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Astro-Tamagotchi, Light Up a Virtual Star

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Abstract

Astro-Tamagotchi introduces an innovative approach to engage audiences with astrophysical concepts by blending coding, educational robotics, and immersive technologies like augmented reality (AR). This interactive activity enables participants to explore the lifecycle of a star, fostering a hands-on understanding of stellar formation and evolution.
The activity draws inspiration from the iconic 1990s Tamagotchi, reimagining its nurturing gameplay in the context of astrophysics. By blending nostalgia with cutting-edge technology, it transforms the care and evolution of a virtual pet into an engaging exploration of star formation and stellar lifecycles.
The experience begins with the birth of a star from an interstellar cloud of gas and dust. Guided by intuitive commands provided in coding language by a Telegram Bot, participants trigger the processes necessary for star formation. However, the journey does not stop at creation: the star requires ongoing care and attention to progress through its evolutionary stages.
Each stage of the star's life is accompanied by an exploration of its properties. To encourage a deeper engagement, AR and 3D models are integrated into the path game as a key role in the evolution. These models offer an immersive visual representation of the star's current stage, providing an accessible yet scientifically accurate depiction of complex astrophysical phenomena.
By merging playful interaction with robust scientific principles, this project enhances understanding and learning while fostering curiosity about the universe. It also highlights the potential of augmented reality and educational robotics as tools for making complex topics more relatable and engaging.
Astro-Tamagotchi is not just about stars; it's about inspiring the next generation to explore, question, and connect with the wonders of the cosmos.
The activity was developed by INAF and it's available on the Play INAF website. We premiered this activity at the Genoa Science Festival 2024, where it attracted 1.964 participants. We will showcase the results from the evaluation of both participant satisfaction and learning outcomes.

Keywords: *Astronomy, stellar evolution, augmented reality, coding, robotics, education*

1. Introduction

Engaging students in complex astronomical concepts, such as stellar evolution, poses a significant educational challenge. To achieve this goal, the National Institute for Astrophysics (INAF) developed "Astro-Tamagotchi" an innovative educational activity that combines coding, augmented reality, educational robotics, and logical problem-solving to make abstract astrophysical phenomena more accessible and engaging. It was premiered at the *Genoa Science Festival 2024*.
This study outlines the game dynamics we designed to help students intuitively grasp stages of stellar evolution, from the birth of a star in a nebula to its potential final forms, such as a white dwarf, neutron star, or black hole. We detail how we translated intricate scientific concepts into interactive and gamified experiences, leveraging digital tools to foster curiosity and understanding.
Finally, we present the results of our evaluation, conducted with students, to assess the educational impact and effectiveness of the activity. Our findings provide insights into the pedagogical value of merging game design and astronomy education through hands-on technological experiences.
"Astro-Tamagotchi" was conceived as an educational tool designed to foster inquiry-based learning and computational thinking in astronomy education. The integration of coding, augmented reality, and logical problem-solving offers a multi-modal learning experience. This educative approach emphasizes learning through active engagement, experimentation, and self-discovery [1]. By interacting with dynamic simulations

of stellar evolution, students are encouraged to formulate hypotheses, test their understanding, and adapt their strategies as they observe the consequences of their choices.
The gamified structure of “Astro-Tamagotchi” plays a key role in sustaining student motivation. Challenges embedded within the activity prompt learners to apply coding principles to control and discover the evolution of virtual stars [2]. Moreover, the use of augmented reality enhances spatial reasoning by allowing students to visualize astrophysical processes in three dimensions, bridging the gap between abstract concepts and tangible representations [3]. Collaborative problem-solving elements further reinforce peer learning and critical thinking skills, creating an interactive environment where students actively construct knowledge rather than passively receiving information [4].
Astro-Tamagotchi exemplifies how digital technologies can transform traditional science education by combining game design principles with rigorous scientific content.

2. Game Design

The activity is inspired by the famous *Tamagotchi*, an electronic game well known between the nineties and the 2000s, which allowed one to take care of a virtual animal activated by a micro-chip. The etymology of the word Tamagotchi combines, in fact, the Japanese words *tamago*, which means "egg", and *uotchi*, the English equivalent of “to watch”, or "to look" so “to take care of” a creature since its birth. In “Astro-Tamagotchi”, players can adopt a star after having spotted it among the coloured clouds of a molecular cloud, a cosmic region of intense star formation (the *stellar nursery*), and they have to help it to light up and continue its evolution by overcoming, as already mentioned, logic challenges, solving coding puzzles and using augmented reality.

Fig. 1. The setting of the room at Palazzo Ducale in Genoa during the Science Festival.

The game, aimed at middle and high school students, is run by a *Telegram Bot* (@astrotam) that indicates from time to time the various challenges and checks their correctness [5]. To play it is necessary to install the *CoSpaces Edu* application on a mobile device: a smartphone or tablet. At the *Genoa Science Festival 2024*, participants were divided into five groups, each marked with a different colour. However, people can also play alone or in pairs. The time allotted to complete all the phases of the activity is about 50 minutes.
Before starting the activity, we proposed an introductory video that offered explanations and hinted to help students navigate through the challenges.

2.2 Start the Game (Birth)

Once ready to start playing, participants simply scan the “welcome QR code” with the mobile device’s camera. This triggers a welcome message from the bot on Telegram, which reveals the nebula assigned to each player/team, where they should search for a suitable *protostar* to be adopted and provides instructions to begin the challenges. In astronomy, a *protostar* is the stage of star formation between the collapse of the molecular cloud and the stage when the star becomes stable by burning hydrogen. Not all stellar clumps in molecular clouds can produce stars: only if the "cocoon" of gas and dust reaches a certain mass, nuclear reactions in its core can lead to the formation of an actual star.

Fig. 2. Students looking for a protostar to adopt in the nebula.

The Telegram bot will recognize the QR code where a protostar could be hidden. If the protostar is not suitable to be adopted, one of the following messages appears in the bot chat:
"*Sorry, but this dust clump is still too young to be adopted. Try looking elsewhere in the nebula";*
"Oh no, the star you have found is already too old and cannot be adopted. Try looking elsewhere in the nebula".
But when the correct QR code is found, the message gives further instructions to proceed with the game: "*Congratulations, you have found a protostar ready to be adopted ⍰ The challenge begins! At the table assigned to you, you will find the game 'Light up your star'. Read the instructions on the board carefully and deal with all cards correctly to make nuclear reactions happen. At the end, you will have some leftover cards in your hand: scan the QR code on the table to check if the star is lit*!"

2.3 Light Up the Protostar (Growth)

Once the protostar to be adopted is identified, players have to solve simple "equations" using a card game representing fundamental particles and atomic nuclei [6]. This first challenge is designed to help participants understand what happens inside the stars, as they grow and evolve, and how protons, electrons, positrons, deuterium, and helium atoms must be combined to reproduce the chain of nuclear reactions that take place within a star while evolving. At this stage of the game, players have to deal with the deck cards on the board and correctly complete a set of nuclear reactions using the cards. To verify that the remaining cards from the deck give the correct answer to pass the first step of the game, players must interrogate the telegram bot by scanning the QR code on the game board and selecting the correct answer:
What cards are left in your hand?

1- *4 protons and 2 helium-4 atoms*
2- *2 protons and 4 helium-4 atoms*
3- *4 atoms of helium-3*

The correct answer is number 2. If the answer is wrong, they will have to try the game again, but if it is correct, they can proceed with the activity and "meet" their star using augmented reality.
At this point, the bot will provide a code that can open a cryptex, which is an encrypted, locked device based on a combination of letters. The cryptex contains information about the mass of the star and a QR code that, once scanned, will open the application CoSpaces and, thanks to augmented reality, show the kindled star up close, in all its features.
Augmented reality activates a bot command that tells players to solve quizzes and discover the evolution of their star and its final stage. They may answer this quiz by searching for answers in the specially made roll-ups, that lay inside the room and describe stellar evolution in its various phases. These were spread all around the room, to help participants deepen their knowledge of the evolution of their particular star. If they answer correctly, players will get the code needed for the further step of the game. The bot will check the correctness of the code found.

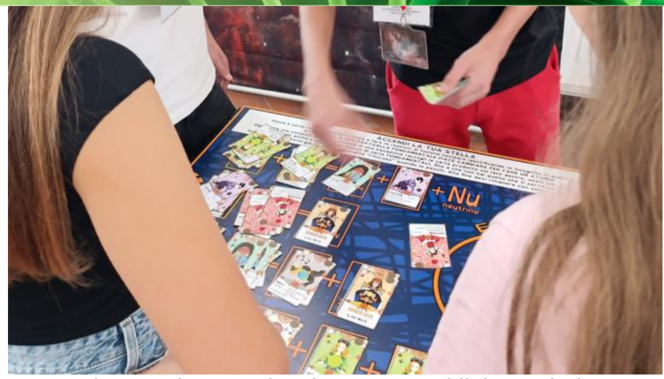

Fig. 3. Students trying to solve the game and light up their protostar.

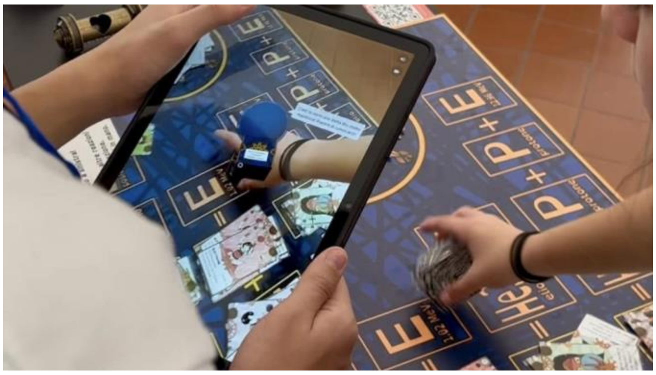

Fig. 4. Students meeting their star at the Genoa Science Festival; in this case, it turned out to be a blue star.

2.4 The Labyrinth of Ozobot (the Final Stages)

The code obtained in the previous phase must be interpreted to program the robot Ozobot to move across a specially designed labyrinth and reach the final stage of the evolution of the adopted star. Ozobot is a small educational robot designed to teach programming, robotics, and problem-solving concepts interactively and engagingly. Thanks to its compact size and advanced sensors, it can follow colour-coded lines and interpret commands based on colour sequences drawn on paper or displayed on screens. In this case, Ozobot had to be programmed to reach the final stage of the adopted star.
Again, at the end of the challenge, the bot checks whether the path of the Ozobot is correct by scanning the QR code placed on the labyrinth. This allows players to discover whether their star's final stage will be a white dwarf, neutron star, or black hole.

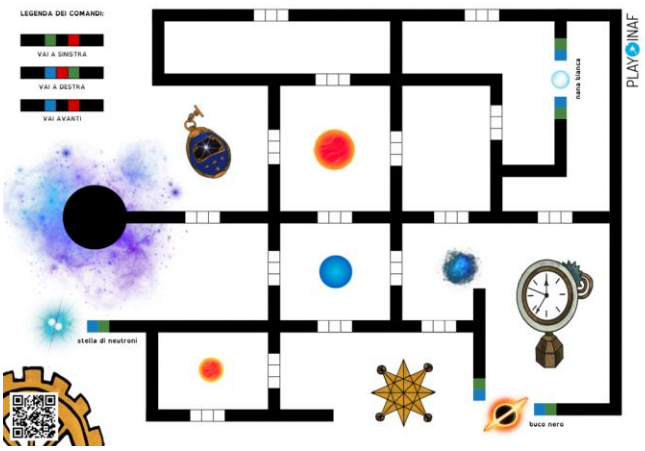

Fig. 5. The labyrinth may be coloured to reveal the evolutionary direction that Ozobot must take, and therefore the star adopted, to reach its final stage.

2.5 Final Phase

For the Genoa *Science Festival 2024*, we prepared a large 60x60 cm Merge Cube and placed it in the middle of the room, so that the players could use it to explore the AR simulation of the last stage of their star in a more immersive and interactive way. The prize for each player was a postcard showing the evolutionary moments of the star in augmented reality. The game ends here.

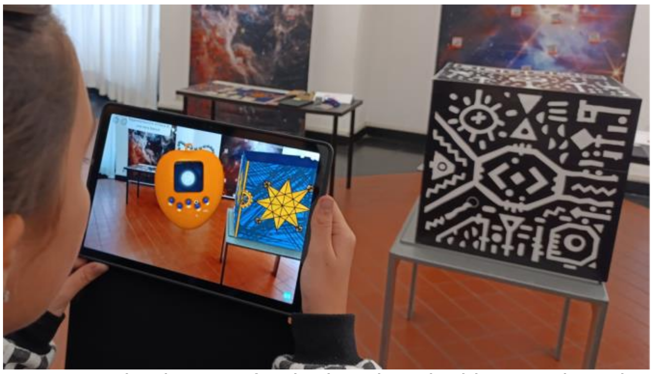

Fig. 6. A student in Genoa meeting her star for the last time; in this case, it evolved into a neutron star.

3. Technological Implementation

As described in the article, several interactive tools were chosen and used to support the educational activity: among them CoSpaces, Merge Cube, and Ozobot. These tools are well known by most schools, low-cost, and easily available. Here we will explain why we chose these tools in particular, starting from **CoSpaces**. This platform was selected for its flexibility in creating virtual environments where students could visualize and manipulate astronomical concepts, fostering an engaging learning experience; **Merge Cube** added an augmented reality dimension, allowing students to interact with 3D astronomical models tangibly, enhancing spatial understanding; **Ozobot** was chosen for its ability to combine coding and storytelling, encouraging problem-solving and logical thinking while exploring scientific themes.
In our years of experience with schools and research conducted at INAF on the use of emerging technologies to explain astronomy, we can say that by merging digital creativity with physical interaction, these tools created a dynamic and stimulating educational environment.
Moreover, we chose to use **Telegram** and develop a custom bot as part of the educational experience to provide students with an engaging, dynamic, and easily accessible communication platform. The bot was designed to guide participants through the learning activities, offering interactive prompts, hints, and educational content tailored to their progress. This approach not only enhanced engagement but also encouraged active participation and problem-solving.

4. Methodology of Evaluation

The data collected during the 2024 *Genoa Science Festival* revealed an impressive turnout of 1,964 participants at our activity. The enthusiastic participation of students, educators, and families was a testament to the success of the event and its engaging presentation, reinforcing the importance of fostering curiosity and knowledge through immersive learning environments.
This high level of participation provided a unique chance to understand the effectiveness of our educational methods and identify areas for improvement. To evaluate the impact and effectiveness of the activity, we administered a pre and post-activity feedback survey to collect quantitative and qualitative data, inviting students to share their perspectives, reflections, and suggestions. This feedback provided valuable insights into their engagement, comprehension, and overall satisfaction, guiding further improvements to the educational experience.
Before participating in the Science Festival in Genoa, we asked participants to answer a preliminary survey in which insights about their prior knowledge and experiences were gathered. The online form explored their familiarity with augmented reality technologies, previous participation in INAF workshops, and understanding of stellar evolution. Around 400 students completed the pre-activity form, compared to only 80 who filled out the post-activity form. This significant gap presents a challenge in analyzing the impact of the activity, as it limits the ability to draw comprehensive conclusions and compare initial expectations with outcomes. The reduced number of responses in the post-activity phase may be due to several factors, such as insufficient follow-up reminders, or logistical difficulties in data collection.
Despite this discrepancy, the available post-activity responses still provide valuable insights into the students' experiences. The comparison between the two sets of responses revealed a clear evolution in their

perspectives and knowledge, demonstrating an increased understanding of astronomical concepts and a heightened interest in the educational technologies employed. The shift in their answers highlighted the positive impact of the activity, offering meaningful insights for future educational initiatives.

4.1 Results and Analysis

As part of our evaluation, we asked students, among other questions, to explain what augmented reality (AR) is. We considered this an essential aspect of the learning experience, as AR represents a transformative technology with growing applications in education, science, and everyday life. The comparison between the responses collected before and after the activity revealed a notable shift. Initially, many students provided vague definitions: many answers like “*I don’t know*” as shown in the pie chart, indicating that only 44,5% of respondents had an idea of what it was. However, post-activity responses demonstrated a clearer understanding, highlighting AR's ability to integrate digital elements into the real world for educational and scientific purposes.
After playing the Astro-Tamagotchi, the answers to questions in the form changed. Students gained a clearer understanding of AR (Augmented Reality), which is evident in the updated responses. Notably, the phrase "I don't know," which was a common answer to the pre-activity form (in Italian, “*non lo so*”), no longer appears among words that come to mind when thinking about AR (Figures 7 and 8). This shift reflects the students' deeper engagement with the subject and newfound knowledge. The activity helped them connect with the concept of AR, demonstrating how experiential learning can transform learning.
This change may indicate the power of hands-on, immersive learning experiences in helping students grasp complex ideas. While AR has proven to be an engaging tool for enhancing technological literacy, it is essential for our Institution also to assess how students deepened their understanding of stellar evolution.

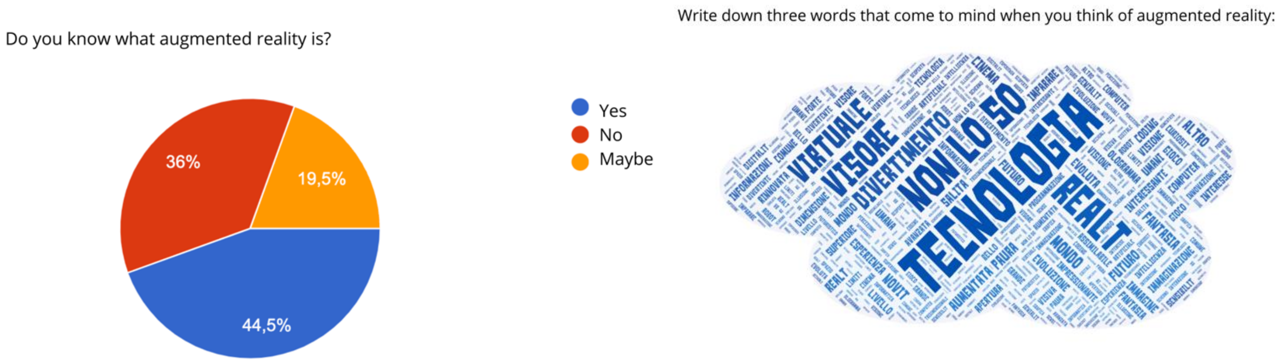

Fig. 7. Graph and word cloud showing students' opinions and expectations regarding AR before participating in the activity.

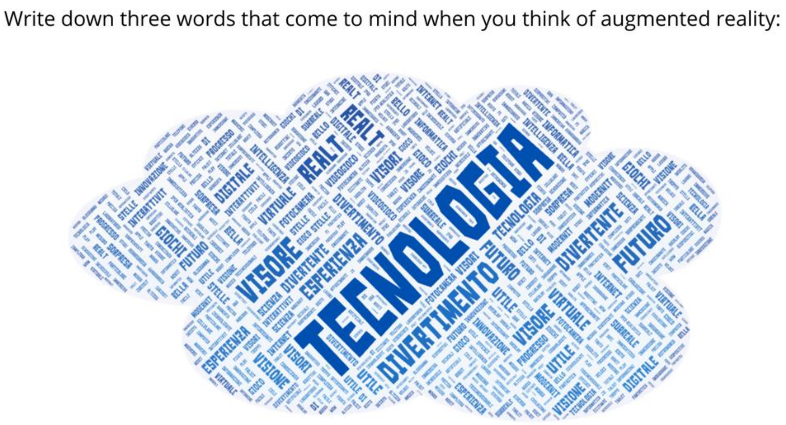

Fig. 8. In the word cloud based on data collected after the activity, the expression "*I don’t know"* disappeared from the answers submitted by the students

Thus, we considered it relevant to investigate whether the immersive nature of the activity effectively facilitated learning about the life cycles of stars, from their birth in stellar nurseries to their ultimate fate, whether as white dwarfs, neutron stars, or black holes.

As shown in the pie charts in Figure 9, before the activity, 11% of respondents weren't able to identify a star as a sphere of incandescent gas or did not correctly respond to the multiple-answer question regarding the nature of a star. This initial gap in knowledge highlights the challenge we faced in introducing students to fundamental astronomical concepts. However, the results following the Astro-Tamagotchi activity show a slight improvement, with 92,4% of students correctly describing a star as a sphere of plasma.
But the progress doesn't stop here. If we examine the next set of pie charts, we observe a more remarkable increase in awareness regarding the key factor that drives stellar evolution. Before the activity, only 64,5% of respondents correctly identified that mass is the key parameter behind the evolution of stars. After the activity, this figure rose to 86,1%, indicating a substantial gain in understanding the complex mechanisms that govern stellar life cycles.
This apparent improvement in student comprehension highlights the potential of combining innovative educational tools, such as AR, with astronomical education.

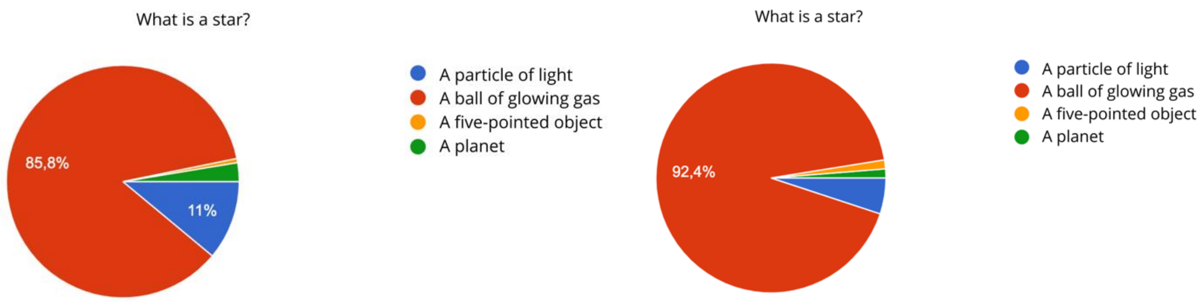

Fig.9. Before (left) and after (right) of the graph showing acquired awareness.

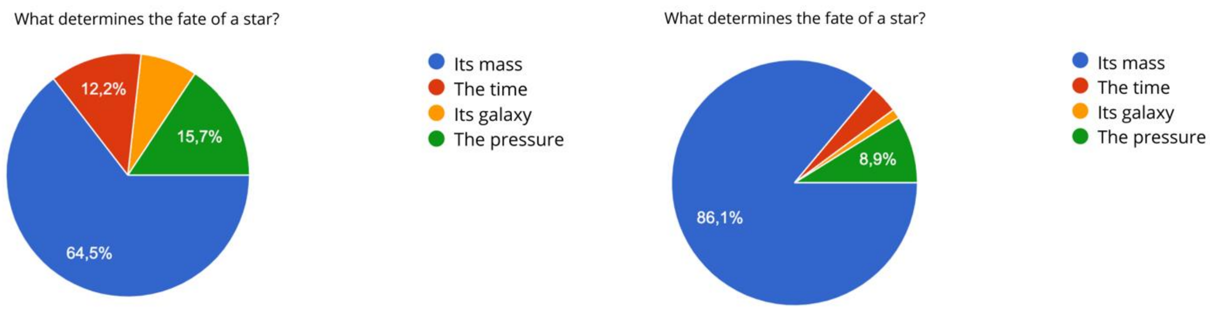

Fig. 11. Before (left) and after (right) of the graph showing acquired awareness.

4.2 Feedbacks

The feedback process didn't end with the pre and post-forms, as we also provided students with post-it notes where they could write their immediate impressions and thoughts once they finished the activity. These notes were then collected in a box, allowing us to gather various firsthand responses. The feedback was overwhelmingly positive, further confirming the activity's success in engaging and educating the students. Some of the comments we received include:
"*The activity was super fun and helped me understand what stars are made of and how they change over time*"; "*It was a wonderful experience, the best laboratory*"; "*The AR experience made it so much clearer*"; "*A truly unique and fun experience*."
These responses showed genuine curiosity and excitement about the activity they had just completed. As astronomers and science communicators, these positive reactions reinforce the importance of continuing to innovate and adapt our educational methods to engage students in science better.

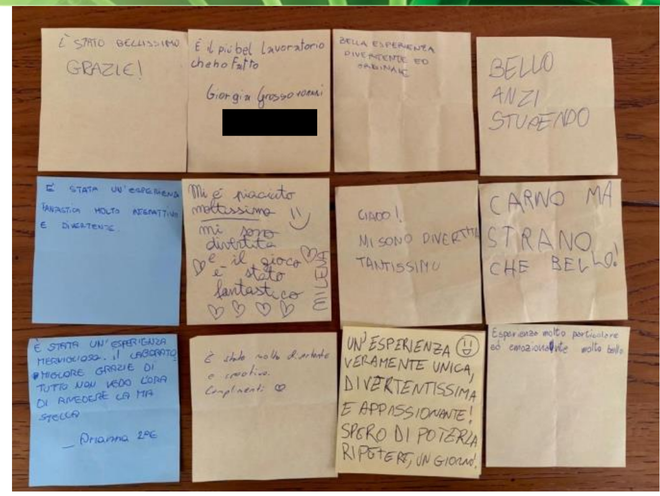

Fig. 12. Some of the posts written by students.

5. Conclusions and Future Work

Astro-Tamagotchi seems to have successfully bridged the gap between education and entertainment, offering an engaging and interactive way to explore the lifecycle of stars. As an institution devoted to research in astrophysics and the dissemination of scientific and astronomical culture, we are proud to know that our innovative educational approach was successful in teaching and engaging and that we are going in the right direction. In the future, we will continue to refine and expand on these methods, ensuring that more students can develop a solid understanding of both the technology and the science behind the universe's most fundamental phenomena.

While expressing their gratitude to CoSpaces Edu for the support in this laboratory the authors would like to inform the readers that since the first author is a CoSpaces Ambassador, she can provide guidance and support to educators interested in integrating CoSpaces into their teaching practices.

REFERENCES

[1] Lee-Cultura, S., Kshitij S., Michail, G., Children's play and problem-solving in motion-based learning technologies using a multi-modal mixed methods approach, International Journal of Child-Computer Interaction 31, 2022.

[2] Kersting, M., et al. "Virtual reality in astronomy education: reflecting on design principles through a dialogue between researchers and practitioners."International Journal of Science Education", Part B 14.2, 2024, 157-176.

[3] Leonardi, L., Daricello, L., Giacomini, L., "Learning astronomy through Augmented Reality: EduINAF resources to enhance students' motivation and understanding", European Planetary Science Congress, 2021.

[4] Daricello, L., Leonardi, L., Maggio, A., Orlando, S., Pillitteri, I., Bocchino, F., "Virtual and Augmented Reality for increasing the awareness of current scientific research", European Planetary Science, 2020.

[5] Sandri, M., et al. "Telegram Bots in Science Education: Applications in the Context of Astrophysics", this volume, 2025.

[6] Paoletti, D., et al. "A Card Game Revealing the Secrets of the Stars", this volume, 2025.