

# G.A. STEM Project: Gaming through Cultural Heritage

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**Abstract.** The article introduces G.A.STEM project aiming at improving STEM (Science, Technology, Engineering, Math) skills acquisition through the use of Arts and mini-games design and development. The project favors STEM learning through valorization and re-evaluation of cultural heritage coming from the promotion of art-works and cultural exchanging among partner countries (Finland, Italy, Belgium, and Estonia), considering art as an effective interconnector focused on problem-oriented creativity development. The work summarizes the intermediate results achieved so far according to the project's progress.

**Keywords:** STEM, Arts, Mini-games, Design Thinking.

## 1 Introduction

The continuous lack of European (EU) students in mathematics and key basic competencies in science and technology, according to worldwide surveys Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS), recently has revealed that even the highest EU performing OECD countries, like Finland, demonstrate a drop of averages in scientific skills as well (OECD, 2016). Undoubtedly, one of the essential influences causing the situation is the pervasiveness of digital communication means and immediate availability of enormous amounts of information that dramatically influence the youth's behavioral patterns and professional path perception (Buckingham, 2007).

Nevertheless, technological means enable another quality of educational approaches such as game-based learning. Since 2000s the rise of a new interest in using computer games in various subjects, and STEM in particular (Sherry, 2013), has brought into learning the new opportunities of personalization and a sound empirical research (Bourgonjon, Valcke, Soetaert, & Schellens, 2010), (Evans, Pruett, Chang, & Nino, 2014), (Hunter-Doniger & Sydow, 2016), (Moyer, Klopfer, & Ernst, 2018) linking digital gameplay together with an effective STEM content learning and problem solving.

From the other side, Arts, as a possessor of a direct impact on perception and an implicit scientific background, have already been reported to be engaging and stimulating for creativity in solving scientific problems related to STEM subjects (Hunter-

Doniger & Sydow, 2016). Moreover, artistic and cultural heritage, as crucial fundamentals for European Citizenship awareness and the identity of a person, lead to “a different way of perceiving the world”, which offers an opportunity to “expand the toolbox” and “free the scientist's and engineer's mind” (Storksdieck, 2011). However, due to the inherent ambiguity of STEM and arts as concepts, their combination is not easily defined (Colucci-Gray, et al., 2017). And critics of the STEAM (Science, Technology, Engineering, Art, Math) movement suggest that combining arts and STEM together either decreases the emphasis on science or weakens the aesthetic experience (Jolly, 2014). Nonetheless, students are likely to gain more with arts and sciences, expanding their interests in both subjects (Simpson Steele, Fulton, & Fanning, 2016).

Thus, combining the attractiveness of both, i.e. games and arts, G.A. STEM project was designed in response to the above-outlined challenges to pursue the following goals:

1. Improving motivation in the scientific study through the use of “Art-works” as a supporter in student creativity development and raising awareness of their applications in everyday life.
2. Utilizing the attractiveness of art and technology (in terms of mini-games design and game assets) to improve social inclusion and gender equality.
3. Supporting STEM skills useful for professional careers for both teachers and students.
4. Improving the collaborative sense among teachers and schools through the exchanging of experience, best practices focusing on the interdisciplinary and multidisciplinary approach.
5. Increasing the community sense and citizenship awareness through the discovery of EU Cultural heritage constituted of art-works produced in the partner project countries.

Below the results obtained so far and critical issues revealed are presented.

## 2 Why Combine STEM with Arts?

According to (Colucci-Gray, et al., 2017) both STEM and the arts are ambiguous already as concepts and the word STEAM is often used differently depending on the context. Author (DeSimone, 2014) claims that the arts are often fit into other curricula rather than standing on their own. However, in the last case, they automatically fit into other subjects, e.g. math's ideas and logic complement the arts, music theory is based on mathematical principles, etc.

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The connections to the real world applications are crucial for the students' motivation today (DeSimone, 2014), making science more interesting to growing children, especially to those who are right-brain oriented as learners (Sousa & Pilecki, 2013). As

a consequence, the students need to focus more on higher-order activities in their learning without neglecting the basic skills needed. The basic core subjects of STEM, in this perspective, provide the tools to work with as well as other contexts to explore, learn and create. The STEAM approach is a whole brain thinking based approach, showing that subjects are not isolated from each other (DeSimone, 2014). The complexity of the modern worlds' challenges, undoubtedly, requires broader views and solutions which do not rely on STEM solely.

Since one cannot predict exhaustively what the future career paths might be like, modern students need to maintain a continuous flexibility in terms of multidisciplinary vision (Hetland, 2013). Today's economy needs different thinkers possessing originality and skills for innovation (P. Moses & E. Cobb Jr, 2001).

The arts, in this regard, and STEAM in particular, by delivering interdisciplinary inquiry (Connor, Karmokar, & Whittington, 2015), stimulate 21st-century skills (Maeda, 2013) needed by students destined to become adults of today's digital world (Sousa & Pilecki, 2013), stimulation and inspiration, engagement, use of imagination (Mishra, Koehler, & Henriksen, 2011), open and creative thinking.

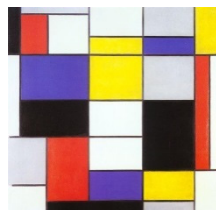
### **3 “Mathematization” Concept and Arts Integration**

The use of an adequate language for the formalization of mathematical concepts is crucial in school education. According to PISA (Grønmo & Olsen, 2006), mathematization follows a dynamics that goes from the real world problem towards its translation into the mathematical language and from the mathematics solution to the real world one. Analogously, in STEAM learning, the situation is similar to learning content being “mathematized” or transferred into the abstract form of any art representing it. Thus, the art becomes a unifying element among different languages, such as visual, sensory, verbal and non-verbal which can encourage the development of both cognitive and emotional dimensions. For this reason, it may be considered as an important element for the harmonious development and growing up of a human being (Dallari & Francucci, 2001), (Montessori, 1970).

Moreover, the arts support students in connecting better scientific subjects and reality by rediscovering their usefulness and their application in everyday life. Therefore, the learners become active in their learning process by constructing their own knowledge in a “meaningful” context through the objects manipulation, tools and the observation and interpretation of their actions' results. In these terms, the meaningful learning gets contextualized and complex, whether one applies the Fibonacci series (Posamentier, 2007), to the growth of flowers, leaves, and branches or discovering the symmetry of crystals. Despite this strong presence of mathematical concepts, in reality, their connection doesn't appear so evident during the learning process due to one-sided exposure causing the perception of mathematics' detachment from everyday life. This may inevitably influence the way the mathematics is learned, e.g. privileging more storage capacity than problem-solving skills.

Thus, to highlight the direct “math-to-real object” relation, G.A. STEM project utilizes different art-works in combination with a range of math exercises related. For

example, a well-known piece of Dutch artist Piet Mondrian (1872-1944), see Fig. 1, has been selected as the artistic auxiliary visual support to introduce a wide range of mathematical concepts and exercises such as ratio/proportion and percentage, golden ratio, area, perimeter. Once the underlining concepts learned, the ultimate task – is to create ones' own Mondrian-like piece with an arbitrary set of parameters to consider.



**Fig. 1.** An example of the art-work used to develop a set of exercises – “Composition A”, Piet Mondrian, 1923.

The approach, in its core, with enhancing the simultaneous involvement of logical reasoning and artistic imagination, contributes to a significantly profound elaboration and mastery of the math concepts, permitting to treat the last not as a purely abstract, but a viable instrument.

#### 4 The Role of the Use of the Games for Math and Science Study

Within the realm of today's increasingly digital society, the imperative for computer literacy may be taken for granted. The extensive research held in the field of game-based learning (Borge & White, 2012), (Chee, 2012) has already defined this approach as an effective pedagogical tool. Students' motivation and interest in STEM careers are documented to be extensively supported by the exposure to science concepts as part of using game applications with virtual apprenticeship component (Beier, Miller, & Wang, 2012). Computer games and digital game-based learning in particular (DGBL), have been reported to possess a positive impact on students' mathematics (Ke, 2014), STEM (Borge & White, 2012), computer science (Serrano-Laguna, Torrente, Manero, & Fernandez-Manjon, 2015), programming (Masso & Grace, 2011) achievements while being closely linked to a range of perceptual, cognitive, behavioural, affective and motivational impacts and outcomes (Connolly, Boyle, MacArthur, Hainey, & Boyle, 2012). In addition, the method is known to be particularly effective when combined with robotics as well (Leonard, et al., 2016).

Nevertheless, to amplify the effectiveness of educational technology applications further incorporating supplemental programs into the regular classroom curriculum may be beneficial (Cheung & Slavin, 2013). And despite the intense interest in games, it is important to keep in mind that the field is complex and costly and still has a lot of challenges to deal with.

## 5 Conclusions

The lack of attractive role models and understanding of what careers in STEM are about, negative stereotypes of scientists, engineers, researchers, and other STEM experts' career can be found among European youth.

In response to the challenge, G.A. STEM project relies on a new pedagogical concept unifying digital tools and arts. Currently, the school partners have selected math and science exercises and the related art-works projecting those towards mini-games and game setting development. The partnership is under the production of the pedagogical tools to be tested by secondary school teachers with 13-16 years old students from January 2020. During the piloting phase, the research team will gather the experimental data to estimate the methodology effectiveness in the exploiting of the art-works in STEM development skills.

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## References

- Beier, M. E., Miller, L. M., & Wang, S. (2012). Science games and the development of scientific possible selves. *Cultural studies of science education*, 7(4), 963-978.
- Borge, M., & White, B. (2012). Supporting STEM learning with gaming technologies: Principles for effective design C3. *AAAI Workshop - Technical Report. WS-12-17*, 44-50.
- Bourgonjon, J., Valcke, M., Soetaert, R., & Schellens, T. (2010). Students' perceptions about the use of video games in the classroom. *Computers & Education*, 54(4), 1145-1156.
- Buckingham, D. (2007). *Youth, identity, and digital media*. the MIT Press.
- Chee, Y. S. (2012). Possession, profession, and performance: Epistemological considerations for effective game-based learning. *Interactive and Digital Media for Education in Virtual Learning Environments*, 1-18.
- Cheung, A. C., & Slavin, R. E. (2013). The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: A meta-analysis. *Educational research review*, 9, 88-113.
- Colucci-Gray, L., Trowsdale, J., Cooke, C. F., Davies, R., Burnard, P., & Gray, D. S. (2017). *Reviewing the potential and challenges of developing STEAM education through creative pedagogies for 21st learning: how can school curricula be broadened towards a more responsive, dynamic, and inclusive form of education?*

- Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, 59(2), 661-686.
- Connor, A., Karmokar, S., & Whittington, C. (2015). From STEM to STEAM: Strategies for enhancing engineering & technology education. *International Journal of Engineering Pedagogy*, 5(2), 37-47.
- Dallari, M., & Francucci, C. (2001). *L'esperienza pedagogica dell'arte*. La nuova Italia.
- DeSimone, C. (2014). The necessity of including the arts in STEM. *Paper presented at the 2014 IEEE Integrated STEM Education Conference*.
- Evans, M. A., Pruett, J., Chang, M., & Nino, M. (2014). Designing personalized learning products for middle school mathematics: The case for networked learning games. *Journal of Educational Technology Systems*, 42(3), 235-254.
- Grønmo, L. S., & Olsen, R. V. (2006). TIMSS versus PISA: The case of pure and applied mathematics. *Paper presented at the 2nd IEA International Research Conference*.
- Hetland, L. (2013). *Studio thinking 2: The real benefits of visual arts education*. Teachers College Press.
- Hunter-Doniger, T., & Sydow, L. (2016). A journey from STEM to STEAM: A middle school case study. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, 89(4-5), 159-166.
- Jolly, A. (2014). STEM vs. STEAM: Do the arts belong. *Education Week*, 18, 16.
- Ke, F. (2014). An implementation of design-based learning through creating educational computer games: A case study on mathematics learning during design and computing. *Computers & Education*, 73, 26-39.
- Leonard, J., Buss, A., Gamboa, R., Mitchell, M., Fashola, O. S., Hubert, T., & Al-mughyirah, S. (2016). Using Robotics and Game Design to Enhance Children's Self-Efficacy, STEM Attitudes, and Computational Thinking Skills. *Journal of Science Education and Technology*, 25(6), doi: 10.1007/s10956-016-9628-2, 860-876.
- Maeda, J. (2013). Stem+ art= steam. *The STEAM journal*, 1(1), 34.
- Masso, N., & Grace, L. (2011). Shapemaker: A game-based introduction to programming C3. *Proceedings of CGAMES'2011 USA - 16th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational and Serious Games*, doi: 10.1109/CGAMES.2011.6000334, (pp. 168-171).
- Mishra, P., Koehler, M., & Henriksen, D. (2011). *The 7 trans-disciplinary habits of mind: Extending the TPACK framework towards 21st Century Learning (Vol. 11)*.
- Montessori, M. (1970). *Come educare il potenziale umano*. Garzanti.
- Moyer, L., Klopfer, M., & Ernst, J. V. (2018). Bridging the arts and computer science: engaging at-risk students through the integration of music. *Technology and Engineering Teacher*, 77(6), 8-12.
- OECD. (2016). *Education at a Glance 2016*.
- P. Moses, R., & E. Cobb Jr, C. (2001). *Radical Equations: Math Literacy and Civil Rights (Vol. 36)*.
- Posamentier, A. S. (2007). *The fabulous Fibonacci numbers*. Prometheus Books.

- Serrano-Laguna, A., Torrente, J., Manero, B., & Fernandez-Manjon, B. (2015). A game engine to learn computer science languages C3. *Proceedings - Frontiers in Education Conference, FIE. 2015-February(February)*. doi: 10.1109/FIE.2014.7044112.
- Sherry, J. L. (2013). Formative research for STEM educational games: Lessons from the Children's Television Workshop. *Zeitschrift für Psychologie*, 221(2), 90.
- Simpson Steele, J., Fulton, L., & Fanning, L. (2016). Dancing with STEAM: Creative movement generates electricity for young learners. *Journal of Dance Education*, 16(3), 112-117.
- Sousa, D. A., & Pilecki, T. (2013). *From STEM to STEAM: Using brain-compatible strategies to integrate the arts*. Corwin Press.
- Storcksdieck, M. (2011). *STEM or STEAM. The Art of Science Learning*.
- Tzou, C., Carsten-Conner, L., Pompea, S., & Guthrie, M. (2014). Colors Of Nature: Connecting Science and Arts Education to Promote STEM-Related Identity Work in Middle School Girls (Vol. 3).

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