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Marshmallows, Fun, and Constellations: A Mixed-Methods Evaluation of a STEAM Astronomy Workshop

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Abstract

This study evaluates a STEAM-based astronomy workshop for children, delivered at two science engagement events in Malta: Science in the City 2023 and Unconventional Science Careers Days 2023. The workshop integrated storytelling, mythological narratives, creative making activities, and digital tools within the 5E instructional model and the creative pedagogy CREATIONS, with constellations as the central theme. Using a mixed-methods approach, we collected survey data from 122 participants (aged M=10, SD=2.4) and practitioner observations. Quantitative analysis showed that most children (80.3%) found the workshop easy to understand, though 91.8% reported not learning new content. Despite this, 51.6% expressed strong interest in learning more about astronomy, and 55.7% wanted similar school workshops. Significant differences emerged by setting: open-air festival participants reported higher levels of enjoyment and clarity than classroom-based participants. Qualitative analysis revealed children emphasized astronomy knowledge, enjoyment, and creative processes, often linking learning to personal contexts such as zodiac signs. Practitioner observations highlighted parental involvement as both supportive and potentially intrusive. These findings suggest STEAM workshops emphasising artistic processes, can stimulate curiosity, engagement, and cultural relevance in astronomy education, while underscoring the importance of facilitator training and careful scaffolding to balance creativity with conceptual accuracy. The study contributes to research on non-formal STEAM learning by demonstrating the potential and challenges of integrating arts, storytelling, and science in astronomy education.

INTRODUCTION

The integration of STEAM (Science, Technology, Engineering, Arts, and Mathematics) into education has gained momentum as an effective pedagogical approach that fosters creativity, critical thinking, and scientific inquiry. Early science exposure profoundly impacts students' future scientific citizenship, fostering critical thinking and encouraging engagement with scientific discussions (Dijkstra et al., 2014; Deak & Kumar, 2024). STEAM methodologies can help bridge gender gaps in science engagement by incorporating creative, collaborative, and artistic approaches (Ortiz-Revilla et al., 2021); girls tend to be more engaged in astronomy-related activities including storytelling, artistic expression, and interdisciplinary learning (Sanz-Camarero et al., 2023). However, traditional science education often fails to emphasize scientific knowledge's evolving nature, presenting it as fixed facts rather than a dynamic, human-driven process (Santilli & Boudemont, 2008). To address this, non-formal science education -delivered through hands-on activities, interactive workshops, and real-world applications- has gained recognition as an effective approach for engaging students in STEM and STEAM disciplines (Dijkstra et al., 2014; Mathieson & Duca, 2021).

Non-formal learning environments, as spaces where science learning is not confined to the classrooms, play a critical role in shaping children's attitudes toward science (Leventhal et al., 2024; Xia et al., 2024). Research highlights that interactive, engaging workshops and hands-on learning significantly enhance students' understanding of science, encourage critical thinking about its societal implications, improve retention, engagement, and the willingness to participate in STEM fields (Dijkstra et al., 2014; Hu et al., 2021). Science fairs, workshops, and public engagement initiatives provide critical opportunities for learning outside traditional school settings. These experiences allow students to explore scientific concepts in an interactive and engaging manner, often leading to increased curiosity and long-term interest in STEM careers (Duo-Terron et al., 2022). They demystify science, illustrating that it is an evolving field of inquiry rather than a collection of fixed facts (Santilli & Boudemont, 2008).

Astronomy is particularly well-suited for science engagement, as it naturally captures children's imagination and fosters curiosity about the universe and humanity's place within it (Roche et al., 2021; Silverman et al., 2024). It provides a unique gateway into scientific exploration by encouraging students to ask questions about the universe, developing both scientific reasoning skills and a sense of global citizenship, connecting physics, mathematics, and technology (Sit, 2019). Astronomy workshops, particularly when delivered through STEAM-based methodologies, can bridge the gap between science and the arts, making learning more accessible and engaging for diverse student populations (Silverman et al., 2024). Despite its potential, astronomy education at the primary and lower secondary levels remains underexplored in formal curricula, with limited opportunities for students to engage with the subject in a creative, interdisciplinary manner (Sonia et al., 2023).

Existing research highlights the cognitive and affective benefits of introducing astronomy concepts to young children through the arts. Storytelling, for instance, has been shown to enhance conceptual understanding by making abstract astronomical phenomena more relatable. Hu et al., (2021) explored how personification storytelling -where celestial bodies are depicted as characters in a narrative- improved conceptual understanding of astronomical phenomena by supporting preschool children's grasp of complex space science concepts. Similarly, the use of maker activities, arts integration, and digital fabrication has been recognized as an effective means of making complex scientific concepts more relatable and increasing engagement and participation in science education (Hartikainen et al., 2022). Similarly, integrating craft-based projects (e.g., building star models, designing constellations) has been found to increase students' engagement and long-term interest in science (Kahn et al., 2018).

Nevertheless, recent studies have identified a lack of emphasis on the Arts as a pedagogical approach, with limited rigorous research on the relevant learning outcomes such as creativity or art-specific outcomes (Perignat & Katz-Buonincontro, 2019). Perignat & Katz-Buonincontro argue for a shift in discourse from "adding arts to STEM" toward treating STEAM as an equitable five-discipline pedagogy, accompanied by rigorous instruments that document gains in creativity, problem-solving and aesthetic understanding. The practical difficulty of such integration is echoed by teachers who report uncertainty about concrete strategies for including the arts (Herro & Quigley, 2017) and by classroom observations showing that artistic components often collapse into superficial decoration rather than substantive inquiry (LaJevic, 2013; Singh et al., 2024)

It seems, therefore, that despite the growing interest in STEAM education, critical gaps limit our understanding of effective practice. First, while studies demonstrate benefits of arts integration, rigorous empirical research examining specific learning outcomes remains limited (Perignat & Katz-Buonincontro, 2019). Most research focuses on adding arts as supplementary activities rather than investigating truly integrated approaches. Second, educators report uncertainty about concrete pedagogical strategies for meaningfully integrating arts beyond superficial decoration (Herro & Quigley, 2017; LaJevic, 2013; Singh et al., 2024). Finally, astronomy education at primary and lower secondary levels remains underexplored within formal curricula, with few documented examples of creative, interdisciplinary engagement (Sonia et al., 2023). While astronomy naturally captures children's imagination, systematic approaches to integrating storytelling, cultural narratives, and creative making with astronomy concepts are scarce.

This study addresses these interconnected gaps through three distinct contributions to STEAM education research. First, we present a theoretically grounded pedagogical framework that systematically integrates the 5E instructional model -traditionally used in formal science classrooms- with the CREATIONS creative pedagogy in a non-formal workshop setting. This integration demonstrates how inquiry-based and arts-based approaches can be combined, with the arts embedded throughout the inquiry cycle rather than relegated to communication phases. Second, our mixed-methods evaluation provides empirical evidence of children's cognitive, affective, and creative responses to astronomy education that explicitly combines storytelling and hands-on making activities. Third, by comparing implementation across two distinct non-formal settings, we offer insights into how environmental context and participant motivation (voluntary vs. mandatory attendance) shape engagement and learning.

The study reports on the design, implementation, and preliminary evaluation of a STEAM astronomy workshop delivered at two science fair events: Science in the City, Malta's largest science and arts festival (Jensen et al. 2021, Farrugia et al 2024), and the Unconventional Science Careers (USC) Days, a school-led initiative introducing secondary school students to different professions through interactive workshops at the University of Malta. The main research questions guiding our study were:

1) How effective was the workshop in raising the awareness of the children on topics related to astronomy?
2) Was the workshop engaging and fun for the children?
3) To what extent did children's reported astronomy knowledge increase?
4) Did factors such as the venue and type of event, and the children's gender and age impact the enjoyment and the learning outcomes of the children?

METHODS

This study employed a mixed-methods evaluation design to examine the implementation and outcomes of a STEAM astronomy workshop. The research combined quantitative survey data from child participants with qualitative analysis of open-ended responses and practitioner field observations. The study was designed in two phases: (1) co-design and development of the workshop intervention using participatory methods with university students, and (2) implementation and evaluation of the workshop with children at two public science events. This section first describes the intervention design process and theoretical frameworks that guided the workshop development, then presents the implementation contexts, and finally details the research methods used to evaluate the workshop's effectiveness.

Conceptual Foundation, Learning Goals, and Theoretical Frameworks

The main theme of the children's workshop was the constellations, as it can be linked to the experience and daily life of the children, making learning more relevant, meaningful and engaging. Children can see the constellations by just observing the sky, while at the same time they may not be able to see them due to light pollution, a common problem for professional and amateur astronomers (Perez, 2023). It is also an appropriate topic for addressing Astronomy misconceptions, and particularly the difference between astrology and astronomy and the number of zodiac constellations (Oktay et al., 2022). In Oktay et al.'s findings (2022) learners further recommended including mythological stories about constellations. This recommendation is in line with Santilli & Boudemont's (2008) and Dijkstra et al.'s (2014) emphasis on storytelling and cultural references. We, therefore, opted to implement activities for mapping the celestial shapes and linking these to mythological stories bringing together relevant science and arts activities.

For the design of the activities, we combined the 5E instructional model and the CREATIONS pedagogy, in order to help the co-creation workshop participants design the intervention with specific pedagogies and approaches in mind.

The *5E instructional model* provides a framework for the design of inquiry-based educational activities implemented in science and STEM education (Koyunlu Ünlü & Dökme, 2022). Based on constructivist learning principles, it guides learners from initial motivation and curiosity, to investigation, explanation, transfer to new contexts, and assessment (Ruiz-Martín & Bybee, 2022), positively impacting conceptual change, understanding, and science education (Bybee et al., 2006; Ancona et al., 2024). The 5 stages of the model are: a) engagement – presenting a phenomenon and eliciting prior knowledge; b) exploration - investigating through hands-on experiences; c) explanation - articulating understanding while teachers introduce formal concepts; d) elaboration - applying knowledge in different contexts; and e) evaluation - assessing conceptual understanding and skills.

The CREATIONS framework incorporates Inquiry-Based Science Education (IBSE) with the arts (Chappell et al., 2016). IBSE reflects scientific methods through seven classroom stages: Question, Evidence, Analysis, Explaining, Connect, Communicate, and Reflect (Bogner et al., 2013). Creative pedagogy in STEAM enables purposeful activities producing original, valuable outcomes through critical reasoning using available evidence to generate ideas, explanations, and strategies individually or collectively while acknowledging risk and emotions in transdisciplinary contexts (Chappell et al., 2019).

Integration of Cultural and Historical Perspectives. We considered insights of previous studies on astronomy workshops emphasising the need for a more contextual, historical, and philosophical approach to teaching science, rather than traditional technology and mathematics-oriented curriculum (Santilli & Boudemont, 2008). By viewing Astronomy through a cultural lens, we may help children understand that science is social and cultural practice, shaped by human activity and societal influences (Salimpour & Fitzgerald, 2024). At the same time, storytelling is an effective approach for making science more accessible to young children (Dijkstra et al., 2014). These were the theoretical underpinnings of the STEAM Astronomy workshop created.

The STEAM Clinic Co-Creation Workshop

To design the STEAM astronomy workshop for children, we organised a content co-creation workshop (The STEAM Clinic). The participants were 6 Higher Education students of various fields such as Astrophysics, Biology, Health and Social Sciences, as well as science communication intern students from the UK, Turkey, and Malta at the University of Malta.

The criteria of basic STEAM education, the stages of CREATIONS pedagogy, and CREATIONS Planning Tools (https://sciartsedu.co.uk/planning-tools/) were introduced to the participants of the co-creation workshop. The participants were asked to use the CREATIONS Planning Tools to combine creative pedagogies with a variety of teaching approaches to facilitate the creation of STEAM projects. This provided a comprehensive framework for encouraging creativity and innovation.

Prior to the co-creation workshop, we had selected 3 STEM educational resources focused on astronomy, to form the basis for discussion and co-creation. The participants were asked to work on these resources, modify, enhance, emphasise creativity, and adapt them to the needs of our target group (primary and secondary education children at the workshop). These activities and resources were:

Marshmallow Constellations activity (developed by the Pacific Science Center, https://pacificsciencecenter.org/wp-content/uploads/2023/02/cah-marshmallow-constellations-6-8.pdf). In this activity, the children are asked to create the model of a constellation using toothpicks and marshmallows. They are asked to create a story about this constellation drawing from relevant stories of different cultures, share them with the group and compare their stories.

Star Clock activity (developed by the Pacific Science Center, https://skyandtelescope.org/observing/make-a-star-clock/). Children use pre-made printouts to create a paper clock and then use it to calculate the current time by aligning it with the Big Dipper.

Stellarium (https://stellarium.org/): we opted to use the Stellarium program as a virtual planetarium (Oktay et al., 2022). Stellarium is an open-source planetarium software that allows users to explore and simulate the night sky, view stars, planets, constellations, and other celestial objects in 3D, offering an educational and immersive astronomy experience. It is a common tool for astronomers and teachers. Digital media and interactive tools are found to be effective in teaching astronomy and making complex topics and abstract concepts more concrete and easier to understand; they improve observation skills, enhance student learning and engagement, and trigger curiosity and motivation to learn astronomy (Oktay et al., 2022). It is also an enjoyable tool that can support our theme (Oktay et al., 2022).

The Astronomy Workshop Protocol

Five different activities combining astronomy with mythology, art and creativity were designed for the children's workshop. To enhance the children's learning experience, all activities were tied together with a narrative. The activities' protocol was adjusted to the environments to be implemented (e.g., outdoors or indoors, number of children, available time for each of the festivals, sequential or parallel implementation of the scenario's steps). The activities complement each other and constitute 5 steps following the 5E Instructional Model. They were:

Step 1 – Engagement: In this step, we aimed to attract the attention of the children, trigger their curiosity, and provide a preliminary context of the concepts to be examined. This stage was carried out in the form of a dialogue with the children, with questions led by the practitioner of the workshop. The questions also aimed at allowing the practitioner to examine the children's prior knowledge and experience on the topic. Indicative questions to the children were:

1. Do you like looking at the sky?
2. Have you ever tried to make shapes out of clouds?
3. Have you ever noticed the patterns in the night sky, like how the stars move throughout the night or how the sky changes from season to season?
4. Do you have a favourite constellation? Why is your favourite?
5. What is a constellation?

Step 2 – Exploration/Discovery: The children were given cards depicting constellation patterns and were asked questions about what these images looked like (Figure 1). After this short exchange, participants were asked to choose an image they liked and were asked to create the shape of the constellation pattern they chose using marshmallows and toothpicks (Figure 2). In this step, children are actively participating and can also work individually. Through this 10-minute activity, the children gained an idea about what kind of patterns they could see in the night sky. At the end of the activity, the real names of the constellations on the cards were shared with the children. The visual constellation patterns shown were: Big Bear (Ursa Major), Lidle Bear (Ursa Minor), Cassiopeia, Leo, and Orion. The constellations of this activity were selected considering the next activity (i.e., Star Clock) which mainly focuses on three of the aforementioned constellations.

Figure 1. Example of a constellation card

When implementing this activity, attention was given to potential misconceptions, such as the constellations' sizes and distance from earth. Stars are at different distances from earth, with different magnitudes, and therefore different brightness. The models created may lead to misconceptions that the stars are equidistant and of equal magnitude. The activity's purpose is focusing only on constellation patterns. Therefore, after completion, children receive a brief explanation about constellations, their formation, star distances from the Earth, and whether gravitational effects exist between them.

Figure 2. Marshmallow Constellations activity (Sitc-2023)

Step 3 - Explanation: In this step, general information is presented using Stellerium about how these constellations are seen in the night sky, the distances, sizes, and brightness of the stars, how many constellations there are, and their visible movements in the night sky (Figure 3). The practitioner shows the constellations and asks the names of the constellations. The practitioner facilitates recall by showing the mythological pictures of the constellations. Therefore, there is a constant question-and-answer process while information is being presented. Through this process, knowledge acquired in the previous activities as well as the previous knowledge and experience of the children is examined and established.

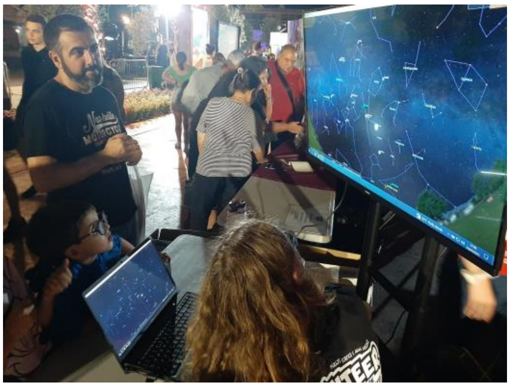

Figure 3. Using the Stellarium program

Step 4 – Elaboration: The children are asked to model a Star Clock. Before this activity, children learn what constellation are, and which care important for navigation. The children learn how to determine time using the starts' positions. First, the top and bottom clock pieces are cut and attached to centre, where the North Star is shown, using a pin (Figure 4, Figure 5). Then, the participants are asked to find the North Star and the Big Dipper constellation in Stellarium. The practitioner then indicates their locations in the sky. Following the practitioner's instructions, the children set the current month by turning the moon indicator on the big clock to 12. Then, the small clock is rotated to match the position of the Big Dipper in the sky. In this way, the participants determine the time from the clock window, and an hour is added during summertime. This activity allows participants to develop their skills in determining direction and time using the stars. At the end of the activity, the participants' questions are answered using Stellerium and information is given about the mythological patterns and stories of the constellations.

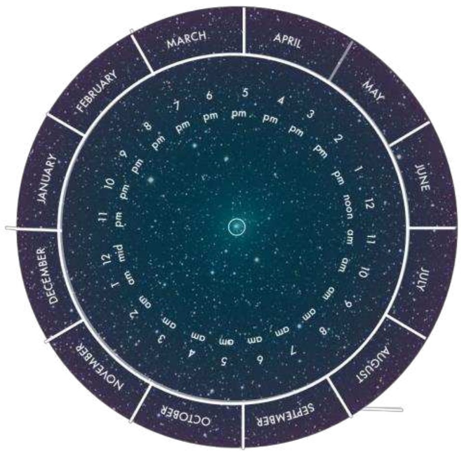

Figure 4. Star Clock Base

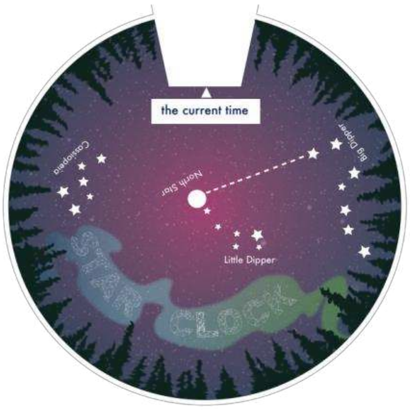

Figure 5. Star Clock Top

Step 5 – Evaluation: Within the scope of the activity, after all stages are completed, a printed sky map of that day is designed together with the participants. The children are asked to create their own constellations by connecting the star points on the map with crayons (

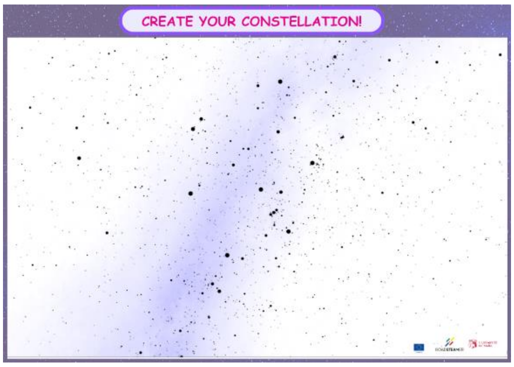

Figure 6, Figure 7). The participants were asked to create a short mythological story for their constellations. Through this process, we emphasise the storytelling component of the workshop. At the end of the workshop, participants are asked to share their own constellations and stories.

Figure 6. Printed sky map for the design of children's constellations

Figure 7. The children design their own constellations on the printed sky map of the day

Implementation Context

The Astronomy Workshop was implemented in two science fair events:

Event A (Science in the City, SITC-2023): The festival takes place in Malta and is part of the European Researchers' Night event. Three different groups of children participated in each session of the Astronomy Workshop. In total, 42 different groups of a maximum 10 participants participated. Each group included both children and their parents/guardians. The workshop was implemented using a non-sequential station technique due to the open-space setting. Participants could start from one activity and move to the next without following a prescribed order, though they always completed the constellation creation activity (Step 5) last.

Event B (Unconventional Science Careers Days, USC-2023): The festival was held at the University of Malta campus. Four different groups consisting of maximum 25 children, a total of 85 children, participated in our workshop. The workshop was implemented in a closed classroom environment using a sequential approach, where all activities followed the designed 5E order.

Research Design

This evaluation study employed a convergent parallel mixed-methods design, in which quantitative and qualitative data were collected concurrently and analysed separately before being integrated during interpretation. The quantitative component consisted of a structured survey administered to the children immediately following workshop completion. The qualitative component included open-ended survey questions and practitioner field observations recorded throughout workshop implementation.

Participants

The sample from both events was 122 children: 79 (64.8%) of the total responses came from Event A (SITC-2023) and 43 (35.2%) from Event B (USC-2023). Overall, more girls than boys attended the events with 72 (59%) of the children identifying as girls, 45 (36.9%) as boys. Five (4.1%) children did not share their gender. During the analysis, this last group (children that did not share their gender) was excluded when the gender was examined. Students' average age was 10 years (M=10, SD=2.4).

Data Collection Instruments

For this study, we collected data through a survey, consisting of 9 closed and open-ended questions to examine their perceptions and assessment of the workshop. The survey format was adapted to the reading skills and age of the children. Closed questions aimed to evaluate issues such as the content of the event, the implementation process, and participant satisfaction. Open-ended questions aimed to obtain participants' suggestions and comments. The survey was online, and children were asked to fill in the responses after the completion of each workshop using tablets provided by the research team.

In addition, for gaining a more holistic understanding of the workshop implementation, the field observations and insights of the practitioner facilitating and coordinating the workshop, one of the authors of this paper, were recorded. Due to the pace and time limit of the workshop implementations and the sustained engagement of the children by the practitioner, a systematic and structured observation and field notes by the practitioner was not possible. Nevertheless, her insights were valuable in gaining an in-depth understanding of the positive aspects and the challenges or problems that emerged.

Data Analysis

The quantitative data were statistically analysed using SPSS 29.0. We conducted descriptive statistics, and Pearson's Chi-Square tests to compare the results of the two events (two independent groups) and to identify any differences (e.g. in engagement). The Chi-Square test is used to examine whether there is a significant association between two categorical variables. In cases where the basic assumptions of the Chi-Square test were not satisfied (e.g. when expected cell counts were too low), Fisher's Exact test was used to ensure the validity and accuracy of the results (Field, 2009).

For the qualitative data (responses to open-ended questions) a thematic analysis was conducted through focused coding (Saldaña, 2009) to identify themes emerging from the children's responses and grounded on the data (Braun & Clarke, 2006). The codes were data-driven rather than theory-driven. Three of the researchers coded the data independently and the themes emerged were negotiated among them until a consensus was reached and a final coding scheme and relevant themes was agreed upon (see Table 1 for the final coding scheme). The thematic analysis revealed the perceptions of the children regarding their engagement with the workshop, its impact, and its learning aspect.

Table 1. Final coding scheme of open questions

Category	Subcategory	Codes	Examples
Descriptive Words (3 Words Question)			
Cognitive Aspect			
	Educational Aspect Value		Interesting informative stars coolness
	Knowledge		
		Astronomy Knowledge - Sky Culture	Constellation Leo Gemini star signs and astrology Beginning of the world Animals zodiac signs
		General Concepts of STEAM	Technology science experiment arts Math
Creative Aspect			Marshmallow Creative sticks building and drawing artistic toothpicks
Emotional Impact			
		Negative	bit boring
		Positive (enjoyment)	Fun Cool Good ENTERTAINMENT Amazing lovely 🌹
Social Aspect			participation teamworking
Learning Outcomes (What Did You Learn)			
Emphasis On Emotional Impact			
		Enjoyment	It was very fun It Slayed
		Inspiring	I learn that i like astronomy
Emphasis On Knowledge and Skills			
	Knowledge	Astronomy Knowledge (Sky Culture)	About the different stars Learned about star clocks

Category	Subcategory	Codes	Examples
			My zodiac sign is different. Theres a lot of shapes in the sky What constellations are I learnt about a star clock.
	Social Skills		Everyone is nice
Emphasis on the Process of Learning			
		Info Through Making - Creative Aspect	Learned about star clocks How people create their own constellations How to use stars as time I like marshmallows we learnd how to connect dots (stars)
		Link to Personal Info	My zodiac sign is different. I like marshmallows I learnt how my star sign looks There are 44 constellations in Malta.

RESULTS AND DISCUSSION

Observations of the Practitioner

During the workshop, the children exhibited creativity, initiative, and engagement with the activities. Indicatively, in Step 2 Exploration, some created their own imaginary constellations, and several returned to this activity after Step 5, indicating preference for creative tasks.

This step attracted accompanying guardians' interest who wanted to help their children. This indicates that creative activities may promote family co-creation and co-operation, but raises questions about parental/guardian roles in such activities and the implications of their mediation.

Learning Outcomes (understandability)

For examining the learning outcomes of the workshop, we analysed question items 4 (Was the workshop easy to understand?), 5 (Did you learn something new today?), and 7 (Would you like to learn more about Astronomy?) and the open questions of the survey.

Overall, the results reflect a positive evaluation of the workshop's clarity (Table 2). The majority of the participants (54.9%) found the workshop very easy to understand, while only a small percentage (0.8%) considered it very difficult. The majority of the participants (91.8%) reported that they did not learn something new during the workshop. However, more than half (51.6%) expressed a definite interest in learning more about astronomy, with an additional 38.5% saying "maybe."

Table 2. Students' responses distribution in the questions 4, 5, and 7

Questions	Responses	Frequencies	Relative Frequencies
Q4. Was the workshop easy to understand?	Very difficult	1	0.8
	A bit difficult	7	5.7
	Neither easy nor difficult	16	13.1
	Somewhat easy to understand	31	25.4
	Very easy	67	54.9
	Total	122	100.0
Q5. Did you learn something new today?	Yes	10	8.2
	No	112	91.8
	Total	122	100.0
Q7. Would you like to learn more about Astronomy?	No, not really	12	9.8
	Maybe	47	38.5
	Yes, definitely!	63	51.6
	Total	122	100.0

No significant differences between boys and girls were identified regarding their understanding (x2(3)=2.775, p=.428), enjoyment (x2(1)=.009, p=.925), and understandability (x2(1)=1.204, p=.273) of the workshops.

When we compared the results of q4 (workshop easy to understand) between the two groups (Event A, Event B), significant differences were found (x2(4)=33.642, p=.001). Participants from the SITC-2023 event rated the workshop more positively, with 70.9% finding it very easy to understand, compared to only 25.6% in the USC2023 group (Figure 8). This suggests that the understandability and applicability of the workshop change depending on the environment (in an open-air festival or inside a classroom).

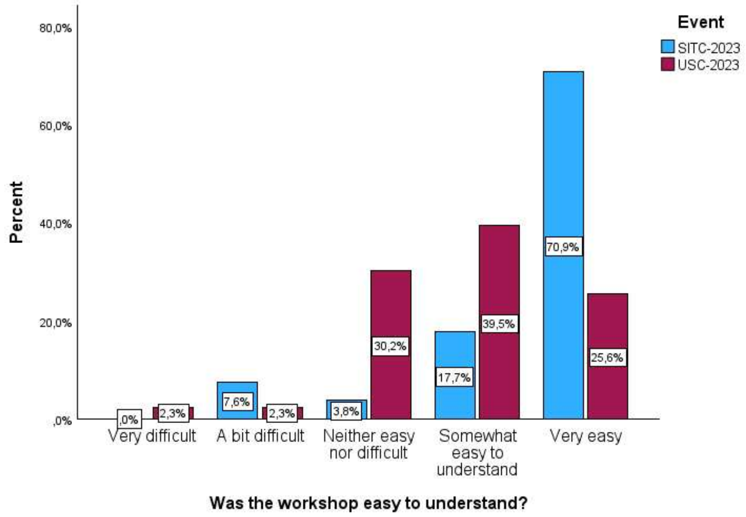

Figure 8. Perceived Ease of Understanding the Workshop by Event

The children that responded yes to q5 (Did you learn something new today?) were asked to elaborate in the next open question (q6). Through the analysis of the children's comments, three main categories emerged:

Emphasis on the Emotional Impact of the workshop (5 references) with comments such as "It was very fun", and "It Slayed", and the inspirational impact ("I learn that i like astronomy")

Emphasis on Knowledge and Skills (28 references), where we identified reference to astronomy knowledge ("What constellations are") and also to the social skills involved ("Everyone is nice").

Emphasis on the Process of Learning (21 references), where children referenced procedural knowledge such as "How people create their own constellations" and "How to use stars as time".

Some of the quotes coded under the Knowledge subcategory made references which did not seem relevant to the Astronomy Workshop (e.g., "About sharks", "I learnt how to take blood", "How to respect the sea"). These are most probably references to other workshops running in parallel to our workshop in both events. This indicates that either it was not clear to the children that the survey only assessed the specific workshop or that there was probably a stimuli overload for the children with the varied learning content in different workshops.

Unsurprisingly, since the question referred to learning outcomes, most of the children's quotes were relevant to specific astronomy knowledge and concepts. However, it was interesting to find that in many cases the children referenced learning outcomes that emerged through the more creative activities (marshmallows, connecting the dots, drawing) (e.g., "we learned how to make constellations.") or learning outcomes linked to their personal and lived experiences (e.g., "My zodiac sign is different.", "There are 44 constellations in Malta."). 14 quotes were coded under the subcategory “Information through Making and Creativity” and 7 references were coded under the “Link to Personal Information” subcategory of the “Emphasis on the Process of Learning” category.

The Workshop at School

The results of item 8 (workshop at school) showed that 55.7% of the respondents stated they would definitely like to attend a similar workshop at school, indicating overall enthusiasm despite limited new learning. This distribution did not differ significantly between genders (Figure 9).

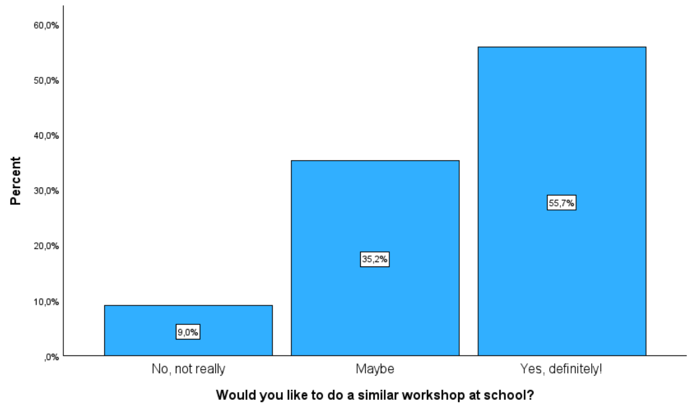

Figure 9. The interest of the children to attend a similar workshop at school

Enjoyment

The level of enjoyment of the children was examined through a survey closed question (3. Did you enjoy our Astronomy Workshop?) and further explored through the analysis of the two open questions (6. If your answer above is "Yes" [I learned something], explain it in one sentence, 9, When you think about this workshop, what are 3 words that comes through your mind?). 33.6% of the children responded that it was okey (response b). 66.4% responded that they loved it.

When we further compared the levels of enjoyment between the two groups (Event A SITC-2023 and Event B UTC-2023), it seemed that the children of Event A enjoyed the workshop more than the children of Event B ($\chi 2(1)=14.677$, $p=.001$). It was found that 78.5% of Event A participants responded that they loved it, but in Event B, the results were slightly different (44.2% responded that they loved it) (Figure 10).

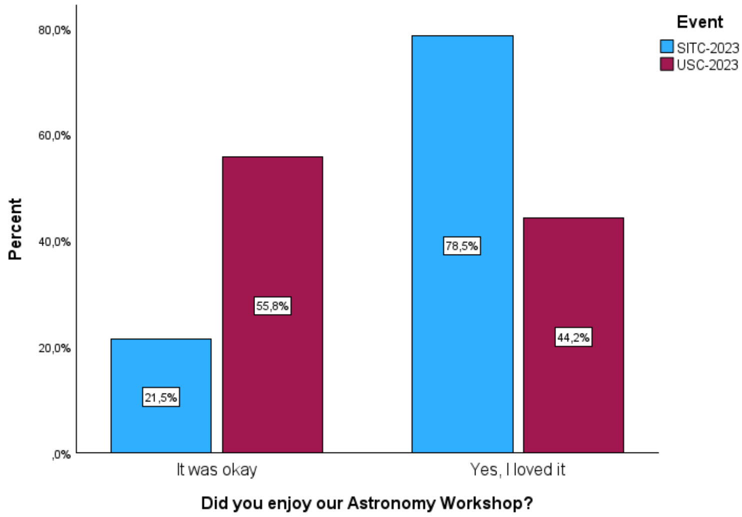

Figure 10. Levels of enjoyment by Event

The enjoyment aspect also came up in the analysis of the open questions (items 6, 9). When analysing the responses of the children we found comments such "Cool", "Good", "ENTERTAINMENT", "Amazing", "lovely" (q9, coded under the "Positive" subcategory, and "Emotional Impact" category), and also comments such as "It was very fun" and "It Slayed" (q6, coded under the "Enjoyment" subcategory, and "Emphasis On Emotional Impact" category). We did identify 2 references to negative emotional impact such as "bit boring" (q9). This was particularly interesting, especially as a result of q9 (3 words about the workshop) regarding the positive emotional impact was one of the most referenced themes with 43 references (Table 2). It seemed that the fun aspect of the workshop was one of the aspects that impressed the children the most.

Overall perceptions of the workshop

Through q9 (When you think about this workshop, what are 3 words that comes through your mind?) we examined the general impressions of the children about the workshop (Figure 11). Through our thematic analysis, four main categories emerged regarding the content of the children's quotes:

Cognitive Aspect (92 references): In this category, we coded quotes to specific concepts and information relevant to the content of the workshop (e.g., "solar system"). By further analysing the quotes in this category, we identified quotes directly relevant to Astronomy (Astronomy knowledge subcategory, 47 references), e.g., "planets, stars, constalletion, astronomy", quotes relevant to the broader STEAM field (General Concepts of STEAM subcategory, 13 references) e.g., "Teknology", "scients and experiment", and was also identified some persisting misconceptions (5 references) e.g., "star signs and astrology", "astrology" indicating that the distinction between astronomy and astrology was not entirely clarified for some of the children. A third subcategory that emerged was relevant to the *Educational Aspect Value* (24 references), where children did not reference specific learning concepts but rather seemed to appreciate the educational value of the workshop in more general terms, e.g., “Interesting”, “informative”, “the best stars coolness”.

Creative Aspect (16 references): Children’s responses that referenced the creative activities they were engaged in e.g., “creative”, “Marshmallow”, “building and drawing” “sticks”.

Emotional Impact-Enjoyment (45 references): In this category, we coded children’s responses that indicated the emotional impact the workshop had on them, with 43 positive references (“fun”, “ENTERTAINMENT”, “Nice fun and lovely”) and also 2 negative (“bit boring”).

Social Aspect (3 references): This category emerged from the children’s responses that were relevant to the social aspect of the workshop and the collaboration among the children (“participation”, “teamworking”) as aspects that impressed them the most.

It was interesting to see that most of the overall final impressions of the children were linked to the learning content of the workshop and also the fun aspect of the workshop.

Figure 11. Word cloud based on frequency of terms mentioned by the children in q9 (When you think about this workshop, what are 3 words that comes through your mind?)

CONCLUSION

The findings indicated that the children enjoyed the STEAM Astronomy workshop more in Event A, the science and arts festival, than Event B, the hands-on open university career day. This could be attributed to the fact that while Event A was voluntary, participation in Event B was mandatory by the organiser (a school) and therefore children in Event A might have already been interested in the topic before participating. Event A was a non-formal learning activity, situated within a science and arts festival in a public space happening after school hours, while Event B was situated within a university setting and within school hours. Since, Event A was outdoors, it allowed for free exploration and movement. This qualitative difference may have contributed to the enjoyment of the children (Trina et al., 2024). It aligns with previous findings on situational interest in science education, where learner autonomy and environmental factors play key roles in engagement (Sonia et al., 2023). Considering that the content and format of the astronomy workshop were identical in both settings, it is worth further examining how the learning environment itself shapes children's experiences.

No significant gender differences emerged in understanding, enjoyment, or reported learning. However, more girls than boys expressed a desire for similar school workshops. This supports previous research indicating that STEAM approaches incorporating artistic and storytelling elements may be particularly effective in engaging female students in STEM (Sanz-Camarero et al., 2023). Encouraging inclusive, interdisciplinary approaches in astronomy education could help address persistent gender disparities in science participation (Sanz-Camarero et al., 2023).

As shown by the qualitative analysis of the 2 questions (learning, impressions) content knowledge on Astronomy and STEM emerged as the strongest component in both cases, with less references in the creative, emotional, and social aspects. This may indicate that the children perceived the workshop primarily as an educational experience rather than just entertainment. Knowledge acquisition was emphasised by the children more than other aspects, in line with more traditional perspectives on learning. At the same time, however, the quantitative findings showed that 91.8% of participants reported not learning something new, even though more than half expressed a strong interest in learning more astronomy. Taken together, these results indicate that while children framed their experiences largely in terms of astronomy knowledge, the workshop may have functioned less as a source of new knowledge and more as a catalyst for curiosity and future learning. This dual role highlights the importance of addressing not only factual understanding but also the broader processes of science -learning how to be inquisitive, how to observe and ask questions, how to gather and analyse data to reach a conclusion (Constantinou, 2018; Urdanivia Alarcón et al., 2023). Strengthening this metacognitive dimension could enhance the impact of such workshops by fostering both conceptual understanding and inquiry-based scientific thinking.

The creative dimension of the workshop also emerged strongly. Practitioner observations noted that several children chose to invent their own constellations in Step 2 and even returned to this activity after Step 5, suggesting a particular preference for open-ended creative tasks. Children's open-ended responses reinforced this, with many linking astronomy knowledge to creative activities (e.g., marshmallows, drawings). These findings suggest that making processes facilitated memory retention ("we learned how to make constellations").

It was also interesting that, particularly in the question on learning outcomes, they recalled concepts linked to their personal context and environment, such as their star sign or living in Malta (e.g., "My zodiac sign is different," "There are 44 constellations in Malta"). These findings suggest that embedding cultural and personal relevance into astronomy education can strengthen both conceptual retention and engagement.

Additionally, the study highlights the importance of teacher and facilitator training in STEAM education. Inquiry-based and art-based learning approaches, while effective, require practitioners to develop specialized pedagogical content knowledge. This aligns with the Content Knowledge (CK) and the Pedagogical Content Knowledge (PCK) of the TPACK model discussing teachers' necessary competencies (Koehler & Mishra, 2009; Willermark, 2024). Others are also developing STEAM frameworks for formal and non-formal education that incorporate initial teacher training programmes or continuous professional development programmes to try and help teachers incorporate these approaches (Chappell et al., 2025). These competences, though, may be challenging for teachers unfamiliar with student-centred approaches, who consequently rely on traditional teaching methods, like direct explanations (Ampartzaki, Chatzoglidou, et al., 2024). The complex and multiple competences a non-formal learning activities practitioner needs for running an effective workshop have been reported to be one of the main challenges (Christidou et al., 2022). This has implications for the professional development training of Astronomy workshops practitioners (Ampartzaki, Tassis, et al., 2024): they must be trained not only in astronomy content but also in creative pedagogies that blend science with art.

Finally, practitioner observations noted that guardians frequently engaged with their children's constellation-making, sometimes actively helping them. This indicates that such activities can promote family co-creation and intergenerational learning but also raises questions about the role of parental mediation. Prior research has shown that parental explanations may both support and constrain children's inquiry, depending on whether they stimulate or replace children's own questions (Joy et al., 2021). Future research should therefore explore how parental involvement in non-formal workshops shapes both enjoyment and learning outcomes.

Moving forward, further research is needed to investigate the long-term impacts of STEAM-based astronomy workshops on students' science attitudes and career interests. Additionally, exploring cross-cultural applications of similar workshops could provide deeper insights into how cultural narratives and local traditions enhance science education. By refining and expanding creative methodologies in STEAM education, we can cultivate a new generation of scientifically literate, creatively and critically engaged learners who see science as an evolving, human-centred pursuit.

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DISCLOSURE STATEMENT

The authors have no potential conflict of interest.

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