

	t	df	Significance	
			One-Sided p	Two-Sided p
Group A	1.000	9	0.172	0.343
Group B	1.964	9	0.041	0.081

This leads to the conclusion that in the case of Group A, the mean performance score did not significantly decrease, while in Group B, there was a statistically significant decrease in the mean score. Thus, the educational significance of the specific narrative technique was confirmed both in terms of understanding the concept it concerned and for improving its memorization.

Appropriate Energy Amount for Exciting an Electron in an Atom

The excitation of an electron in an atom to a higher energy state requires a specific amount of energy. However, this concept is particularly difficult for students of this age to grasp. A common question often raised by students is why the electron cannot absorb any amount of energy, as would happen with a ball that is given energy to move. To further explain this concept, we used the narrative technique.

"The world's loneliest whale, known as the '52-Hz Whale,' is a mysterious sea creature that has garnered global interest. Its name comes from the unique frequency of its song, which is at 52 Hertz, much higher than the usual frequency that other whales can decode. This means that its song cannot be heard by other whales, making it extremely lonely. Therefore, there is a specific frequency at which the transmitter and receiver are tuned and communicate. This unusual characteristic was discovered in the 1980s by the US Navy, which was recording sounds in the ocean.

The story of this whale has touched many people, as the idea of a whale singing in the ocean without being able to communicate with its kind evokes feelings of sadness and sympathy. Scientists have tried to locate and study the whale, but so far, they have not been able to see or identify it. It is not clear whether the whale belongs to a known species or if it is a unique hybrid. Despite its isolation, the 52-Hz whale appears to be healthy and continues its journey through the oceans.

The '52-Hz Whale' has become a symbol of human loneliness and the need for communication. Books, songs, and documentaries have been written about its story, making it known worldwide. The whale's song continues to be heard by scientific monitoring stations, and the search for it remains active. Although we still do not have answers about its origin or future, the story of this whale reminds us of the importance of communication and connection, not only for humans but for all living creatures."

Just as a whale must emit a signal at a specific frequency to be detected by other whales, an electron must absorb the appropriate amount of energy in order to become excited.

A written examination followed, and the results obtained from the two groups were tested with an independent samples t-test using SPSS software to determine whether the mean scores differed statistically significantly at a 95% significance level. In each case, prior to the use of the t-test, the normality of the distributions was tested, and through the Kolmogorov – Smirnov test, it was determined that at a 95% significance level, they do not statistically significantly differ from a normal distribution. It should be noted that the narrative technique was applied to Group B. The average score of Group A was 17.2, while that of Group B was 18.4.

Table 17. Mean and Standard Deviation of Scores for the Two Groups

Group	N	Mean	Standard Deviation
A	10	17.2000	1.93218
B	10	18.4000	2.06559

Assuming the null hypothesis (H_0) that there is no significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.098 > \alpha$. This means we accept the null hypothesis and conclude that the mean score of Group B is not statistically significantly higher than that of Group A at a 95% confidence level.

Table 18. t-test for Independent Samples

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
-1.342	18	0.098	0.196	-1.20000

The written examination was repeated—with different closed-type questions—on the same thematic after three months. The results were tested to see if the mean score differed statistically significantly both between the different groups and between the individuals who were members of the same group. The first test aimed to check the effectiveness of incorporating the specific historical narrative into the teaching unit, and the second to assess the possibility of extending the memorization of knowledge over a more extended period.

The average score of Group A was 16.0, while that of Group B was 17.6.

Table 19. Mean Scores of the Two Groups After Three Months

Group	N	Mean	Standard Deviation
A	10	16.0000	2.66667
B	10	17.6000	2.79682

Assuming the null hypothesis (H_0) that there is no statistically significant difference in the mean scores of the two distributions and the alternative hypothesis that there is, we obtained $p = 0.103 > \alpha$. This means we accept the null hypothesis and conclude that the mean score of Group A does not differ statistically significantly from that of Group B at a 95% confidence level.

Table 20. t-test for Independent Samples After Three Months

t	df	Significance		Mean Difference
		One-Sided p	Two-Sided p	
-1.309	18	0.103	0.207	-1.60000

Additionally, we conducted a paired-samples t-test for each group separately at a 95% significance level to determine whether the mean score significantly decreased or not, to assess the improvement or otherwise of the long-term memorization of the taught material. For Group A, we obtained $p = 0.041 < \alpha$, while for Group B, we calculated $p = 0.082 > \alpha$.

Table 21. Paired-Samples t-test Separately for the Members of the Two Groups

	t	df	Significance	
			One-Sided p	Two-Sided p
Group A	1.964	9	0.041	0.081
Group B	1.500	9	0.082	0.168

This analysis indicates that for Group A, the mean performance score significantly decreased, whereas for Group B, there was no statistically significant decrease in the mean score. Therefore, the narrative technique did not lead to a further understanding of the topic but supported the students in better memorizing the taught material.

Conclusions

Four narrative techniques were alternately applied to groups of ten third-year Model Junior High School students, and the results showed that in three out of these four cases, there was a fuller understanding of the thematic concept, while in all cases, the techniques led to a longer retention period of the taught material. The narratives covered advanced Chemistry concepts, specifically:

- How a catalyst remains qualitatively and quantitatively unchanged while involved in a reaction.
- The role of surface area in reaction rate involving solids or pure liquids.
- The concept of energy degeneration.
- The appropriate amount of energy required to excite an electron in an atom.

This research provides a foundation for further exploration of narrative approaches and the application of existing ones to a broader audience of similar age or different age groups.

Regarding the limitations of the research, it would be useful to mention the small sample size and the lack of previous research on the narrative technique. Specifically, the sample of twenty participants is considered small for drawing generalized conclusions, given that this research technique in the selected thematic areas has not been studied in the past. To overcome these limitations, it is suggested to replicate the application of the same thematic areas in new samples and compare the results with those already recorded.

It could potentially spark significant research interest to design and implement narrative techniques at an interdisciplinary and cross-curricular level, or even to approach sections of the current school curriculum using this technique.

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