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EASA Expert Group: Science, Technology, Engineering, Mathematics in Arts and Culture (STEMAC)

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Conceptualization of STEMAC and Academy's commitments

Emerging STEMAC in pedagogics

The Science, Technology, Engineering and Mathematics (STEM) with Arts (STEMA) (Fenyvesi *et al.,* 2016; Burnard *et al.,* 2017; Psycharis, 2018; Houghton *et al.,* 2022; Lavicza *et al.,* 2022) introduces students and educators to an attractive approach with increased learning output in classroom. STEAM removes limitations and replaces them with wonder, critique, inquiry, inquiry, innovation, and method of training students in the arts, humanities and social sciences with skills suitable for the 21st century workforce. The status and potential of this field initiates a further step to encompass Culture, as well (Liritzis, 2018). This is the STEMAC (Science, Technology, Engineering, Mathematics for Arts and Culture), novel, and, surely integrated rapprochement, which reinforces coherence between natural sciences and engineering and technology and humanities (art / culture). This new transdisciplinary and interdisciplinary field that emerges in pedagogics is developed further through an initial proposal for the formation of a specialist task committee in EASA as proposed by Ioannis Liritzis (Dean Class IV) and Klaus Mainzer (President of EASA) and a first group of experts comprised of Members and non-members was formed.

The basic development of STEM in Arts+Culture is made by expert Members from the 5 Classes (I, III, IV, V, VI). Non-Members shall participate occasionally to share expertise and disseminate the developed knowledge to other Institutions and participate in joint projects.

Experts from five Classes to cover dimensions of STEM: From Class I (archaeologists, anthropologists, historians of Art, Culturalists *etc*.); from Class III (music, painting, architecture, dance, intangible heritage *etc*); from Class IV (natural Sciences for STEM); from Class V (sustainability, economics in education); and from Class VI (engineers, environmentalists, *etc*.).

Recommendations for action by EASA Expert Group

- We need to clarify and explore the interdisciplinary and integrated scope of STEM with Arts and Culture (Science, Technology, Engineering, Mathematics for Arts and Culture; STEMAC or STEM4AC) in Education and tie this with previous Expert Groups (Education, Research, Innovation, ERI; Digitalization, AI, and Societal Impact) as methodology and applications in the different Classes and disciplines of our Academy.
- However, economics, sustainability, infrastructures, and innovative models should balance various digital tools (distance learning, virtual reality in education, STEM in arts and culture-STEMAC, etc.) to achieve a more sustainable world in this inter/trans-disciplinary topic managed as a whole and not as independent events in the evolution process. This new model supports cooperation and transdisciplinary development and innovation but sustainability goals too.
- Therefore, besides concrete technologies, the importance of prioritizing R&I as norms needs to be taken into account for the current and future of interdisciplinary STEMAC in research centers and education on the courses of Arts and Culture implementing fruitful efficient courses and models in syllabuses.
- Besides established R&T, IT tools, new promising interdisciplinary fields emerging from the continued advanced technologies should be developed and applied to enhance Europe's position in a worldwide competition of research, innovation, and education. STEMAC as an educational component includes the experiencing dimensions in the class, in the field, and in the virtual educational environment applied to Arts and Culture.
- Our Academy should concentrate the expertise of its members in the development of research on Science and technologies covering intelligent systems (AI), machine learning, virtual instrumentation, sustainable production of energies at low cost for all as well as research questions that tie in with the innovation of STEMAC, in various aspects of Arts and Cultural Heritage and education, to sharpen the profile of the Academy.

- STEMAC via digital models should aim at a sustainable R&I and learning environment with escalated advanced perspectives in innovation and service systems for enhancing and preserving past culture and traditional tangible and intangible heritage through education.
- Interdisciplinary education stemming from the balance of humanities (arts and cultures), design and architecture, and natural sciences and technology, but human autonomy as well, are in the best of European philosophical and educational traditions, as well as with the leading values of the European Academy of Sciences and Arts.
- From the fusion of STEM with the arts and culture to explore the extension of applications in other scientific fields of life, of science and technology. EASA promotes research on key performance indicators for measuring the impact of R&D in STEMAC
- Interdisciplinary Scope: Creation of a digital collaboration platform to facilitate interdisciplinary projects, enhancing dialogue and sharing of methodologies between STEM and Arts and Culture professionals.
- Economics and Sustainability: highlighting case studies demonstrating the economic sustainability of digital tools in archaeology, such as VR applications that enhance tourism and education, thereby generating revenue for further research.
- Prioritizing R&I: Dedicated fund to support AI applications in artifact preservation and restoration could significantly impact cultural heritage conservation.
- Emerging Fields: Exploring the potential of blockchain technology for artifact provenance tracking could revolutionize the field, and I suggest initiating pilot projects to assess its benefits.

STEM, STEAM or STEMAC?

In the current era, science with technology, engineering and mathematics can work together with Arts (STEAM) to enhance the benefits from science-technology-engineering-mathematics (STEM) by merging these principal disciplines. STEAM lifts STEM to the next level: it helps students network their learning in these critical areas together with arts concepts and practices, design principles, and standards to provide new learning (Watson and Watson, 2013).

STEAM is developed to integrate STEM scientific subject categories into various relevant disciplines for education. These constructed programs aim to teach apprentices to think critically and use engineering, technology, natural sciences in virtual designs or creative approaches to real-world problems. Thus, STEAM programs add Art to STEM curriculum by focusing on design principles and invigorating creative solutions[1] (Yakman, 2012).

The STEM, STEAM and more anticipated acronyms are entering the educational systems designed by policy makers.

In any case, a *sine qua non* condition to accept and foster by proper implementation expected new disciplines to overcome problems of communication and establish an ordering procedure is a prerequisite and needed issue; disambiguation through the definition of terminology (or jargon). For the most part, this has been achieved in the digital era, or the cyber era, of coupling computer

[1] https://vtnews.vt.edu/articles/2012/07/073112-uged-steampartnership.html; http://www.miscositas.com/steam.html

sciences with archaeology and cultural heritage (Liritzis *et al*., 2021, and references therein). The *Arts* could include Musical Arts and Sounds, Performing Arts, Language Arts, Visual Arts, Social Arts, Ecological Arts and Architecture. The *Culture* encompasses the *tangible* (material culture *e.g*. cultural heritage, cultural property) and *intangible culture* (*e.g*. religion, dance, traditions, singing, mythology, literature etc.) much overlapping with Arts. From the *Exact Sciences* STEM encompasses natural sciences and engineering and technology, with all sub-fields.

Any study, research development, presentation of each artistic and cultural item either as performance, (digital) visualisation, still or animated, 3D images, virtual reality, virtual environment (Levy and Jones 2018), representation of myths in the space, natural phenomena and mechanisms that are applied to extract complex bits of information from Arts+Culture, need the appropriate use of STEM. Thus, it is encouraged to work on collaborative projects, on various multiple issues from arts and culture through STEM applications and innovative approaches, validate the effectiveness, and draws the present final Expert White Policy from EASA (Figure 1). This deep level of transdisciplinary work will open up opportunities for new research avenues and publication.

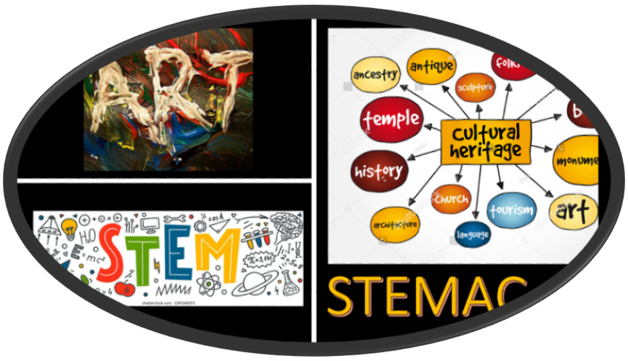

Figure 1. Schematic concept of STEMAC.

STEAM and STEMAC are both variations of the *STEM* acronym, with additional letters added to include other areas of study.

STEAM stands for Science, Technology, Engineering, Arts, and Mathematics. This approach incorporates arts into the traditional STEM curriculum, recognizing the importance of creativity and design thinking in the STEM fields. By integrating the arts, STEAM aims to foster innovation, communication, and critical thinking, which can lead to new discoveries and solutions in the field of the Arts.

STEMAC stands for Science, Technology, Engineering, Mathematics, Arts, and Culture. It incorporates various artificial intelligent (AI) techniques in archaeology and cultural heritage (CH) issues. This approach expands on the STEAM model (which however includes modern fields of machine learning, deep learning, AI) by including cultural studies. The inclusion of cultural studies recognizes the importance of cultural diversity, cultural heritage, and museology and their impact on the development and application of STEM knowledge. By including cultural studies in the STEAM curriculum, STEMAC aims to produce graduates who are more globally aware, culturally sensitive, and able to adapt to diverse environments that bridge the Humanities and creative disciplines with Natural Sciences. STEMAC in essence is the umbrella of any natural sciences development applied to artistic and cultural issues (see Mantovan and Nanni, 2020; Salazar *et al*., 2020; Romanengo *et al*., 2020; Gualandi *et al*., 2016; Liritzis *et al*., 2020) (Figure 2).

STEAM vs. STEMAC: To illustrate STEMAC's unique contributions, detailing a project where AI was utilized to analyze archaeological data could provide clarity on its advantages over STEAM (see below).

Cultural Studies Integration: Methodologies for incorporating *cultural sensitivity* [designing and training artificial intelligence systems in a way that acknowledges, respects, and accurately represents the diversity of cultural backgrounds, values, and historical contexts] into AI models, such as involving cultural historians in the AI training process, would ensure models are informed by deep cultural understanding.

Example: STEMAC, a new development for cultural heritage

To study past cultures and rejoin arts and cultural heritage with STEM, any holistic approach to understanding cultural change must also include consideration of changes in the environment in which a society exists throughout time (Palaeolithic, prehistoric, historic societies). It recalls Cyber-archaeometry which is the digital IT process of simulation, restructuring and management of archaeometric processes from the field of natural sciences in relation to material culture, investigated through dating, prospection, analysis-characterization, technology, provenance, archaeoastronomy, monument and palaeoenvironmental and ancient human reconstruction, re-assembling artifacts and monuments, deciphering ancient scripts etc.), either as optimum recruited image or as targeted research quest (Liritzis *et al*., 2015; Liritzis and Volonakis, 2021; Magnani and Clindaniel, 2023). The outcome of STEMAC benefits the education, research and innovation, museums and the society.

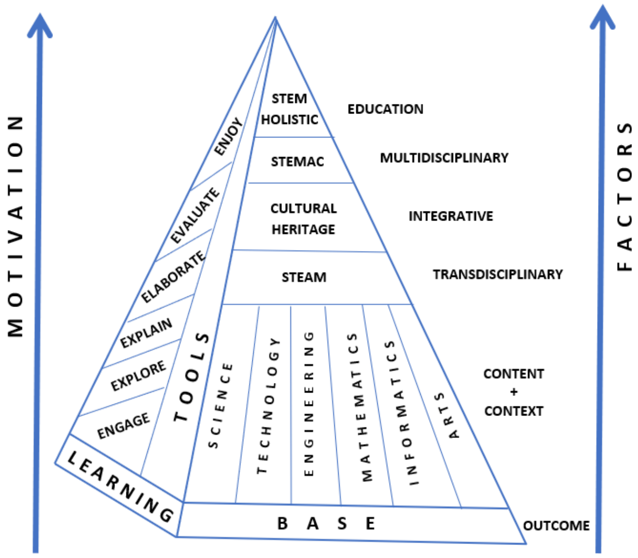

Figure 2. STEMAC: motivation, tools, factors (Liritzis, 2018).

According to this view, STEMAC emerges as a novel and integrated rapprochement that reinforces the fragmentary bridges and brings coherence between natural sciences and engineering and technology, with the humanities (art / culture) and design / architecture (Figure 3). STEMAC aids the transculturation via STEM in a globalized society preserving the cultural roots, reinforcing common traits of humanity, diversified from various environmental factors (Liritzis, 2013). The introduction and implementation of educational programmes from STEAM to STEMAC reinforces long-known efficient learning procedures in combining the different left and right brain functions. Both sides of the brain determine personality, traits, personal abilities: the left controls muscles on right side of body, language, mathematics, logic, speech, analytical processes, and intellect; the right controls the spatial abilities, facial recognition, visual imagery, art and music, emotion and creativity (Nielsen *et al*., 2013).

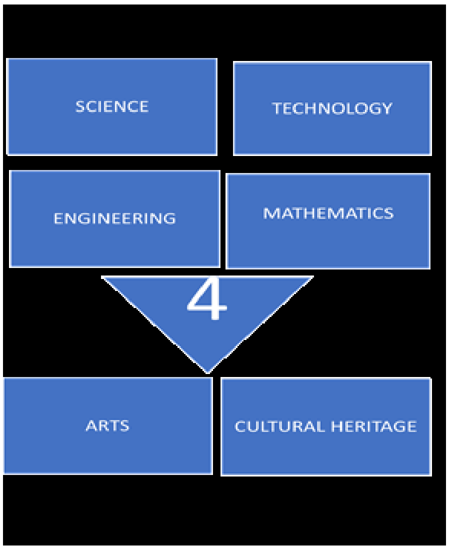

Figure 3. STEM for Arts and Culture (STEMAC).

Using software from computer sciences and mathematic (PHP progammes, online games, Java script programming, and other algorithms and software) one can start working with STEMAC and on various archaeological, anthropological, artistic subjects, monuments, tangible and intangible cultural heritage issues.

STEM or STEAM alone misses several key components that lead to the feasible holistic approach, that many employers, educators, and parents consider critical for children to thrive in the present and rapidly approaching future.

STEM to STEAM whose pedagogical purposes increase awareness and enhance learning outcome must be expanded to the new field of STEMAC to include arts and cultures i.e. humanities and integrate in a more efficient way the interdisciplinarity – transdisciplinary between the natural sciences and technology and engineering with arts and cultures especially cultural heritage. The latter has been going on under another name (archaeometry) and can easily be integrated and form the strong knot of STEMAC.

Holistic Approaches: A framework incorporating DNA analysis for understanding past landscapes could offer a comprehensive approach to archaeological research. Such a framework could, for example, include data collection and sampling, laboratory analysis and aDNA sequencing, interdisciplinary data integration, etc.)

Cyber-archaeometry: Developing an open-source software tool for cyber-archaeometry analysis would encourage community contributions and innovation.

Integration in Education: Implementing a pilot program that integrates STEMAC projects into school curricula, utilizing VR and AI, could significantly impact student engagement.

<u>*Case Studies*</u>: A case study on the use of 3D printing technology by students to recreate historical artifacts would vividly illustrate the educational benefits of STEMAC.
Our motto in EASA is: *STEMAC in Education, in Society, in Research and Innovation*

Artificial intelligence in archaeology

Artificial intelligence has the potential to transform archaeology by enabling the analysis and interpretation of massive amounts of data from historical sites and artifacts[2]. Here are some approaches to apply artificial intelligence in archaeology:

- *Data analysis* with multiple applications (from art, geology, environment, human data analysis). For example, large amounts of data from terrestrial, aerial imagery, and satellite imagery for the identification of patterns and trends not visible to the human eye, helping archaeologists for decision making where to excavate and which areas to focus on. Moreover, large data sets from the chemical analysis can be treated by special algorithms of complexity measures (fractals, etc.) to classify hierarchical order similarities and differences, classify typologically archaeological artifacts, Byzantine icons, archaeomaterial characterization for conservation purposes and more (Anichini *et al*., 2020; Andronache *et al*., 2023, 2024; Karapanagiotis *et al*., 2022; Liritzis *et al*., 2023; Pavlides, 2023; Peptenatu *et al*., 2023; Smith, 2023).
- *Image recognition*: (recognition and Classification of different types of artifacts (typology) based on images, see, Rouse (1960) versus modern AI in Gualandi *et al*., 2021).
- *3D modeling* and Image analysis, from CT scans (for creation of highly detailed 3D models of archaeological artifacts, sites and monuments that can be used to visualize and study the site and monument in more detail (Hatzopoulos *et al*., 2017). This can help archaeologists better understand the layout of a building and site, the architecture of a monument and operational functioning of a device such as the Antikythera astrolabe mechanism; Pakzad *et al*., 2018; Efstathiou *et al*., 2023).
- *Predictive modeling* (Predicting archeological site locations using geological and environmental data. Archaeologists can pinpoint new regions to explore and uncover previously uncovered historical sites; Yaworsky *et al*., 2020).
- *Language translation* and *deciphered scripts* (AI helps archaeologists better grasp ancient languages through translation. Texts discovered at archeological sites. This can offer vital insights on the cultures and societies that created these ancient texts or inscriptions / scripts; Luo *et al*., 2021; Zhang *et al*., 2020; Faigenbaum-Golovin, 2016).
- *Digital automation* for archaeology addressing these issues requires a collaborative effort among archaeologists, technology developers, policymakers, and communities. Striking a balance between embracing technological advancements and addressing the associated challenges is crucial for the responsible and sustainable use of digital automation in archaeology. For example, the integration of robotics in digital archaeology not only

[2] https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/747120/EPRS_BRI(2023)747120_EN.pdf; Magdalena Pasikowska-Schnass, Briefing on Cultural heritage in EU policies, PE 621.876 –June 2018; https://www.microsoft.com/en-us/ai/ai-for-cultural-heritage

enhances the efficiency and precision of archaeological processes but also allows researchers to explore and document sites in ways that were previously challenging or impossible. As technology continues to advance, the synergy between digital archaeology and robotics is likely to play a significant role in the future of archaeological research and exploration Examples include (Automated Excavation, Underwater Robotics, Remotely Operated Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs), Drone Technology (*e.g*. Unmanned Aerial Vehicles (UAVs), or drones, equipped with cameras and LiDAR sensors can be used for aerial surveys and mapping of archaeological sites), Robotic Mapping and 3D Scanning, Remote Sensing with Robotics, Robot-Assisted Conservation, Haptic Feedback Systems, Data Analysis and Interpretation i.e. machine learning algorithms and artificial intelligence can be integrated with robotic systems to aid in the interpretation of archaeological findings (Hugget, 2022; Hotta *et al*., 2023; Levy *et al*., 2023)

- In an exemplary case, artificial intelligence can be applied in several ways in Bioarchaeology, *i.e.* to the interdisciplinary study of ancient skeletal remains, assisting in data processing and providing useful insights. The following are some applications of artificial intelligence in the analysis of human remains from archeological sites:
- *Automation* (automatic analysis of imaging and skeletal data. This can minimize manual work while increasing process speed and precision).
- *Facial reconstruction* (algorithms coupled with aDNA can generate 3D models of skulls and predict face characteristics based on bone structure. This can improve the accuracy and lifelikeness of face reconstructions for ancient persons). See: Myrtis young girl in ancient Athens; Papagrigorakis *et al*., 2006
- *Skeletal and dental databases* (AI searches and matches bone and dental data in databases. This can aid in identifying persons and reconstructing their lives).
- *Ancestry and migration* (Analyzing the genetic makeup of skeletal remains enables anthropologists to track ancestry and migration patterns among groups; Lazaridis *et al*., 2022)
- Skeletal analysis (identification and reconstruction of the physical characteristics of individuals, such as age, gender, and ancestry)
- *Age estimation* (analysis of dental images and other features of remains estimate the age of individuals.
- Sex estimation: (particular algorithms used to estimate the sex of skeletal remains from bone density, tooth wear, and skull morphology; Cavalli *et al*., 2017).
- *Image analysis* (analysis of images of remains, from CT scans, for face and body reconstruction; see: iceman Otzi, Figure 4, and Myrtis reconstruction young girl in Classical Athens at https://www.myrtis.gr/)
- *Predictive health analytics* (Predicting illnesses and disorders using prior population health data.)

- *Facial recognition* (analysis of facial features and identification of patterns that may be typical of particular populations, or this provides a better understanding of human migratory patterns and the evolution of physical traits).
- *Genomic analysis* (AI can evaluate genomic data, helping bioarchaeologists and anthropologists trace population evolution and uncover genetic markers linked to certain traits or situations; see Papagrigorakis *et al*., 2006; Lazaridis *et al*., 2022).
- *Disease detection*: Algorithms for detecting disease in skeletal remains, including arthritis and tuberculosis. This may provide insight into understanding disease prevalence and evolution among populations across time.
- *Trauma analysis* (identification and reconstruction of trauma morphology that can provide insight into the causes of death or injury and provide clues regarding social and political contexts in which these injuries occurred (Vodanović *et al*., 2023 and references therein).

Figure 4. A reconstruction of the Iceman in the South Tyrol Museum of Archaeology in Bolzano, Italy (Source: South Tyrol Museum of Archaeology/Ochsenreiter made by Dutch brothers Adrie and Alfons Kennis). See also Wang *et al*., 2023).

Another aspect of STEM is Digital automation in archaeology, which involves the use of advanced technologies and computerized systems to streamline and enhance various aspects of archaeological research and data analysis (Avni *et al*., 2023). Here are some examples of digital automation in archaeology:

- *Geographic Information Systems (GIS):* Example: Archaeologists use GIS to map and analyze the spatial distribution of artifacts, features, and archaeological sites. This helps in understanding the landscape, identifying patterns, and making informed decisions about excavation strategies (Wheatley and Gillings 2002). Also, the use of on-line geospatial databases rooted in GIS such as the Digital Archaeology Atlas of the Holy Land (Savage and Levy, 2014).

- *3D Modeling and Visualization*: Example: Digital tools like Structure from Motion (SfM) or LiDAR are used to create highly accurate 3D models of archaeological sites, artifacts, or landscapes. This aids in documentation, preservation, and virtual reconstructions for public engagement and research purposes (Opitz and Cowley, 2013).
- *Remote Sensing Technologies*: Example: Satellite imagery, aerial photography, and drones are employed to survey and monitor archaeological sites. These technologies help identify hidden features, such as ancient structures or landscapes, without the need for extensive ground excavation. (Masini and Lasaponara 2016)[3].
- *Digital Recording and Documentation*: Example: Traditional paper-based field notebooks have been replaced or complemented by digital recording systems rooted in photogrammetry and geospatial databases (Levy *et al*., 2023). Archaeologists use tablets or other devices to record excavation data, stratigraphy, and artifact information directly into digital databases, improving accuracy and efficiency (Campana and Remondino 2008; Liritzis *et al*., 2016; 2017; May *et al*., 2023).
- *Automated Artifact Analysis:* Example: Computer vision and machine learning algorithms are applied to automate the analysis of artifacts. For instance, automated classification of pottery types or identification of specific tool types based on shape and characteristics can be achieved using image recognition.
- *Database Management Systems:* Example: Archaeological data, including artifact catalogs, site information, and excavation records, can be managed more efficiently using database systems. This allows for easy retrieval, analysis, and sharing of information among researchers (Sebastian and Bynon, 2012).
- *Radiometric Dating and Chronological Modeling:* Example: Computer programs and algorithms help archaeologists analyze radiocarbon, OSL (Optical Stimulated Luminescence), and other radiometric dates and create chronological models. This assists in establishing high-precision timelines for archaeological sites and understanding the temporal sequence of human activities, often at the sub-decadal level (Ramsey, 2009; Shaar *et al*., 2015).
- *Artifact Conservation and Restoration*: Example: Automated techniques, such as laser cleaning and 3D printing, are employed in the conservation and restoration of artifacts[4]. These technologies aid in preserving cultural heritage items while minimizing the risk of damage (see: CSCH 2018).
- *Public Outreach and Education*: Example: Virtual reality (VR) or augmented reality (AR) applications are used to create immersive experiences for the public. Virtual tours of archaeological sites, interactive exhibits, and educational games contribute to public engagement and awareness (Liritzis *et al*., 2015; Forte and Kurillo, 2016; Pavlidis *et al*., 2018; Sobieralski, 2023).

[3] Near Eastern Archaeology, Vol. 77, No. 3, Special Issue: Cyber-Archaeology (September 2014)
[4] https://amt-lab.org/blog/2022/5/how-can-technologies-help-with-culture-heritages-restoration-and-preservation

Digital automation in archaeology not only improves the efficiency of fieldwork and analysis but also opens new possibilities for collaboration, data sharing, and public outreach in the field of archaeology.
Overall, the application of AI in archaeology has the potential to significantly accelerate our understanding of the past and allow us to gain new insights and learn more about the lives and cultures of our ancestors.
In summary, while STEAM emphasizes the importance of the arts in STEM education, STEMAC further expands on this by adding culture and cultural studies to the mix.

STEMAC: some concrete ideas for the three educational levels

Develop STEMAC for primary, Secondary and Higher educational (and Life-Long Learning) levels. For example: a*rchaeoastronomy* (astronomy impact to ancient cultures, rituals, celebrations, religious events, sundial devices, etc), *cyber-archaeometry, cyber-archaeology* (Levy and Liss 2020), *3D construction and visualisation of scientific (archaeological) hypotheses, 3D creation of abstract substitutes for complex concepts, 3D reconstruction of artifacts/ monuments*, *Virtual tours*, *ancient music/theaters, Virtual Labs (for dating, provenance, spectroscopy analysis, optical microscopy analysis, image analysis by fractals, complexity in cultural/archaeological materials, Geogebra in cultural heritage issues etc.* Along with STEM for learning basic sciences in primary-secondary and higher education, these developments can contribute as interdisciplinary subjects with history, arts, humanities.

Innovative Teaching Methods: Augmented reality (AR) apps that allow students to interact with historical figures could revolutionize history education.

Interdisciplinary Subjects: Designing courses that combine archaeology, environmental science, and computer programming would offer students hands-on experience with real-world applications.

Vision + sustainability

The vision for STEM (Science, Technology, Engineering, and Mathematics) in arts and culture is to integrate these fields in a way that fosters creativity, innovation, and critical thinking. This aim fits the EASA task force on this subject by involving active members of EASA working on these interdisciplinary fields. STEM subjects provide the scientific and technological knowledge and skills necessary to create and develop new scientific expertise as well as technologies, tools, methods and techniques that can be applied in the arts and culture industries. In turn, the arts and culture sectors can offer new avenues for scientists, engineers, and mathematicians to explore and express their work in a more accessible and engaging way.
By integrating STEM into arts and culture, we can also promote diversity and inclusivity in all these fields. This approach encourages the involvement of people from different backgrounds and perspectives, who can bring fresh ideas and insights to the creative process. Additionally, this

integration can help bridge the gap between the sciences, creative disciplines and humanities, fostering a more holistic approach to problem-solving and innovation. Such a goal fits also the Task Force of EASA Education-Research-Innovation and the relevant White paper made and already uploaded to EASA's website.

Overall, the vision for STEM in Arts and Culture – abbreviated to STEMAC- is to create a symbiotic relationship between these fields, where the benefits of each can be fully realized, and where creativity, innovation, and critical thinking can thrive. Of particular importance to museum management, cultural heritage stakeholders, and educational systems of advanced ways of experiencing positive results in learning output. Both (education and cultural heritage/art) are promoting sustainability and development to every country, as well as a much-needed understanding between peoples. Peace and mutual understanding presuppose comprehension, and STEMAC (STEM in ARTS+CULTURES) can achieve this vision (about the impact of the Research Infrastructures for social sciences and humanities, see Maegaard and Pozzo, 2019; Hohenegger, 2019; Petrovich, 2019; Fantoli, 2022).

Example: STEMAC and promotion of interdisciplinary arts-based therapies

An indirect innovation of STEMAC can be found in its collateral contribution to human health. Looking back over the evolution of human culture sheds light on the health promoting power of the arts (Mastnak, 2015), which eventually inspired today's arts therapies such as music therapy, dance therapy (Mastnak and Mao, 2021), drama therapy or visual arts therapy[5]. Regarding the multifaceted nature of art-based therapies, related research requires interdisciplinary approaches involving domains such as medicine – *e.g*. music in neuropsychiatry and schizophrenia (Jia *et al*., 2020), neurosciences, genetics and epigenetics (Sotiropoulos and Anagnostouli, 2021), cultural ethnology – *e.g*. healing arts in ethnic minorities, aesthetics and ontology – *e.g*. profound interdependencies between aesthetic experience and the human nature (Mastnak and Kremer, 2023). Healing arts involve cultural heritage, also in terms of UNESCO – *e.g*., Vietnamese Mo Mường (Mastnak, 2023), and concern WHO policies such as referring to culturally sensitive sustainable public health systems (World Health Organization, 2020).

With regard to education we have to distinguish between 'learning about' and 'specific application', which relates to all levels of education – *e.g*. arts-based self-regulation of stress in secondary education, policies on health education in various countries, as well as best practice models (Yang 2023), academic programmes on arts-based therapies and various modes of in-service- as well as life-long-learning – *e.g*. in the context of the WHO's target of universal health coverage (World Health Organization, 2023) or community music therapy (Pavlicevic and Ansdell, 2008).

[5] For more than eight centuries, the Asclepieia in ancient Greece offerred health care, combining experimental therapeutic Methods with a variety of religious and magical elements. The later are artistic and cultural triggers, which may become revisited and rectified under modern STEMAC conditions.

An EASA-based STEMAC institute – possibly in form of a WHO-collaborating centre – could importantly contribute to interdisciplinary scientific developments as well as beneficial implementation in public health systems.[6]

Strategy for STEM in arts and culture

Developing STEM in arts and cultural heritage requires a comprehensive strategy that involves several key steps, such as:

- *Collaboration and Establishing Partnerships*: Encouraging collaboration and partnerships between STEM professionals, artists, and cultural institutions can help bridge the gap between these fields. This can include joint projects, workshops, and exhibitions, where STEM concepts are applied to art and cultural heritage. Developing STEM in arts and cultural heritage requires collaboration among various stakeholders, including museums, galleries, libraries, and scientific, cultural and educational institutions. By forming partnerships, stakeholders can share knowledge, expertise, and resources to develop effective STEM programs that integrate arts and cultural heritage.
- *Curriculum Development*: Developing and implementing STEM-based curricula for arts and cultural heritage education can provide students with a solid foundation in the STEM fields, while also fostering creativity and innovation in their work. A well-structured curriculum that combines STEM with arts and cultural heritage can help foster innovation, creativity, and critical thinking. The curriculum should include hands-on activities that engage learners in real-world problem-solving and allow them to explore and experiment with different technologies.
- *Creating opportunities for experiential learning*: Providing opportunities for students to engage in experiential learning, such as internships, apprenticeships, inclusion in research projects and project-based learning, can help students develop practical skills, knowledge, and expertise. Experiential learning also enables students to connect theoretical concepts to real-world applications, which can enhance their learning experience.
- *Integration of Technology*: The integration of technology, such as virtual modeling, virtual and augmented reality, AI, can provide new ways to engage with art and cultural heritage. For example, 3D scanning and printing technology can be used to create replicas of historical artifacts or monuments in AI and VR environments.
- *Teacher Training:* Providing training for teachers in STEM-based pedagogy and arts integration can equip them with the necessary skills to effectively teach STEM concepts through the arts and cultural heritage. Teachers play a crucial role in delivering STEM in arts and cultural heritage education. Therefore, providing them with professional development opportunities to learn new teaching methods, technologies, and strategies can enhance the quality of STEM education in these humanities fields.

[6] For logistic reasons close collaboration with a relevant University, *e.g.* Shandong University in China, can be realised with Prof. Mastnak, Member of Expert Group of EASA.

- *Evaluation and feedback*: Regular evaluation and feedback can help improve the quality of STEM education in arts and cultural heritage. By improving the effectiveness of STEM programs and collecting feedback from stakeholders, educators can continuously refine their strategies and approach to better meet the needs of learners.
- *Providing access to resources*: Ensuring access to resources such as technology, equipment, and materials can help students and teachers/tutors in delivering effective STEM education in arts and cultural heritage.
- *Community Engagement*: Engaging with the community through public events, workshops, and exhibitions can raise awareness exploiting the benefits of STEM in arts and cultural heritage. This can also promote greater interest and engagement in STEM fields among students, artists, and the general public. By creating Cultural Heritage District Assets with communities, new economic opportunities can be established that benefit all the inhabitants of a region, regardless of their ethnic and cultural differences (Levy *et al*., 2020).

Overall, the strategy to develop STEM in arts and cultural heritage should be multidisciplinary, collaborative, and inclusive, involving all stakeholders in the process for all the three levels of Education (primary, secondary, and College, as well as lifelong learning).
In summary, developing STEM in arts and cultural heritage requires a holistic strategy that involves partnerships, curriculum development, teacher training, experiential learning opportunities, access to resources, and regular evaluation and feedback.

STEMAC for applications in geo-education and environmental education

One of its greatest advantages compared to conventional teaching methods is that it fosters critical thinking. The latter is necessary for all potential scientists, as well as geo-educators (Ennis, 2011; Murawski, 2014; Demir, 2015; Santos, 2017). Besides this, other advantages of the STEMAC approach in include proficiency in science, digital competences, creativity, increased curiosity, team spirit, increase of self-esteem and development of social skills (McAuliffe, 2016; Gates, 2017; Chen and Chang, 2018; De la Garza and Travis, 2019; Lestari, 2021; González-Pérez and Ramírez-Montoya, 2022). The application of the STEM(AC) approach has the advantage of aiding students to come up with potential solutions to real problems, rather than theoretical ones (Jeong and Kim, 2015).
Specifically, regarding geoscience and environmental education, STEMAC has proved to be essential (*e.g*. Falk *et al*., 2016; Gates, 2017; Gupta *et al*., 2018; Nguyen *et al*., 2020; Georgousis *et al*., 2020; Chen, 2021; Mereli *et al*., 2023). Besides all the above-mentioned benefits, the use of STEM(AC) in geo-education can also increase the student's interest in geoscience (Musavi *et al*., 2018; Janowicz, 2020; Tillinghast *et al*., 2020).
Geoscience education consists in multiple educational fields, such as the purely scientific part (that is, basic and theoretical approach) and the applied part. Just like any other discipline, geoscience consists, besides the basic knowledge, in problem-solving, scientific abilities, digital competences

and creative thinking skills (Runco, 2014; Huda *et al*., 2019; Irwandani *et al*., 2020). Even though one could (wrongly) say that the scientific part may not seem necessary for all students, the applied part provides students with skills and knowledge that are necessary for their professional development, as well as their way of living. Natural disasters are the most typical example. The familiarization with merely the ways of protection against them does not suffice; students need to comprehend the mechanism(s) behind which such events occur, the factors that affect them, as well as the human interventions that lead to either their mitigation or deterioration (Muttarak and Lutz, 2014; Ronan and Towers, 2014; Drabo and Mbaye, 2015; Yasuda *et al*., 2018; Rahma, 2018).

By engaging STEMAC in natural disaster education, students can comprehend these aspects, but also become more aware concerning: i) their actual impacts on their safety, the infrastructure, the environment and the society in general; ii) the necessity for them to be mitigated; iii) their potential contribution to this mitigation and its importance (Han *et al*., 2019; Rizqillah *et al*., 2022; Mereli *et al*., 2023). What is more, they will become more aware of the hazard posed to them by a natural disaster; it is worth mentioning that many fatalities caused by natural disasters were owed to the victims' underestimation of their potential impacts, which in turn was owed to limited education (*e.g*. Jonkman and Kelman, 2005; Morss *et al*., 2016; Mereli *et al*., 2021, 2023). Other geoscience-related issues are the environmental ones, such as environmental awareness, climate change and sustainability. In a similar way, STEMAC can be proved very significant to these aspects as well (Taylor and Taylor, 2019; Santi *et al*., 2021).

Arts is also a component of STEMAC that can perfectly fit the needs and purposes of geo-education (Clary, 2016; Frajer and Šimáček, 2019). Arts have advanced the formerly "STEM" methodology by fostering the creativity of students, motivating them to share their thoughts and ideas in a more creative way, which is often easier for several students compared to expressing them in words. Arts can also foster the communication between students and teachers (*e.g*. Connor *et al*., 2014; Hunter-Doniger, 2018; Aerila and Rönkkö, 2023).

Finally, culture has played a very important role in geoscience education, and this has been indirectly recognized and applied since the 20th century, even though it had not been included in the curriculum until recently. The term "geological heritage" or simply "geoheritage" refers to a total of sites of geological interest, which reveal part of the Earth's history and can contribute to our comprehension of the natural processes (*e.g*. Grandgirard, 1997; Reynard, 2005; Ruban, 2010; Brilha, 2016; Gioncada *et al*., 2019; Palacio Prieto *et al*., 2019). Understanding the principles of geoscience is a key in geoscience education (Zafeiropoulos *et al*., 2021). And culture can aid in geo-education, as it is a necessary component of a site of geological heritage, besides the purely scientific part (Piacente, 2005; Critelli *et al*., 2012; Drinia *et al*., 2022; Triantaphyllou *et al*., 2023).

One of the most common forms of STEMAC applications in geoscience education are, for example, the virtual field trips (*e.g*. Hurst 1997; Stainfield *et al*., 2000; Carmichael and Tscholl, 2011). Field trips and field education are necessary parts of geo-education and environmental education, whether it refers to school or higher education (Clark, 1996; Hurst, 1997; Çalıskan 2011; Han, 2020) and can often not be substituted by any virtual means (Spicer and Stratford, 2011; Mead *et al*., 2019; Evelpidou *et al*., 2021a, 2022). However, they have several drawbacks, including weather, financial and accessibility issues. In any case, though, by executing a virtual field trip in the classroom for geo-educational purposes can bring about most of the advantages of physical field trips, without these drawbacks, while being, at the same time, much more interactive and entertaining than common teaching methods, such as PowerPoint presentations or spoken lectures (Hurst, 1997; Gilmour, 1997; Stainfield *et al*., 2000; Ramasundaram *et al*., 2005; Gilley *et al*., 2015; Cliffe, 2017; Evelpidou *et al*., 2022). Another STEM(AC) tool used widely in geo-education is the so-called “stream table”. This is a tub, which is filled with material (*e.g*. sand, cobbles, etc.) to resemble the natural flow of a river, along with related issues of basic geoscience, such as relief development, as well as applied geoscience, i.e. landslides, soil erosion, floods, etc. (*e.g*. Lillquist and Kinner, 2002; Evelpidou *et al*., 2021b). The conduction of stream table-based experiments in the classroom can help students understand the purely scientific part (basic knowledge) and the applied aspects (Lillquist and Kinner 2002; Evelpidou *et al*., 2021b). Students can better visualize a drainage basin, as well as the natural processes occurring on them. In this way, they can develop a critical thinking that is necessary in obtaining the desired skills and knowledge. At the same time, they are not pathetic observers, but instead they participate actively in the configuration of the imaginary basin, thus engaging all aspects of STEMAC education.

STEM for applications in education, research and innovation

STEM involves applications as well as research and innovation. STEM encompasses Science, Technology, Engineering, and Mathematics, and these fields are involved in both the practical application of knowledge and the creation of new knowledge through research and innovation.

STEM applications involve the use of knowledge and skills in science, technology, engineering, and mathematics to develop new products, processes, and systems that address real-world problems, especially encountered in the field with archaeology and anthropology. For example, engineers use their knowledge of mathematics and physics to design and develop new instrumentation and physical-chemical processes, from phenomena that are the basis of various analytical (archaeometrical) techniques *e.g*. in the determination of time and the characterization of ancient materials that are well comprehended, timely and of zero cost: thus accurate and efficient. Moreover, new concepts of dating methods, or ancient alloys, mixing metals at various proportions**,** or reconstructing ancient devices lead to innovative approaches and problem-solving issues.

STEM research and innovation involve the creation of new knowledge through scientific discovery and technological innovation. For example, scientists conduct research to explore new phenomena and develop new theories that can explain archaeomaterial technology, accurate chronology, and procurement strategies of tools and other goods between ancient societies, while technologists and engineers develop new technologies and tools that can improve the efficiency and effectiveness of existing systems; all on an algorithmic design through our PC (see an initial example: The cyber archaeometry which ties to STEMAC and concerns a new virtual ontology in the environment of cultural heritage and archaeology. This study concerns a first pivotal endeavor of using virtual polarized light microscopy (VPLM) for archaeometric learning, made from digital tools, tackling the theory of mineral identification in archaeological materials, an important aspect in characterization, provenance, and ancient technology (Liritzis and Volonakis, 2021; Liritzis *et al.*, 2021).

Practical Applications: Detailing the use of drone technology for mapping archaeological sites could provide a tangible example of digital technology's impact on the field.

Research and Innovation: AI's potential to predict archaeological site locations based on environmental data warrants further exploration and support.

In summary, STEM applies to both the practical application of knowledge and the creation of new knowledge through research and innovation. STEM encompasses a wide range of activities, from developing new products and systems in hardware as well as in software to conducting scientific research and discovering new knowledge in all three educational levels, in Museum exhibitions, and the Society as part of LLL.
As discussed here, STEMAC (Science, Technology, Engineering, Mathematics for Arts and Culture; or STEM4AC) is a novel integrated approach that integrates the natural sciences, engineering and technology, with the humanities (art / culture) (Figures 1-3). STEMAC transmits innovative transdisciplinary research via STEM in a globalized society preserving local cultural roots but addresses the larger common characteristics of humanity in diverse cultural, historical and environmental contexts.

General suggestions

- *Diversity and Inclusion*: Initiatives to involve local communities in archaeological projects using digital technologies would ensure a more inclusive approach to cultural heritage.
- *Global Perspectives*: Establishing an international consortium for digital archaeology could foster a global approach to preserving, restoring, and enhancing cultural heritage.
- *Future Outlook*: Monitoring and evaluating the implications of emerging technologies like quantum computing on archaeology could prepare the field for future advancements.

Satellite round table in Athens, June 2023

The first discussion on STEMAC was holding an evening satellite meeting during a scheduled conference held in Athens in June 2023 initiated by EASA members of the Expert Group - Member in Class IV Zsolt Lavinca and collaborators and member of Class IV Ioannis Liritzis - along with representatives from Greece (Universities, Schools, Scientific Associations) (https://euro-acad.eu/events?id=176).

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