12-7-2022

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Research-in-progress

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Abstract

This paper presents the theoretical background to explore the relationship and identify factors involved in the connection of art with science information systems through artistic experience to enhance innovation competency of science, particularly STEM, students in higher education. This theory informs the design of an art-science fusion workshop (ASF-WS) to foster innovation. The workshop intends to create an interspatial interactive learning environment by connecting the remote information systems of elite interdisciplinary performing arts (classical singing, piano, and dance), literature (poetry), embodied perception, somatic learning, and STEM-related academic fields in higher education (HE). The ASF-WS design is taking into consideration the latest views of neuroscience on embodiment, human cognitive functions and it is structured in accordance with the soft skills of innovation competency. It intends to provide a pedagogical measure that allows data collection of students' innovation competency changes.

Keywords innovation competency, art-science, higher education, embodied cognition, performing arts, pedagogy

1 Introduction

Current times are characterized by a series of critical events on a global scale (Muller and Nathan 2020) and our societies expect to face growing challenges (i.e.: climate change, energy crisis, overpopulation). Numerous theoreticians and scholars (Maxton 2018) suggest radical changes might be inevitable to design a sustainable future. There is a general consensus on the key role of innovation in the possible coping strategies (Parida et al. 2019). Innovation competences have a particular importance when applied in STEM (Science, Technology, Engineering, and Mathematics) sciences (Khadri 2022). These four fields emphasize innovation, problem-solving, and critical thinking. It is common to classify engineering and economy related fields (i.e.: information systems management, business and enterprise architecture etc.) as STEM (Marshall and Underwood 2022). Some fields in STEM (i.e. mathematics and physical sciences, Chen 2013) are facing difficulties in terms of attracting, motivating talented young students especially on the academic level. Scholars suggest that the traditional learning environment in STEM is not specific for many of the innovation competency and for nurturing 21st century skills (Lavi et al. 2021). The emerging pedagogical approach that intends to offer a new horizon is STEAM: blending the STEM cluster with arts (i.e., liberal arts, social studies, physical, fine arts, and music) in order to foster creativity, innovation, divergent thinking etc. (Madden et al. 2013). Although STEAM's support and presence educational policy making is growing (Meijas et al 2021), there is a lack of evidence-supported guidelines on how to blend STEAM with existing pedagogies.

This paper intends to close this gap of knowledge and presents the first phase of a STEAM pedagogical measure that allows to systematically observe and describe innovation competency changes, to develop new validated psychometric tools in the STEAM environment, and to further investigate already existing practices, as well as to provide data for evidence-based future STEAM guidelines in HE. While Cortese (2003) suggests that Higher Education (HE) institutions have a responsibility for creating a sustainable future and in this field, there is a need for participation in innovation activities. Although some authors (Carter et al. 2021) dealt with STEAM in higher education, White and Delaney (2021) suggest that there is still very little empirical evidence that can support the development of applicable models of STEAM implementation into higher education pedagogy. Keinänen et al. (2018) highlight the unique role of higher education as an innovation contributor and state that "although education plays a central role in the development of human innovation skills, several studies suggest that HE cannot fulfill these demands". They further suggest that there is a need to update the curricula in higher education. As the body of knowledge in this field is in its infancy and therefore limited, further investigation into the connection of art with science information systems through artistic experience to enhance innovation competency in the STEAM domain will make a contribution to understanding the efficacy of employing creative arts in STEAM pedagogy in HE. The scope of the planned pedagogical measure is the higher education of STEM and the measure is a interdisciplinary learning environment White and Delaney (2021) that connects the remote information systems of elite interdisciplinary (classical singing, piano, and dance) performing arts, poetry, embodied perception, somatic learning and STEM itself.

1.1.1 First WS day

Knowledge transfer and reinforcement: the ASF WS starts with the teaching of the chosen science concept, using predominantly a traditional (frontal) teaching method i.e. slide presentation. This conventional method of teaching is often criticized as inadequate for the demands of 21st century but still widely used. Due to the fact that it has been the norm for years in higher education, the application of the lecture format offers an entrance point to the ASF WS that, as it can be considered a familiar learning environment. After the presentation the artists distribute printed, summarizing handouts to support the deepening of the newly acquired knowledge and to initiate a first interpersonal interaction.

Section of embodiment exercises (Kiefer 2012): in this section, various exercises are planned to support and facilitate behavioural choices, soft skills and emotional processes that are linked to innovation competency. The participants' task are: reorganizing the space (stimulating interactions and teamwork, supporting active learning (Kariippanon et al. 2021), stimuli induced multidirectional walking (creative output support), mirroring game (verbal and non-verbal communication, teamwork, empathy (Salo et al. 2018), trust fall (to enhance social skills and self-confidence), synchronized circle walk (attention, discussions), yarn net (goal orientation, accountability and networking (Poortvliet et al 2007)) and reshaping the space for a performance.

Performance: the chosen segment of an interdisciplinary performing artwork is presented live and recorded and artistically analysed with the help of the performers. Beyond its artistic content that can positively impact social and cognitive skills (Greenberg et al 2021) art facilitate the avoidance of the familiarity trap. The artistic analysis inspires analytical and systems thinking and creative problem solving in an unusual field.

Connecting remote information systems: the participants are revisiting the scientific concept and try to identify or create 1-3 connection points between the science concept and the performing arts work. Connections can be based on free association (Bower 1972), structural similarities on any level or dimension, may that be visual, emotional, etc. Besides creative problem solving it reflects, system thinking, goal orientation and teamwork at the same time in organic synergy. Ideas are collected to an interactive word cloud.

Homework: student identify 1-3 further connection points at home name them and add to the word cloud and create a movement section or a pose that they perceive as embodiment of any element of the word cloud (recombination, embodiment enhancement of creative potential.

2 Innovation competency in HE

Innovation competency has great value and importance as compass to understand, improve, or combine information systems in order to generate meaningful innovation. The educational strategy known as "innovation pedagogy" describes innovative ways of assimilation, production, and application of information that can lead to innovations (Lehto et al. 2011). The goal of innovation pedagogy is to create conditions where multiple types of expertise can be combined to gain a competitive advantage (Watts et al. 2013). To offer reliable methodologies that result in increased innovation competency fostered by innovation pedagogy, the creation of a validated tool for assessment became necessary. One validated tool was developed by TUAS, a lead partner in charge of management and coordination of the Innovation Competency Development (INCODE) Project (Watts et al. 2013). The validated assessment tool (Innovation Competency Barometer, ICB) consists of 25 questions grouped in three categories: individual, interpersonal, and networking. The tool was further refined by Keinänen et al. (2018) (Five Factor Model). To build the design of the Arts Science Fusion (ASF) workshop (WS) introduced in this paper, the innovation competency defined by the five-factor model were adopted as dimensions of the pedagogical measure. The five factors suggested by Keinänen et al. (2018) are: creative problem-solving, systems thinking, networking, goal orientation, teamwork. The self-assessment tool consists of the same 25 self-assessment questions of Likert scale. The five factors identified have the potential to serve as a compass when developing and designing innovation interventions in HE STEM pedagogy.

3 STEAM: Art-Science Fusion (ASF) in Higher Education

In the academic and business fields the relevance of STEM cluster is growing as rapid social changes are extensively demanding innovative practical answers and solutions. Academic science distanced itself from subjective perception and divergent thinking and this has resulted in challenges when considering creative innovation. Conversely, art can be considered as the subjective perception of the self and of the world. (Langer 1954) STEAM concepts that merge ARTS to STEM (Colucci-Gray et al. 2017) suggest that beneficial fusion can be conceptualized. In the present time, “art” in STEAM is typically referring on performing or creative art, not on other liberal arts and this paper is following this definition.

Structural conceptualization of ASF as STEAM is attributed to a National Science Foundation symposium (NFS 2007) on the relationship between arts, STEM learning and workforce development (Colucci-Gray et. al 2017). STEAM reflects on the view, that rapid change of technology and society requires new core skills. In the last 15 years, the focus of STEAM in education reached popularity, most probably because of it’s potential to support science learning and participatory science. In this regard, STEAM is an educational framework that enhances and guides 21st century soft skills i.e., critical thinking, dialogue, networking, collaboration, creativity, problem solving etc.

Meta-ideas and tools resulting from ASF idea-exchanges through open pedagogy and work practices gained popularity in the scientific and technological organizations of the last century (Schnugg 2019). Schnugg (2019) identified the benefits of ASF as: “heightened creativity or fostering innovation; new perspectives, imagination, and inspiration for both artists and scientists; dynamics that lead to creativity, and the need to communicate science to a bigger audience through art”. In the past 70 years ASF projects have shown their benefits on multiple levels both in science and educational fields. Growing evidence suggests (Barnish and Barran 2020) that various artistic experiences can have a positive impact on cognitive functions related to scientific performance and creative innovation i.e., long- and short-term memory, decision making, social skills, emotional self-regulation (Aschauer et al. 2022). Further than that, somatic art fields are particularly impacting cognition and also influence neuroplasticity and adult neurogenesis (Micheli et al. 2018).

The potential benefits of artist-scientist interactions are not limited to structured collaborations: information exchanges through spontaneous interpersonal communication can also deepen knowledge, breaking routines, or suggest new practical methods (Schnugg 2019). Of note here is that “Nobel laureates in the sciences are seventeen times more likely than the average scientist to be a painter, twelve times as likely to be a poet, and four times as likely to be a musician.” (Pomeroy 2012; cited in Colucci-Gray et. al 2017).

The majority of STEAM related literature (Green et al. 2018) focuses either on STEAM experiences in primary and secondary education or on general community (Cremin and Barnes 2018). Even though in the recent years several academics (Carter et al. 2021) investigated STEAM in HE, there is still a lack of empirical evidence-based literature that informs on ASF interactions in this regard and at present state no literature can be found that aims to explore the impact of an ASF WS or program on the potential changes of HE student’s innovation competency. There is also no reference on the importance of elite performing artists’ participation, or on the relevance to the quality of artworks involved (canonized elite artworks vs popular contemporary art of amateur self-expression).

The STEAM literature commonly references the arts as a field that is as significant for human development as it is both intrinsically and instrumentally social, inclusive, humanizing (Belfiore and Bennett 2007) but as Yakman (2010) points out, STEAM literature misses to provide a credible definition of the arts or arts education.

From the artistic point of view, elite performing art has very few representations in STEAM concept. As a reflection on reliability and reproducibility concerns of STEAM cluster, this paper suggests a sociological definition of artist and art that is to have an income as a full-time professional performer and having a specific degree in HE or teaching the artform in HE or teaching it to pre-professionals. We defined performing art as an artistic performance performed by professional artists.

Elite artistic performance needs to be introduced to STEAM with a clear concept that is not only beneficial for STEM but safe and beneficial for the artists too. Elite artists are proven to be more prone to psychological challenges including PTSD, addiction, eating disorders or depression (Thompson and Jaques 2015) and this indicates the need for a trauma informed STEAM environment for the suggested ASF WS. From the other hand, HE students can highly benefit of a trauma informed and/or trauma aware framework that is considering the individual and group identity related experiences of trauma i.e., discrimination, abuse, war, or natural disasters etc.

4 Art-Science Fusion Innovation WS design

The ASF innovation WS design presented in this paper is planned to target innovation competency of the five-dimensional innovation competency model of Keinänen et al. (2018) and intends to use the assessment tool by Keinänen et al. (2018) to collect data for the support of evidence based pedagogical guidelines and curricula for STEAM. The design is based on modern pedagogy approaches rooted in learning paradigms of cognitivism or socio-constructivism (Ekkekakis and Zenko 2016) and optimized for HE students of STEM.

4.1 Somatic perception and embodied learning

There is a growing consensus, that the traditional cartesian mind-body division failed to describe the reality of the human individual. The human brain is an integrated part of the body and brain function is not separable from somatic experience and embodiment (Nguyen and Larson 2015). Lack of awareness of the somatic dimension of the human cognition might compromise the rise of new, creative approaches to learning, innovation, and research. To further improve STEAM cluster related innovation pedagogy methodologies, it is reasonable to include and emphasize the somatic perception and communication. The ASF design presented in this paper aims to include both aspects by offering somatic experiences guided by elite performing artists through a participatory WS. Focusing on the learning theory of somatic learning and the somatic aspect of perception and conceptualization, multiple links are identifiable that have a relevance in terms of innovation pedagogy. Adult hippocampal neurogenesis that is hypothesized as a crucial factor in memory formation and is accepted to be enhanced with physical activity and somatic experiences (Micheli et al. 2018). From the other hand, human memory formation is contextual, and both long term and short-term memory formation can be supported or disabled through somatic experiences (Rosatto et al. 2018). Cognitive functions that include innovation skills as well can be positively influenced by complex associative experiences, complex sensory and somatosensory input that are provided in the suggested ASF design by a multi-and interdisciplinary participatory artistic activity.

4.2 Units of the WS

4.2.1 Preparation

A HE lecturer/professor and an artistic team (opera singer, pianist, dance artist, choreographer) choose together a scientific concept from the curriculum that is typically presented in one lecture and a section of performing art piece that they intend to connect in the WS, and they develop the pedagogical details.

4.2.2 Second WS day

Reinforcement: reprise of the walking and mirror exercise of the 1st day but with new coordination elements.

Kinetosphere: students take distance from each other and imagine a big cube around their body. A series of exercises follow which aim to define reference points on the body (body architecture), and reference points on the imagined cube (Haffner et Al. 2012) that are connected by improvisative movements added cross-hemisphere coordination.

Participants' creative impact: presentation of the embodied homework in a circle that has particular relevance in human interactions, it is democratic and symbol of many positive values. (Karomatovich and Shodiyevich 2022).

Artistic creation: the choreographer places in the artwork the embodiment element developed by the students and the performers learn the new structure demonstrating cooperation, flexibility and adaptability. This way a new interdisciplinary performing artwork is created which incorporates all the connection points chosen by the students. As the closing of the WS the newly created artwork is performed by the artists, the performance is recorded and the access to the recording is sent to all participants.

5 Outlook and contribution

The ASF WS might be slightly modified in accordance with the data protection regulations of the country and institution where it is carried out. Prior to the WS an ethical approval will be requested, that is going to be completed with the WS's own trauma awareness concept. As next step the exact process and methodology of a research is intended to be conceptualized. The proposed research aims to assess the changes that might occur in the innovation competency of students due to the ASF WS, described in this paper. The assessment tool is planned to be the validated five-dimensional digital self-assessment tool developed and validated by Keinänen Et al. (2019). The independent variable of a potential research is the ASF WS. The dependent variables are the innovation competency of the participating students. The electronic self-assessment questionnaire is going to be filled two times by the participants. First one, six days before the ASF WS, the second one the day following the art-science WS. The null hypothesis is that there will be no difference between the results of the two questioners. The hypothesis of the research is that the art-science WS is going to improve the innovation competences of the student therefore the result of the second assessment is going to show measurable improvement.

Given the fact that there is extremely limited literature which could show relevant data in the field of HE collected using validated assessment tools before and after an ASF WS, the proposed study aims to fill a gap and contribute to the understanding of the role that interdisciplinary elite performing arts and embodied perception can play in science and academic innovation. The ASF WS presented in this paper describes an innovation pedagogical instrument that may, later, be integrated into evidence-based STEM pedagogical guidelines and curricula.

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