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The "wow effect" is out-of-date

Developing digital skills in the citizens of the future

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Abstract. In line with the school's digital innovation strategy published in MIM (Ministero dell'Istruzione e del Merito) and MUR's (Ministero dell'Università e della Ricerca) guidelines, INAF has been involved for years to providing students with effective learning solutions. By organizing school workshops and academic training, often through Augmented and Virtual Reality activities, our institution aimed at the dissemination of astrophysics, allowing students not only to experiment with a new method of learning but also to reproduce it, supporting them in acquiring the skills necessary for the challenges of the future. In particular, the activities and strategies we developed allow the building of computer skills and cross-functional competencies, such as logic, creativity, and problem-solving, to promote teamwork and collaboration, improving the teaching experience and learning outcomes. In this study, we especially show the experiences carried out at the INAF Astronomical Observatory of Palermo from 2020 until today, which allowed university students, involved in courses of Physics and Engineering, to take academic training dedicated to the application of innovative technologies for communication, teaching and dissemination of astronomical research, and the results of an innovative workshop conducted in schools which have produced unexpected results.

Key words. Academic training, Innovative workshop, Augmented Reality, Virtual Reality, Scientific communication

1. Introduction

The Third Mission initiative by the INAF Astronomical Observatory in Palermo represents a pioneering effort to integrate Virtual Reality (VR) and Augmented Reality (AR) into educational settings, transforming the way students engage with science and technology (Bailenson et al., 2008). By using VR visors or just their digital devices, students can experience immersive learning environments where they can: Explore complex phenomena (i): Visualize and interact with stars or planetary systems directly on their computer, providing a hands-on understanding of otherwise abstract concepts; Perform advanced experiments safely (ii): Conduct electronics and physics experiments or handle materials that might be dangerous in the real world, ensuring complete safety while deepening practical knowledge; Expand the limits of accessibility (iii): Access environments and objects that would typically be out of reach-like distant stars, or microscopic structures. Since 2018, this initiative has aimed to revolutionize education both at school and university levels by merging cutting-edge VR and AR technologies with traditional learning (Roopa et al., 2021). By allowing students to "see" and "touch" the previously untouchable, it fosters engagement, curiosity, and a deeper grasp of scientific concepts (Yildirim, 2018). This effort reflects the broader goals of the Third Mission, which seeks to bridge scientific research and society, making advanced knowledge and tools accessible to all (Tambunan, 2014). At first, it was not easy to convince some fellow researchers and some teachers of the potential of these new technologies for communication and science education, because new technologies were often seen only as a game. Everything changed so fast by 2020, accelerated by the pandemic emergency. The difficulty in running school programmes has led many teachers and research organisations to find innovative, low-cost, affordable solutions. In May 2023, the Ministry of Education and Development (MIM) released a Preparatory Document to update the National Digital School Plan (PNSD). This document aligns with key international and European strategies, including the "2030 Agenda for Sustainable Development", particularly Goals 4 (Quality Education) and 10 (Reducing Inequalities), and "European Commission's Digital Education Action Plan 2021-2027", promoting digital innovation and inclusion in education. As part of the "National Digital Skills Strategy", the updated PNSD integrates resources from initiatives like School Plan 4.0 and Digital Public Administration 2026 (Digital PA). The updated PNSD aims to: (i) Improve the quality of training and learning; (ii) Bridging the digital divide between schools in implementing innovation processes; (iii) Promote educational and digital innovation processes, encourage the general use of quality digital content; (iv) Promote careers in "STEM" (Science and Technology, Engineering, Mathematics); (v) Activate specific actions on the "confidence gap" and thus promote Girls in Tech & Science actions; (vi) Promoting innovation, diversity and sharing of educational content; (vii) Evaluating the impact assessment on learning. In 2007, a National Plan for the Digital School was discussed for the first time, with the main objective of changing learning environments and promoting digital innovation in the School. In 2018, the "European Council's recommendation on key competences for lifelong learning" `eur-lex.europa.eu` expressed: "Digital competence implies the safe, critical and responsible use of digital technologies and their use in learning, working and participating in society. Includes information and data literacy, communication and collaboration, media literacy, digital content creation (including programming), security (including digital well-being and cyber security skills), intellectual property issues, problem-solving and critical thinking". In this Action Plan, we delineate the pivotal role that INAF has assumed in service to society, showcasing its unwavering commitment to advancing knowledge and fostering innovation for the collective benefit.

2. Tools, skills and content, and digital education

Through the efforts of the PNSD, it's clear that it seeks to create a modern, inclusive, and forward-thinking educational system that prepares students for future challenges. The National Institute for Astrophysics (INAF) introduces students to new technologies by creating immersive educational experiences that blend cutting-edge scientific research with innovative tools. Through initiatives such as virtual reality simulations, interactive workshops, and hands-on experiments, INAF brings complex scientific concepts, such as the structure of the universe, molecular dynamics, and planetary exploration. By integrating these advanced technologies into classrooms, INAF inspires curiosity, cultivates digital skills, and fosters a deeper understanding of the universe, preparing students to navigate and shape the technological landscapes of the future. But we no longer want just to amaze and intrigue, we want to give them tools that can be useful for their future. For this reason, we will anal-

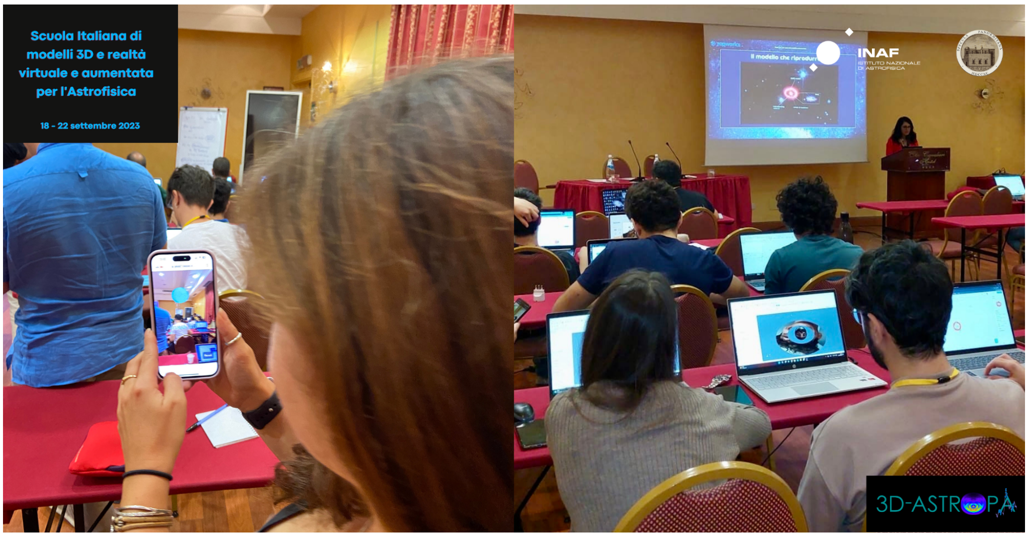

Fig. 1. One of the official photos from the Italian School of 3D Models for Research and Inclusion, organized by INAF Observatory of Palermo, where students are shown experimenting with augmented reality.

yse the steps taken following some of the elements described by the PNSD. Schools frequently receive funding to acquire innovative digital tools, while teachers often lack adequate training to use them effectively. This creates a scenario where the tools are available, but the expertise to utilize them is missing. The core aim of such investments is to improve the educational environment, but the true value lies in fostering excellent teaching practices. To achieve this, it is essential to combine quality tools with well-prepared educators and robust content, ultimately strengthening students' skills and learning outcomes. Digital technology represents the "alphabet" of our era, with computational thinking at its core. A new syntax blending logical and creative reasoning that increasingly shapes how we communicate and interact. To prepare students for this reality, the entire curriculum must embrace the digital dimension, supporting also transversal skills approaches across disciplines. Teachers need access to a portfolio of practical, ready-to-use teaching resources that can be seamlessly applied in the classroom. This is precisely where INAF Palermo Observatory's initiatives play a vital role.

2.1. PRIN "Virtual Reality and Augmented Reality for Science, Education and Outreach" 2020-2023 +1

The PRIN project "Virtual Reality and Augmented Reality for Science, Education, and Outreach" (from 2020 to 2023/2024; PI L. Daricello, INAF OAPa) `https://axt.oapa.inaf.it/prin-vrar/` focused on exploring the potential of immersive technologies to revolutionize science education and communication. By leveraging Virtual Reality (VR) and Augmented Reality (AR), the project aimed to create engaging tools and experiences that enhance the understanding of scientific concepts. These technologies were integrated into educational programs and outreach activities, offering innovative ways to connect with students, educators, and the broader public. The project highlighted the importance of combining cutting-edge technology with educational practices to inspire curiosity and promote scientific literacy. Moreover, within the project were organized webinars to communicate know-how to all INAF colleagues interested in these new methods of communication. This way we offered the opportunity to INAF colleagues spread across Italy to learn new innovative methods and to students from various schools in Italy to receive a higher quality education.

2.2. Italian School of 3D Models for Research and Inclusion

The INAF Palermo Astronomical Observatory, in September 2023, organized a school targeted at Bachelor's and PhD students in Physics and Astronomy `https://indico.ict.inaf.it/event/2527/`. The school is financed by the Scientific Directorate INAF (PI R. Bonito). The program aimed to enhance participants' skills in developing 3D models, utilizing innovative technologies such as virtual reality (VR) and augmented reality (AR), and analyzing astronomical data. The initiative focused on processing photometric data of variable stars observed in bands analogous to those of the upcoming Rubin LSST. Additionally, participants developed 3D models for rendering, 3D printing, and virtual and augmented reality 1 to promote inclusivity by improving accessibility to scientific results for visually impaired students and researchers, with particular attention to fostering gender diversity. After five days of intensive study, participants acquired and analysed scientific data, produced various products in VR and AR and presented their results to their colleague and during public events.

2.3. Academic traineeships

Since 2020, INAF Palermo Astronomical Observatory has been offering academic internships for Physics and Engineering students `https://www.astropa.inaf.it/tirocini/`, focusing on the study and application of science communication techniques through virtual reality (VR) and augmented reality (AR). Objectives of the internship are (i) Design an innovative communication to tell astronomical research and its results using VR and AR; (ii) Implementation of dissemination activities (festivals, exhibitions, workshops, guided tours, etc.) for different

Fig. 2. Preview of the Voyager metaverse exhibition developed with Frame.

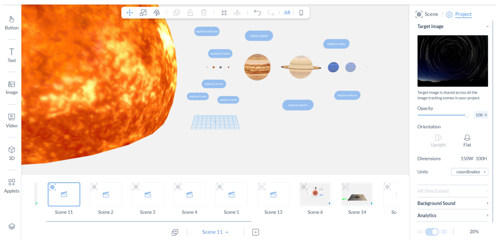

Fig. 3. Preview of the augmented reality activity development on the solar system made with Zapworks.

target groups and transversal educational paths dedicated to schools, which make use of VR and AR, coding, robotics and making; (iii) Develop technical expertise in video editing and gain proficiency in compositing and post-production techniques for moving images. We consider this internship highly valuable, as researchers often excel in their scientific work but may lack the skills to effectively communicate with diverse audiences. The outcomes of this internship have been outstanding. Specifically, we highlight: (i) The VR project 2 developed by student Enrico Maggio, who created a metaverse-based exhibition to showcase the Voyager mission (Maggio, 2023); (ii) The AR application 3 dedicated to the solar system, implemented by Gabriele Pecoraro, who even incorporated aspects of this internship into his final report for his Bachelor's degree (Pecoraro, 2023). These achievements highlight the impact and potential of the program.

3. The evaluation of learning in Scientific Educational Activities

Evaluation helps determine the conditions under which a program is effective, how it achieves its outcomes, and the circumstances under which it may fail. This approach enables communicators to predict whether a program that succeeds in one context could also succeed in another. By uncovering the factors necessary for success, realist evaluation helps identify the optimal conditions and contexts for the success of our astronomy education programs (Bartlett, 2024). Data can be categorized as quantitative, qualitative, or a mix of both. Evaluators decide which type to collect based on their objectives and the specific insights they aim to gather from their audience. Evaluation can be conducted at distinct timepoints: before the program begins (pre), during the program, immediately after it concludes (post), or sometime later (follow-up). The timing of data collection and its objectives determine the questions you ask and the information you aim to gather from your audience. We applied examples of evaluation drawn up by the IAU Office of Astronomy for Education (OAE) and adapted to our context and case study. Below we show one of the results.

3.1. Workshops for students about AR technology

An evaluation test was conducted with high school students, primarily from socio-health disciplines, to assess their engagement and learning outcomes in an interdisciplinary project combining astronomy and augmented reality (AR). The project introduced students to fundamental astronomy concepts and taught them how to design an AR application using first Mentimeter `https://www.mentimeter.com/` to vote for the models to use, then Sketchfab `https://sketchfab.com/` to find and download the selected 3D models, and lastly the CoSpaces Edu `https://www.cospaces.io/` to create the AR activity. A key feature of the activity was group collaboration, where students participated in live voting to select 3D objects for inclusion in their final AR projects. The results highlighted strong engagement and enthusiasm, with notable improvements in both their understanding of astronomy and their AR development skills. The real-time voting process enhanced active participation and teamwork, fostering creativity and a sense of ownership in the completed projects.

The results from the post-questionnaire indicate that 90,6% of the students have learnt new things about astronomy during the activity and 78,1% show that they have practiced their programming skills. Furthermore, the pre and post-activity questionnaire invited students to list three words that came to mind when they thought of "smartphones and tablets", and "virtual and augmented reality". Before the activity, the most frequently mentioned words included "internet", "social", and "app," for the first request, while "real", "technology", and "future", were the three words more mentioned for the second one4. Some words also showed a certain fear of these devices and new methodologies of communication like "addiction", "dangerous", and "radioactivity". Unexpectedly, everything changed after the didactic laboratory, when the most frequent word chosen was: "future"5. Students understand the opportunity of this new educational application to explain science and help researchers make discoveries to improve the future of mankind.

4. Conclusions

Research institutes play a crucial role in enhancing the study of scientific disciplines in schools by bridging the gap between theoretical knowledge and practical application. Their contributions extend beyond supporting traditional curricula to providing opportunities for students to engage with cutting-edge technologies. By integrating innovative tools and methodologies into the learning process, these institutions empower future generations to master emerging technologies, ensuring they become skilled and confident users rather than passive consumers. This synergy between education and research fosters critical thinking, creativity, and technological fluency, equip-

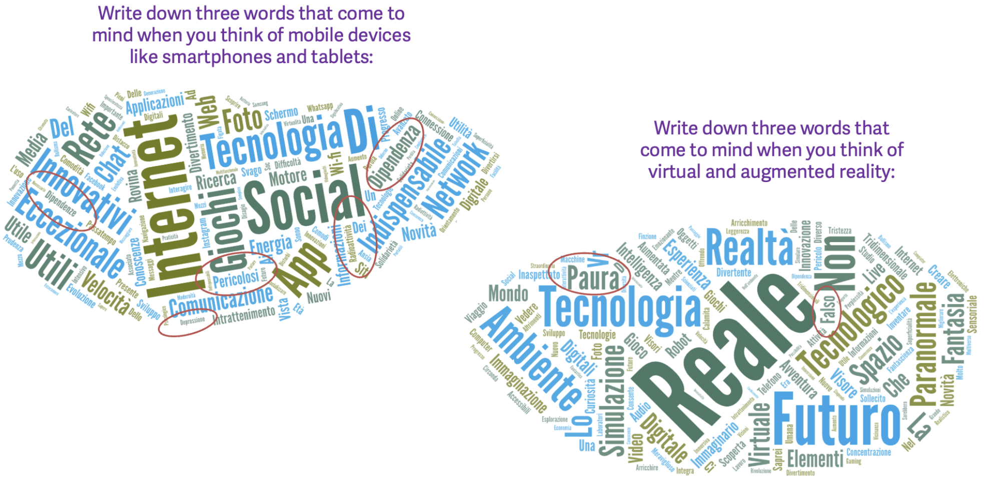

Fig. 4. Results obtained from the pre-activity questionnaire.

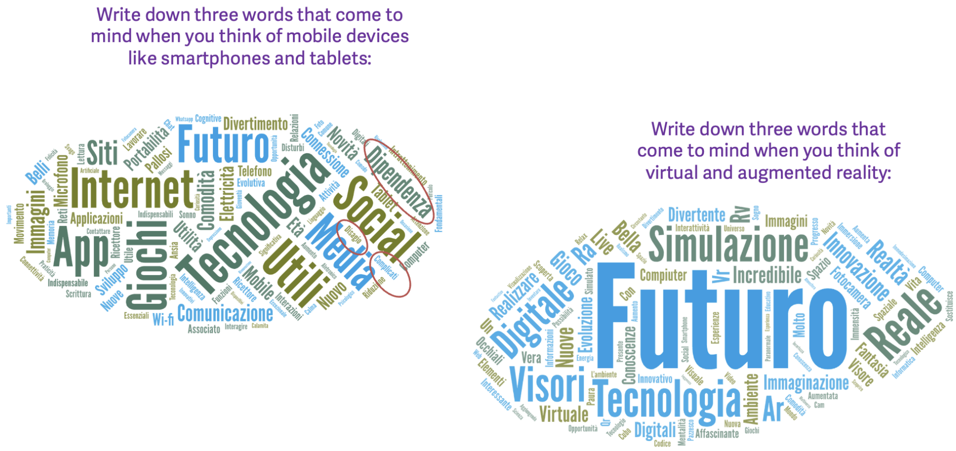

Fig. 5. Results obtained from the post-activity questionnaire.

ping students to navigate and shape the rapidly evolving digital landscape.

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