

Research

From Sky Patterns: Hipparchus' Stars Bridge – İznik & Salerno STEAM Hackathon for Astronomy Education

Brojna Daniela^{1,*}, Kırmacı Hatice², Seydim Arzu Çalik³, Bal Esra Tuğçe⁴, Güney Duygu⁴

1. IC Moscati, Fonseca Middle School, Pontecagnano, Salerno, Italy
2. Women Science Teachers Organisation & ENOVA Training Consultancy, Istanbul, Türkiye
3. Etiler Anatolian High School, Istanbul, Türkiye
4. Kartepe Ertuğrul Gazi Anatolian High School, Kocaeli, Türkiye
5. Correspondence: Hatice Kırmacı; womenscienceteachers@gmail.com

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Abstract:

Within the framework of the Women Science Teachers initiative, the Sky Patterns: Hipparchus' Stars Bridge Between İznik and Salerno STEAM hackathon was implemented between September and November 2025. The project integrates the legacy of ancient astronomy with contemporary STEAM (Science, Technology, Engineering, Art, and Mathematics) education. Inspired by Hipparchus of Nicaea (c. 190–120 BCE), often regarded as the father of scientific astronomy, the project aimed to foster data literacy, inquiry-based learning, collaborative problem-solving, and cross-cultural interaction. The hackathon involved twenty one students aged 11–17 from Türkiye (Istanbul, Kocaeli) and Italy (Salerno). Participants explored astronomical patterns while examining the historical and aesthetic connections between İznik tiles and Italian ceramic traditions. Following training in project management, art history, augmented reality (AR), virtual reality (VR), artificial intelligence (AI), 3D modeling, and coding, students developed original interdisciplinary projects.

Additionally, students from three schools—Beşiktaş Anatolian High School (Istanbul), De Sanctis High School (Salerno), and Yeni Levent Anatolian High School (Istanbul)—contributed to the organization of the hackathon and supported peer learning processes.

A mixed-methods research design was employed, including pre- and post-assessments, student product evaluation rubrics, and semi-structured interviews. The findings indicate that integrating historical scientific heritage with digital technologies contributes to enhancing students' critical thinking, creativity, interdisciplinary understanding, and digital production skills.

Keywords: STEAM education; Hackathon pedagogy; astronomy education; Hipparchus; İznik tiles–Italian ceramics; interdisciplinary learning

1. Introduction

İznik is a multi-layered archaeological settlement that has hosted different civilizations since prehistoric times and has been included in the UNESCO World Heritage Tentative List since 2014. Owing to its rich collection of archaeological remains, monumental structures, and cultural heritage assets, the city represents an important center for cultural and religious tourism (Kapuci & Cengiz, 2023). Consequently, İznik provides a rich context for interdisciplinary STEAM activities that connect science, technology, engineering, art, mathematics, and cultural heritage.

Nicaea (modern-day İznik) occupies a significant place in the history of astronomy as the birthplace of Hipparchus. Astronomy and mathematics have historically played a fundamental role in shaping scientific thought and human understanding of the universe. Hipparchus of Nicaea, who lived in the second century BC, is widely recognized as one of the pioneers of scientific astronomy due to his systematic star catalogues and his use of trigonometric calculations. His approach can be considered an early form of data organization and pattern recognition, which are essential components of modern scientific analysis (Dreyer, 1953).

Recent research based on multispectral imaging has revealed new evidence of Hipparchus' lost star catalogue, demonstrating that his observations achieved an accuracy within one degree and were recorded using an advanced equatorial coordinate system, centuries before later astronomical catalogues (Gysembergh et al., 2022).

Beyond its scientific significance, İznik is also renowned for its ceramic heritage, which represents one of the most significant artistic achievements of the Ottoman Empire. Through cultural and commercial exchanges between the Ottoman Empire and Europe, Iznik ceramics influenced Italian maiolica production, particularly through decorative motifs and ceramic forms such as tondino dishes. These interactions demonstrate the important role of Iznik as a centre of artistic and cultural exchange between Anatolia and Europe (Zidan, 2019).

Building upon this historical foundation, the project titled Sky Patterns: Hipparchus' Stars Bridge Between İznik and Salerno was developed to establish a connection between ancient scientific knowledge and contemporary digital technologies. The project aims not only to integrate astronomy with modern educational tools but also to provide a holistic examination of a city through scientific, artistic, and technological perspectives. The cultural and scientific relationship established between İznik and Salerno contributes to the international dimension of the study and highlights the importance of interdisciplinary and cross-cultural learning environments (Graham, 2013).

Furthermore, the integration of artificial intelligence, augmented reality, virtual reality, and three-dimensional modeling tools into the educational process has created a dynamic and interactive learning environment. This interdisciplinary approach reflects the transition from STEM to STEAM education by incorporating artistic elements. STEM Education is an approach to learning that uses Science, Technology, Engineering and Math as access points for guiding student inquiry, dialogue, and critical thinking, and STEAM builds on this by integrating the Arts, science and culture into educational process (Kralj-Iglič & Istileulova, 2025).

2. Material and Methods

The project was implemented between September and November 2025 within the framework of the Women Science Teachers initiative and involved twenty-one students aged 11–17 from Türkiye (Istanbul and Kocaeli) and Italy (Salerno). The implementation was designed as a STEAM-oriented hackathon integrating scientific inquiry, digital production, cultural heritage, and collaborative problem-solving. Participants represented three schools (**Table 1**).

Table 1. Participating schools and student distribution.

School	Country	Level	Grade(s)	Female	Male	Total
IC Moscati-Fonseca Middle School	Italy	Middle School	8	4	4	8
Etiler Anatolian High School	Türkiye	High School	10–11	4	-	4
Kartepe Ertuğrul Gazi Anatolian High School	Türkiye	High School	9-10	6	3	9

The pedagogical design was based on inquiry-based STEAM education. As noted by Abdi (2014), inquiry-based science education engages students in the activities and thinking processes used by scientists to generate new knowledge. Likewise, Land (2013) emphasised that innovation emerges through the integration of technology with creative thinking and design. These principles formed the conceptual basis of the Sky Patterns project, which connected astronomy, cultural heritage, digital technologies, and artistic expression within a single interdisciplinary learning environment.

The project aimed to establish connections between the astronomical legacy of Hip-parchus of Nicaea and the cultural heritage of İznik and Salerno through collaborative STEAM-based learning experiences. The learning programme began with preparatory sessions delivered by university academics, museum experts, participating teachers, and project mentors from Türkiye and Italy.

The programme included project management, the astronomical contributions of Hip-parchus, cultural heritage, İznik tiles, Italian ceramic traditions, and emerging digital technologies. Digital technology training covered artificial intelligence (AI), augmented reality (AR), virtual reality (VR), extended reality (XR), coding, and three-dimensional (3D) modelling, with contributions from the University of Salerno, Bursa Uludağ University, and the STEAM Coordination Unit of the Istanbul Provincial Directorate of National Education. Museum specialists introduced the artistic and historical characteristics of İznik tiles and Italian ceramics, enabling students to compare the two cultural traditions. Training sessions were delivered in English, Turkish, and Italian to facilitate international collaboration.

Following the preparatory phase, students worked collaboratively in interdisciplinary teams to develop projects exploring the scientific, technological, artistic, and cultural dimensions of İznik. Throughout the project, they investigated astronomical concepts, cultural heritage, artistic patterns, and digital applications while designing their own interdisciplinary products. A peer-learning and mentoring model was integrated into the implementation, with four mentor students supporting teamwork, facilitating discussions, assisting in the use of digital technologies, and promoting communication among participants. Participating teachers provided continuous pedagogical guidance throughout the project.

The completed projects were presented during an international online dissemination event attended by students, teachers, academics, mentors, and invited experts from the participating countries.

Data were collected at the end of the hackathon using a mixed-methods approach. Quantitative instruments included a 28-item STEAM Interdisciplinary Awareness Scale, a Digital Technology Competency Test comprising ten multiple-choice questions and five performance tasks, a 20-item Hackathon Process Experience Scale, and an analytic product evaluation rubric assessing scientific accuracy, interdisciplinary integration, digital competence, aesthetic quality, and innovation. Qualitative data were obtained through semi-structured interviews exploring students' perceptions of STEAM integration, digital technologies, cultural heritage, teamwork, and project outcomes.

Quantitative data were analysed using descriptive statistics, while qualitative interview responses were examined thematically to identify common patterns related to student engagement, interdisciplinary understanding, digital competence, cultural heritage awareness, and learning experiences.

Participation was voluntary. Students and their families were informed about the educational objectives of the project, and informed consent was obtained for participation, data collection, and dissemination of educational outputs.

Within the framework of the project, mentor students conducted a comprehensive STEAM-based analysis of the city of İznik, transforming it into a multidimensional learning environment (Figure 1A).

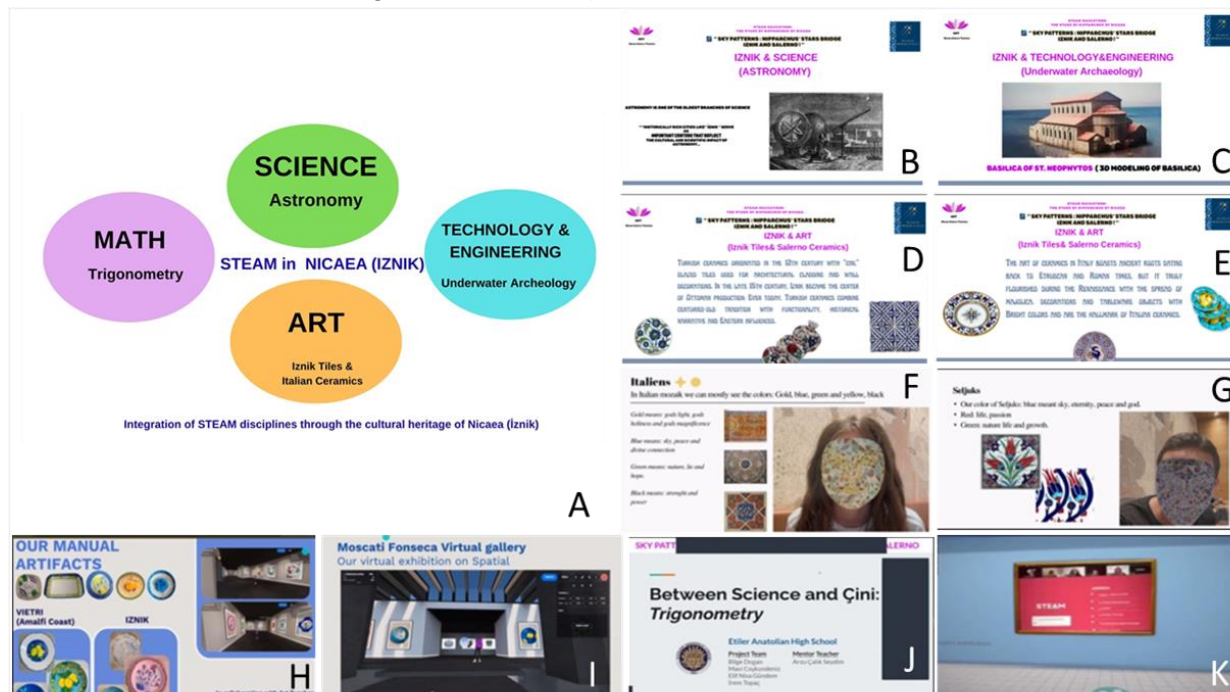


Figure 1. A: Conceptual STEAM model of Nicaea (İznik); B: Scientific heritage in İznik: The legacy of Hipparchus; C: Engineering in İznik: St Neophytos Basilica; D: Art in İznik: Ceramic heritage; E: Mathematics in İznik: Trigonometry; F,G: student presentations on stellar distance measurement through parallax and the comparison of İznik and Italian ceramic traditions, highlighting integration of astronomy, mathematics, cultural heritage and design within a STEAM learning environment; H,I: exploring color symbolism and digital pattern design in Italian and İznik art; J,K: illustration of integration of mathematics, digital technologies and visual communications within the STEAM framework. Panels B-K were frame-grabbed from the online presentations.

From a scientific standpoint, the study was grounded in the astronomical legacy of Hipparchus, including his work on star catalogues, celestial navigation, and observational astronomy (Figure 1B). In the domains of technology and engineering, students explored advanced digital applications such as AR, VR, and 3D modeling, exemplified through the reconstruction of the Basilica of St. Neophytos, alongside investigations into underwater technologies, AI-assisted surveying processes, geomatics engineering, geology, seismology, and sonar systems (Figure 1C). From an artistic perspective, the rich aesthetic tradition of İznik tiles was analysed and comparatively examined alongside Italian ceramics, focusing on geometric patterns, symmetry, composition, colour palettes, and symbolic meanings (Figures 1D). In the mathematical dimension, students applied concepts of trigonometry, geometry, astronomical calculations, and ratio-based pattern analysis to interpret both scientific and artistic structures (Figure 1E).

This interdisciplinary approach enabled students to perceive İznik not only as a historical and cultural site, but also as a dynamic intersection of science, mathematics, technology, and art. Furthermore, the integration of artificial intelligence, augmented reality, virtual reality, and three-dimensional modeling tools into the educational process has created a dynamic and interactive learning environment. As Bequette and Bequette (2012) noted, STEAM education integrates science, technology, engineering, arts, and mathematics while emphasizing creativity, design thinking, and interdisciplinary learning. This inter-

disciplinary approach reflects the transition from STEM to STEAM education by incorporating artistic elements into scientific inquiry, thereby enhancing both analytical thinking and creative production skills.

Figure 1A developed within the project, representing the interdisciplinary integration of astronomy, underwater archaeology, cultural heritage (Iznik tiles and Italian ceramics), and trigonometry. The model reflects a holistic approach to place-based.

3. Results

The educational intervention resulted in a multidimensional STEAM learning environment that integrated astronomy, cultural heritage, digital technologies, engineering, mathematics, and art. The results indicate that this interdisciplinary approach enhanced students' learning outcomes and supported the development of critical thinking, creativity, and digital competences. This interdisciplinary approach reflects the transition from STEM to STEAM education by incorporating artistic elements into scientific inquiry, thereby enhancing both analytical thinking and creative production skills.

Figure 1 illustrates the educational outcomes of the STEAM intervention. From a scientific perspective, students explored the astronomical legacy of Hipparchus, including his work on star catalogues, celestial navigation, and observational astronomy (**Figure 1B**). Within the technology and engineering components, students applied AR, VR, AI, and three-dimensional (3D) modelling to the reconstruction of the Basilica of St Neophytos and investigations of underwater archaeology, geomatics engineering, geology, seismology, and sonar systems (**Figure 1C**). From an artistic perspective, they compared the aesthetic traditions of Iznik tiles and Italian ceramics, examining geometric patterns, symmetry, composition, colour palettes, and symbolic meanings (**Figure 1D**). Within the mathematical component, students applied trigonometry, geometry, astronomical calculations, and proportional pattern analysis to interpret both scientific and artistic structures (**Figure 1E**). **Figure 1A** was developed within the project and presents a conceptual STEAM model integrating astronomy, underwater archaeology, cultural heritage (Iznik tiles and Italian ceramics), and trigonometry. The model illustrates a holistic place-based learning approach that connects scientific inquiry with cultural heritage and digital technologies.

This interdisciplinary approach enabled students to perceive Iznik not only as a historical and cultural site, but also as a dynamic intersection of science, mathematics, technology, and art. Furthermore, the integration of artificial intelligence, augmented reality, virtual reality, and three-dimensional modeling tools into the educational process has created a dynamic and interactive learning environment. **Figure 1A** developed within the project, representing the interdisciplinary integration of astronomy, underwater archaeology, cultural heritage (Iznik tiles and Italian ceramics), and trigonometry. The model reflects a holistic approach to place-based.

Students demonstrated notable levels of critical thinking, interdisciplinary connection, and digital production skills, reflecting the effectiveness of the STEAM-based hackathon model.

Table 2. Analytical Product Evaluation Rubric Results (Students, n = 21)

Dimension	Description	Score	Percentage
Scientific Accuracy	Correct use of astronomy and mathematics concepts	81/105	77.1%
Interdisciplinary Integration	Balanced integration of STEAM components	105/105	100%
Digital Technical Competence	Effective use of 3D modeling, AR, and AI tools	105/105	100%
Aesthetic Quality	Design quality and visual integrity	77/105	73.3%
Innovation	Originality and creativity of project outputs	105/105	100%
Total		473/525	90.1%

Each criterion was scored on a five-point scale ranging from 1 (Beginning) to 5 (Excellent).

The rubric results indicate that students successfully integrated astronomy, mathematics, cultural heritage, and digital technologies into their project outputs. Particularly high scores in interdisciplinary integration, digital competence, and innovation demonstrate the

effectiveness of the STEAM-based hackathon model in fostering creative and technology-enhanced learning.

The digital outputs produced by the participants included three-dimensional models, augmented and virtual reality environments, animated visual content, and virtual exhibitions. These outputs illustrate the ability of students to transform abstract astronomical data into meaningful visual and cultural representations, thereby bridging the gap between scientific knowledge and creative expression.

All n=21 participants attended a hackathon for the first time, and all students expressed willingness to participate in similar activities in the future. This finding indicates a highly positive learning experience and suggests that the STEAM-based hackathon model successfully promoted student engagement, motivation, and interest in interdisciplinary learning.

Table 3. Students' Hackathon Participation Experience (n = 21).

School	Students (Female/Male)	First-Time Hackathon Participants	Willing to Participate Again
IC Moscati-Fonseca Middle School	8 (4F, 4M)	8 (100%)	8 (100%)
Etiler Anatolian High School	4 (4F, 0M)	4 (100%)	4 (100%)
Kartepe Ertuğrul Gazi Anatolian High School	9 (6F, 3M)	9 (100%)	9 (100%)
Total	21	21 (100%)	21 (100%)

Qualitative interview findings further supported the quantitative results. Students most frequently identified the integration of science and art as the strongest connection among STEAM disciplines. Participants reported that digital tools accelerated their learning process and enhanced their engagement with project activities. The historical scientific legacy of Hipparchus was perceived as inspiring and relevant for future projects. Students highlighted collaboration and teamwork as important factors contributing to project success, while the virtual museum was frequently mentioned as the project output of which they were most proud. Furthermore, all interviewed students expressed their willingness to participate in similar international STEAM projects in the future.

The implementation conducted at IC Moscati – Fonseca Middle School in Salerno focused on integrating cultural heritage with digital production through both manual and computational approaches. The exploration of Hipparchus' star catalogue enabled students to link astronomical knowledge with coordinate systems and spatial representations. (Figures 6). Furthermore, the development of Python-based digital tiles intended for execution in the Astro Pi environment demonstrated the integration of coding, astronomy, and artistic design within a unified STEAM framework. Students developed three-dimensional models of İznik and Salerno ceramics using block-based coding and created digital content combining ceramic traditions with elements of local culture.

In addition, they utilized the Europeana digital archive to design animated visual content, thereby connecting historical artifacts with contemporary digital storytelling (Figure 7).

The implementation at Kartepe Ertuğrul Gazi Anatolian High School emphasized the integration of mathematical reasoning, astronomy, and artificial intelligence. Inspired by Hipparchus' trigonometric methods, students constructed geometric models and visualized celestial relationships through angles and spatial measurements. Artificial intelligence tools were employed to analyze facial structures and generate personalized İznik tile patterns, illustrating the intersection of data analysis, digital art, and cultural heritage (Figures 8-9). Additionally, the recreation of Eratosthenes' experiment through a narrative-based approach enabled students to understand complex scientific concepts such as the calculation of the Earth's circumference in an accessible and engaging manner.

Students from Etiler Anatolian High School applied concepts of trigonometry and geometry to explore the relationships between mathematical structures, artistic design, and digital technologies. Through the use of artificial intelligence-supported modeling tools, they

investigated how geometric principles can be transformed into visual and three-dimensional representations. The resulting digital artefacts were presented within a virtual exhibition environment, providing opportunities to examine the integration of mathematics, design, and digital communication within a STEAM-based learning framework (**Figures 1J,K**).

4. Discussion

As Bequette and Bequette (2012) noted, STEAM education integrates science, technology, engineering, arts, and mathematics while emphasizing creativity, design thinking, and interdisciplinary learning. The findings indicate that the integration of cultural heritage, astronomy, and digital technologies within a STEAM-based hackathon provides an effective interdisciplinary learning environment. The high overall rubric score (90.1%), together with the maximum scores obtained for interdisciplinary integration, digital competence, and innovation, demonstrates that students successfully combined scientific, artistic, and technological knowledge in their project outputs.

These findings are consistent with previous studies emphasizing the value of STEAM education in fostering creativity, interdisciplinary thinking, and problem-solving skills (Bequette & Bequette, 2012). Similarly, the inquiry-based structure of the hackathon supported active learning and knowledge construction, in line with the principles described by Abdi (2014). The effective use of AI, AR, VR, and 3D modelling tools also supports Land's (2013) view that innovation emerges through the integration of technology and creative thinking.

An additional indicator of success was student engagement. All participants were first-time hackathon attendees, and 100% expressed willingness to participate in similar activities again, suggesting a highly positive learning experience. Furthermore, the collaboration between students from Türkiye and Italy promoted intercultural learning and strengthened the connection between scientific and cultural heritage education.

However, the study was limited by its relatively small sample size, the use of descriptive statistics only, and the absence of inferential statistical analyses and comprehensive quantitative comparisons. These limitations restrict the generalizability of the findings. Future studies should involve larger participant groups, employ pre- and post-assessments, and incorporate more rigorous statistical analyses to further validate the effectiveness of STEAM-based hackathon models.

5. Conclusions

The Sky Patterns: Hipparchus' Stars Bridge Between İznik and Salerno project presents an innovative and scalable educational model that integrates astronomy, cultural heritage, and advanced digital technologies within a STEAM framework. The findings demonstrate that artificial intelligence-supported learning environments can significantly enhance student engagement, creativity, and interdisciplinary understanding.

The project highlights the potential of cultural heritage as a powerful educational resource, capable of connecting historical knowledge with contemporary technological practices. The international collaboration between İznik and Salerno further emphasizes the importance of cross-cultural learning and global educational exchange.

Furthermore, the project contributed to the promotion of gender equality in STEAM education. By ensuring balanced participation of girls and boys, the hackathon created an inclusive learning environment where female students could actively contribute to scientific and technological activities. In particular, the online format enabled girls from different socio-economic and geographical backgrounds to connect with international peers and collaborate on shared project outputs. These opportunities supported not only interdisciplinary learning but also the empowerment of girls as active participants in science, technology, and innovation.

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Acknowledgements: Project website:

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