

## Art Science Fusion: Learning Enterprise Architecture concepts with Performance Art

Rod Dilnutt,<sup>a</sup> István Simon<sup>b\*</sup>, Boglárka Simon-Hatala<sup>c</sup>

*The University of Melbourne, Australia<sup>a</sup>, Technische Universität Dresden, Germany<sup>b</sup>, Semmelweis University, Budapest, Hungary<sup>c</sup>*  
Corresponding Author [rpd@unimelb.edu.au](mailto:rpd@unimelb.edu.au)

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### CONTEXT

The role of higher education is to prepare graduates to join the future workforce. Pedagogical frameworks focusing on innovation competences in STEM have high potential to facilitate scientific research, technological advancements and unlock creative potential in learners. The extant literature has opened the enquiry at primary, and secondary levels however, our understanding of the benefits in STEM the higher education context is limited.

### PURPOSE

This study puts the A(rts) in STEM (Science, Technology, Engineering, Mathematics) pedagogy. Building on the STEAM concept, the paper leverages the synergy between arts and science to target soft skill development for innovation competences through embodiment-based transformative learning. Its purpose to test the impact of a performance arts intervention into the teaching of enterprise architecture as an illustrative scientific concept.

### APPROACH

This study explores how sensory and somatosensory engagement inherent in performing arts can positively influence cognitive functions critical to developing innovation competency. To do this we choreograph Enterprise Architecture as a dance. As an ongoing study, a previous phase designed a pedagogical approach (Simon et al., 2022) and proceeded through a systematic literature review. This paper reports on the outcome of the pilot workshop at The University of Melbourne 2023.

### OUTCOMES

Results indicate improvements in four of the five innovation competencies: creative problem-solving, systems thinking, goal orientation, and networking suggesting a positive correlation between the intervention and the development of innovation competency. Results also demonstrate the efficacy of the workshop approach and assessment instrument.

### CONCLUSIONS

The study highlights the potential of integrating elite performing arts into STEM education as a catalyst for innovation and harness the full potential of STEAM frameworks. Future work will refine these methods, explore neurobiological impact, and ensure inclusivity and safety within diverse educational settings. Accordingly, the results contribute to our understanding of the role of participative learning in science pedagogy and further informs teaching in practice.

### KEYWORDS

STEAM, STEM, Education; Pedagogy, Innovation Competency

## Introduction

Contemporary global challenges including climate change, energy crises, and overpopulation demand innovative responses, with STEM fields pivotal to the development of sustainable solutions (Muller & Nathan, 2020; Simon et al., 2022). Innovation, defined as the creation, development, and adoption of new ideas or behaviours, is a foundational competency across all STEM disciplines (Keinänen et al., 2018; Parida et al., 2019). Innovation competence, viz. problem-solving and critical thinking, is essential for preparing a future-ready workforce (Simon et al., 2022). Therefore, embedding innovation competency in engineering education curricula is key to equipping learners with the skills needed to navigate complex global issues and contribute meaningfully to sustainability (Kivunja, 2014; Edwards-Schacter et al., 2015; Khadri, 2022).

Our motivation is to understand the effect of introducing performance art into the teaching of science-based concepts, specifically engineering and technology, and the impact this intervention has on the learning experience and the development of soft skills that underpin innovation competency. Our study represents the first phase of a pedagogical intervention allowing systematic observation and measurement of changes in innovation competency. Accordingly, our research question becomes: How does performance art enhance the development of innovation competence in engineering and technology education pedagogy? The objective of this phase of study is to test the efficacy of the proposed approach.

This paper is structured as follows. 1) it describes the theoretical background of innovation competencies in from the extant literature from the art/science pedagogy viewpoint. 2) the methods adopted for data collection and analysis are articulated. 3), the results from the data are presented 4) the study findings are discussed, 5) Conclusions, Limitations are presented and calling for further research. This study contributes to existing science education pedagogy proposing that educators to consider developing the innovation competencies required of the future workforce.

## Background

STEM emphasises innovation, problem-solving, and critical thinking as core competencies to be developed in education. Lavi et al., (2021) note that the traditional learning environment in STEM is inadequate for the development of innovation competencies and for nurturing 21st century skills. They suggest blending art into the STEM cluster of liberal arts, performance, fine arts, and music to foster creativity, innovation, and divergent thinking (Lavi et al. 2021, Madden et al. 2013). The 'Art' in STEAM typically refers to creative arts, music, dance, performance, literature and defines art for the purposes of this study. Although STEAM's influence in educational pedagogy is growing (Carter et al., 2021, Meijas et al 2021), there is limited understanding of how art based pedagogical interventions impact the learning experience and development of innovation competencies.

STEAM frameworks, including artist-scientist interactions, offer multiple potential benefits beyond structured collaborations Adams & Fuchs (1985). Innovation in STEM education is predicated on the transfer and creation of knowledge between instructor and learner. This exchange is interpersonal and contingent of soft skills including communication, emotional intelligence, and relationship building. STEAM frameworks represent a novel intervention modality to promote innovation competencies with (Keinänen et al., 2018) offering an assessment model identifying problem solving, systems thinking, goal orientation, teamwork and networking.

Prevailing models of instruction, particularly in the science disciplines, follow traditional passive learning approaches through teacher led information exchange. In higher education this instruction is commonly delivered in lecture style with presentation of formulae, calculations and information. In this model the instructor actively delivers instructions with the learner largely a passive receiver with limited engagement. Simon et al. (2022) note that performing art has limited representation within the STEAM literature and recommend the introduction of performance art into STEAM pedagogy to develop innovation competency in learners and integrating these methods into broader scientific curriculum. The introduction of active interventions including dance, music and performance art can enhance the learning experience and retention levels (Karomaticovitch &

Shodiyevich, 2022, Malinin 2019). Further, (Barnish & Barran, 2020) identify artistic experience as having a positive effect on cognitive function, scientific performance, and cognitive function.

Information exchanges through spontaneous interpersonal communication broaden knowledge, challenge routines, and suggest new practical methods (Schnugg, 2019). From a learning perspective, the transformation of habits of the mind (schemas) and points of view (transformative learning) leads to a different experience of the world (Le Pertel et al., 2020). Further, performance art stimulates neuroplasticity as an essential vehicle of creativity to facilitate innovation (Dawn & Angela, 2024). STEAM frameworks present an intervention modality to promote subjective perception and divergent thinking, which are highly linked to innovation with creativity highly linked to problem-solving (Calavia et al. 2021). While classical academic science pedagogy offers very little space for this, art is typically viewed as the subjective interpretation of the self and of the world (Langer, 1954). Accordingly, art is a candidate for catalysing transformative learning, defined as a learning process that “involves the adoption of new paradigms and necessitates un-learning previously held concepts, schemas, and beliefs” (Le Pertel et al., 2020) within a favourable environment that will awake, stimulate and develop creative traits (Calavia et al. 2021).

While the promotion of STEAM in higher education policymaking is observable, there is limited empirical evidence to facilitate the development of applicable models of implementation (White & Delaney, 2021). In contrast to the current narrative of cartesian materialism that separates body and mind, performing arts are characterized by a clear embodiment dimension in terms of somatic perception and communication (Adams & Fuchs, 1985). Existing evidence supports the view that physical activity and somatic experiences facilitate memory retention (Epp et al., 2021). Moreover, given its contextual nature, long and short-term memory formation can be stimulated immersion in an experience (Rosatto et al., 2018). A final consideration is that embodiment-based modalities are suggested to be efficient in promoting transformative learning by facilitating the neurobiological processes of un-learning (synaptic pruning and extinction learning). Calavia et al., (2021) further, noted the positive learning impact resulting from active participation in science.

## **Somatic interventions**

There is growing recognition that aerobic and dance-based somatic interventions stimulate brain activity that enhances cognitive function and memory (Barnish & Barran, 2020; Tao et al., 2023). Movement-based, multisensory experiences support neuroplasticity, adult neurogenesis, and central nervous system responses (Dawn & Angela, 2024; Epp et al., 2021; Frizzell et al., 2020). Somatic therapies also aid emotional regulation and trauma recovery (Payne et al., 2015). Radically embodied neuroscience highlights cognition as embodied action, advancing applications in attachment, creativity, and systems thinking (Kiverstein & Miller, 2015).

## **Artistic impact**

STEAM literature highlights the arts as essential in individual development and social cohesion, as they are intrinsically and instrumentally social, inclusive, and humanizing (Belfiore & Bennett, 2007). Integrating the arts with scientific information systems fosters innovation, imagination, and creative dynamics, while enhancing science communication to broader audiences (Schnugg, 2019). Emerging research indicates that engaging in artistic experiences positively influence the cognitive functions vital to creative innovation, including long- and short-term memory, decision-making, emotional regulation, and social competence (Schnugg, 2019; Aschauer et al., 2022).

Simon et al. (2022) proposed a sociological definition of an artist and art to increase reliability and reproducibility. According to this definition, an artist is someone who earns an income as a full-time professional performer, holds a specific degree in HE, or teaches the art form at the HE level or to pre-professionals.

Simon et al. (2022) designed an Arts/Science Fusion approach featuring a performance art intervention to enhance the learning experience through stimulation of adult hippocampal neurogenesis which is a fundamental factor in memory formation (Epp et al., 2021). The hypothesis of the suggested approach was that embodiment-based modalities and complex

sensory and somatosensory input embedded in participatory artistic activity positively influence cognitive functions and soft skills linked to innovation. This multi- and interdisciplinary pedagogical approach to connecting the seemingly unrelated information systems concept of enterprise architecture with elite performing arts, facilitates embodied perception and somatic learning and aims to enhance the development of innovation competence.

Our research proposition is therefore that introducing performance art into STEAM pedagogy has a positive impact on learning experience and development of innovation competencies.

## Method

Based on the design of Simon et al. (2022), an exploratory, shortened, and simplified information gathering workshop was designed as a pilot study (van Teijlingen, 2001). The objective was to assess whether the modality has an impact on innovation competence. The advantage of conducting the pilot was to test feasibility, identify potential issues, and refine methodologies to ensure that the research design, data collection, and analysis methods are effective before full-scale implementation. The adaption was predicated on the need to test the validity of the approach while retaining the performance and science instruction, and cognizance of the practical challenges associated with asking participants to attend a two-day workshop voluntarily. The fundamental approach remained intact, and the workshop proceeded as a single four-hour session.

### The five factor innovation competences model

The design of the pilot was developed based on the five-factor model, a validated tool to measure innovation competences, (Keinänen et al., 2019). In turn, the five-factor model is a refinement of the three category Innovation Competence Barometer namely: individual, interpersonal, and networking competencies. (Watts et al., 2013). The model focuses on creative problem-solving, systems thinking, networking, goal orientation, and teamwork and can be quantified by the validated questionnaire before and after the interventions. Concepts applied in the design of the pilot were interactive embodiment, and multidimensional elite art experience.

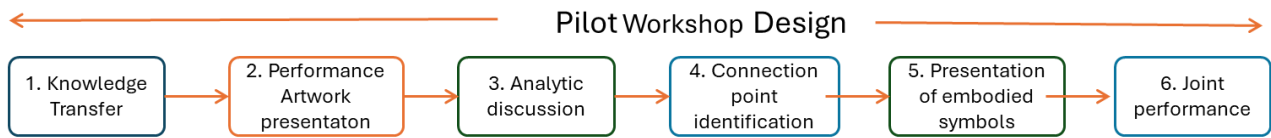
### Science Concept

To provide the STEM context, an enterprise architecture concept, The Zachman Framework (1999), was selected as a rule-based standard with agreed and stable attributes as a representative science concept for instruction. An elite dance performance was selected to embody the enterprise architecture concept thereby measuring the response from learners. and facilitating neuroplasticity on multiple levels. Future studies will select a range of engineering and technology concepts to broaden the range of topics and assess general applicability.

### Pilot design

Associative and experiential learning are incorporated into the methodology, providing a dynamic substitute for conventional lecture-based methods of building knowledge. Pilot design applied the five-dimensional innovation competency model (Keinänen et al., 2018) as the rubric for measuring responses to the interactive experience relative to the Zachman framework concept. For example, the Zachman Framework conceptualises and provides practical guidance for practitioners governing the business architecture of an organisation (Zachmann, 1999). This framework provides a matrix describing practitioner viewpoints within an organisational hierarchy mapped against domains of interest i.e. data, process, people, infrastructure, timing, and strategy. By invoking a response expressed in words and movement to a technical concept, participants create an analogous link between theory and experience. Each participant will respond differently, these movements can be choreographed and played back. Thereby students are part of both the creation (input) and the audience. This offers a different way of teaching than the lecture style 'sit and listen'. Accordingly, the pilot was structured as follows. 1) knowledge transfer of the scientific concept 2) interdisciplinary performing artwork segment presented live 3) analytic discussion with the performer from an artistic point of view 4) identification of connection points (based on

subjective, creative association) between the science concept and the witnessed performing arts 5) connection points transformed into embodied representations (“symbols”) each symbol named by its creator. 6) embodied symbols presented, shared, and connected to a choreographic sequence while participants were positioned in a circle, symbolizing positive values and democratic interactions (Karomatovich & Shodiyevich, 2022). 7) joint performance, participants sequentially displaying embodied symbols 8) performer enacts a modified choreography integrating all symbols.



**Figure 1 - Pilot Workshop Design**

## Data Collection and Analysis

Participants self-assessed their innovation competencies before and after the pilot session using an electronic questionnaire to measure any change in perception of the learning experience. Drawing on Keinänen et al.'s (2018) five-dimensional innovation competency model a questionnaire of 27 statements (Table 1) to self-assess competence on a 5-point Likert scale with the option, 'I can't say'. Because this option does not lend itself to determining the reliability of the instrument, such answers are excluded from the reliability value calculations and factor analyses. The questionnaire included contextual data questions on the respondents' gender, study year, study field, and work experience. Ethics approval for this study was granted by the Ethics Committee, Technische Universität, Dresden, August 4, 2023.

Data from the self-assessment questionnaires were processed and analysed using SPSS version 29 (IBM Inc.). Categorical variables are expressed as absolute (n) and relative (%) frequencies. Items are summarized as mean (M), standard deviation (SD), and median (Med). Constructs were built by the arithmetic mean of the corresponding constructs. Reliability in terms of internal consistency was analyzed by Cronbach's alpha. Skewness and kurtosis were used to describe the shape of the distribution. Absolute values below 1 are indicators to use parametric testing procedures. In cases of violation or doubts over normal distribution, non-parametric tests were applied. To compare differences between pre- and post-course evaluation, paired-sample t-tests or Wilcoxon tests were applied. p-values <0.05 were interpreted as statistically significant.

## Participants

Participants were students and staff from the School of Computing and Information Systems, and College of Dance at the University of Melbourne. Recruitment proceeded through email invitations to current students and staff. Participation was voluntary and the sample group of 14 participants included nine females [64.3%] and 5 males [35.7%], Five participants (35.7%) had a bachelor's degree, four (26.8%) had a doctorate or professional degree, with five (35.7%) holding a master's degree. The sample included 10 university students (71.4%), one self-employed (7.1%), one part-time employed (7.1%), and two (14.3%) full-time employed.

## Results

The data was recorded against Keinänen et al.'s (2018) five factor model and tested for normal distribution. Due to high kurtosis and the low number of participants, non-parametric testing procedures were applied.

Participants (step 5) identified and named connection points which were transformed into embodied representations (“symbols”) that is participants were asked to perform a motion expressing their connection symbol with the science theory as per step 6. Table 1 presents the connection point symbols.

**Table 1 - Connection Symbols**

Adventure	Confusion	Contradiction	Control
Emotion	Flexibility	Impact	Interaction
Limitation	Listening	Reaction	Sadness
Strength	Wanting		

The characteristics of the items and factors are presented in Table 2. Relative to the five innovation competences, most participants showed an increase or stagnation of scales. For each scale only 1-3 non-responders can be identified. Recognising the small sample size, the data shows some significant improvements in key capability areas. Improvements were observed in area of idea generation (I suggest ideas for others to approve how the job should be done,  $d=1.12$ ), collaboration (I bring for the ideas openly for others,  $d=1.29$ ), 'creative problem solving' ( $d=1.03$ ), and 'systems thinking' ( $d=1.18$ ), with effect sizes exceeding 0.8 and p-values well below 0.05. Networking ( $d=0.066$ ), and goal orientation ( $d=0.66$ ) also improved with medium-to-large effects with a recognisable but moderate statistical significance. Several behaviours, such as persistence and conflict resolution, showed some positive trends however cannot be considered significant, while cultural cooperation remained unchanged. Overall, the data indicates a minor enhancement of higher-order thinking and collaborative capabilities.

**Table 2. Characteristics of items and constructs.**

	Before			After			p-value		Cohen's d
	M	SD	Med	M	SD	Med			
I suggest ideas for others to approve how the job should be done.	3.36	1.15	3.5	4.14	1.10	4	0.004	**	1.12
I suggest new ideas for solving problems.	3.79	0.80	4	4.00	1.04	4	0.453		0.31
I suggest new practical solutions to reach a goal.	3.79	0.89	4	4.14	1.10	4	0.234		0.42
I make daring but justified decisions.	3.43	1.02	4	3.64	1.45	4	0.398		0.19
With my competence, I help achieve the goals of the group.	4.00	0.78	4	4.21	1.12	4.5	0.549		0.24
I bring forth new ideas openly available	3.29	0.99	4	4.14	0.86	4	0.002	**	1.29
I can steer the group toward the goal.	3.71	0.91	4	4.36	1.15	5	0.045	*	0.69
I make justified evaluations of what lies behind the activities.	3.54	0.97	4	3.79	0.98	4	0.508		0.28
I understand causal relationships between matters.	3.86	0.66	4	4.14	1.10	4	0.359		0.35
I am capable of looking at a task from different actors' perspectives.	3.93	0.83	4	4.29	0.91	4.5	0.234		0.40
I imaginatively use existing resources.	3.43	0.94	4	4.21	0.98	4.5	0.010	*	0.92
I anticipate upcoming developments.	3.64	1.15	4	4.29	0.83	4	0.016	*	0.86
I can resolve conflicts to achieve a common goal.	3.64	1.08	4	4.14	0.95	4	0.063		0.66
I indicate by my behaviour that I am interested in the matter.	3.43	1.02	4	4.00	1.04	4	0.063		0.61
I work persistently to achieve a goal.	3.93	1.14	4	4.21	1.19	5	0.125		0.61
I concentrate on relevant points to achieve a goal.	3.50	1.09	4	3.93	1.00	4	0.156		0.50

	Before			After			p-value	Cohen's d
	M	SD	Med	M	SD	Med		
I take group members' viewpoints into account.	3.93	1.07	4	4.14	1.23	4.5	0.531	0.27
I am capable of collaborating.	4.21	1.12	4.5	4.64	0.84	5	0.031	* 0.84
Capable of productive cooperation with different cultural backgrounds.	4.36	0.75	4.5	4.36	1.08	5	1.000	0.00
I can use external networks.	3.54	0.97	4	3.93	1.07	4	0.219	0.49
Capable of productive cooperation with professionals of different fields.	3.79	0.89	4	4.07	1.14	4	0.289	0.39
I am capable of networking.	3.71	1.07	4	4.14	1.17	4.5	0.070	0.66
Creative Problem Solving	3.62	0.76	3.64	4.09	0.97	4.29	0.004	** 1.03
Systems Thinking	3.68	0.55	3.82	4.14	0.80	4.33	0.003	** 1.18
Goal Orientation	3.62	0.93	3.67	4.05	0.98	4.33	0.021	* 0.66
Teamworking	4.17	0.85	4.33	4.38	0.96	4.67	0.125	0.50
Networking	3.69	0.87	4.00	4.05	1.04	4.17	0.019	* 0.70

Note: M: Mean, SD: Standard Deviation, Med: Median. P-values resulting from Wilcoxon test, n=14. \* p<0.05, \*\*p<0.01, \*\*\*p<0.001

## Discussion

This pilot study has dual aims 1) to inform how and if performance art enhances the development of innovation competence in science education pedagogy and 2) to test the efficacy of the proposed approach. Prior research revealed that STEM education focuses on innovation competencies of problem-solving, and critical thinking but often lacks the creative environments needed to develop these competencies (Lavi et al. 2021, Keinänen et al., 2018). Integrating the arts into STEM (creating STEAM) to foster creativity and divergent thinking encourages participative embodied learning through music, dance, and performance art, and improves neuroplasticity, memory, engagement, and innovation skills. These approaches emphasize interpersonal communication, emotional intelligence, and transformative learning which strengthens the proposition that innovation competence is both an individual and social construct (Keinänen et al., 2018).

Deployment of the pilot workshop deviated from the Simon et al. (2022) original design by reducing its complexity and shortening its duration, while embodiment exercises targeted all five competencies collectively. In addition, the trauma-informed environment framework was not applied. However, the two main elements hypothesised to influence innovation competence—embodiment tools and complex sensory and somatosensory inputs embedded in a multi-and interdisciplinary participatory artistic activity remained intact. with the interdisciplinary performing artwork segment presented live, followed by an analytic discussion with the performer from an artistic point of view. The connection of remote information systems was processed by identifying connection points (based on subjective, creative association) between the science concept and the witnessed performing arts. These connection points were then transformed into embodied representations (“symbols”) through movement or pose, with each symbol named by its creator. After the gait-based spatial awareness exercises, the embodied symbols were presented, shared, and connected to a choreographic sequence while participants were positioned in a circle, symbolizing positive values and democratic interactions (Karomatovich & Shodiyevich, 2022). Finally, in a joint performance, participants sequentially displayed their embodied symbols linking the science concept and artwork while the performer enacted a modified choreography integrating all symbols, resulting in a collectively created choreography.

Participants reported a positive perception of the workshop experience with a high engagement with the approach with all participants completing the questionnaire. The data indicates a positive

impact on the learning experience particularly across the creative problem-solving and systems thinking dimensions of Keinänen et al.'s (2018) five factor assessment model. Further, this intervention shows promise in enhancing cognitive function and development of soft skills essential for innovation, challenging traditional passive teaching models in science education. This implies the positive impact that various artistic experiences have on cognitive functions related to creative innovation, long- and short-term memory, decision-making, social skills, and emotional self-regulation (Aschauer et al., 2022). The performance art intervention in this pilot and deployment of a self-assessment instrument reinforces the concept of the learner having an active role in learning and assessment practices (Calavia et al., 2021).

The results suggest that these five factors positively impact innovation competence. Notably, changes in at least one of the five factors of innovation competence were observed in all participants. However, a portion of individually assessed factors showed a decline rather than improvement. Nonetheless, a statistically significant increase was noted in four competencies: creative problem-solving, systems thinking, goal orientation, and networking. The lasting effects of these changes remain unknown. This outcome underscores the need for further investigation into how the combination of embodiment-based tools and elite art influences neuroplasticity, learning, competence, and potential impact on personality traits, psychological conditions, or neurodiversity that may significantly contribute to the nature of the impact of such frameworks.

## Conclusions, Limitations and Further Research

This study has significant implications for science education pedagogy and theory of educational practice as similar interventions are considered for inclusion in science curriculum. An understanding of the importance of developing innovation competency in learners has theoretical implications for education pedagogy. From a practice perspective, this contributes to science curriculum design, assessment and teaching as teachers develop interventions and create learning environments to augment current instructional and assessment practices (Kivunja, 2014).

This pilot acknowledges several limitations influencing the results presented. First, the pilot involved a relatively small and homogeneous cohort of faculty and students with common interest in performing art, enterprise architecture, and education. An expanded and more diverse cohort may produce different results. Second, the administration of the survey immediately after the session risks recency bias. Finally, members of the cohort responded to a general invitation to participate and therefore could be considered a self-selecting group attracted to the study because of pre-existing interest. If a randomly selected, more diverse cohort had participated the results could be different. However, despite these limitations, the results from this pilot provide motivation for proceeding with further similarly structured workshops through performance art interventions.

To conclude, the data collected, and outcomes achieved through this pilot confirm the efficacy of the approach taken. This gives confidence that additional studies through similar performance art interventions, anchored on the enterprise architecture scientific concept will further confirm our understanding of the positive correlation between performance art interventions in science pedagogy and innovation.

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