ONTOLOGICAL ASPECTS OF FORMATION OF PERFORMANCE-BASED APPROACHES TO SCIENCE EDUCATION: EUROPEAN EXPERIENCES AND GLOBAL POSSIBILITIES

Jake Lewis,

BA in Philosophy, University of Cambridge,
UNESCO Consultant.
E-mail: jr.lewis@unesco.org
ORCID: 0000-0002-5236-9542

Michael Gregory,

BS in Mathematics, Chemistry and Physics,
B.Ed. Mathematics and Physics at the Intermediate/Senior Level,
UNESCO Volunteer.
E-mail: md.gregory@unesco.org
ORCID: 0000-0001-7920-0475

Daniella Palmberg,

BS in Public Health, University of Texas at Austin,
UNESCO Intern.
E-mail: d.palmberg@unesco.org
ORCID: 0000-0003-2529-6314

Casimiro Vizzini,

MD, UNESCO Expert,
E-mail: c.vizzini@unesco.org
ORCID: 0000-0003-0658-3887

The PERFORM project was a three-year pilot project funded by the European Commission's Horizon 2020 Framework, centred on the development of science communication/education tools in the performing arts. At the heart of the project was an ambition to explore innovative and new ways to inspire and motivate young people to pursue STEM, both academically and professionally, while encouraging young people to develop a more reflective and holistic understanding of science. PERFORM found that educational processes which utilise the performing arts and involve direct interactions with trained early career researchers can be implemented to foster young people's engagement and broaden their perspectives on science. In this paper, we discuss performance-based approaches to science education, outline the authors' experience with PERFORM project, and consider

how PERFORM processes can be implemented more widely – particularly under the framework of the 'myPERFORM' concept. In addition, we recommend policies to foster performance-based approaches to science education, targeting training mechanisms, communication channels, and school curricula.

Key words: performance; science education; Horizon 2020; STEM; STEAM; innovation; engagement.

Introduction

In this paper, we discuss performance-based approaches to science education, outlining the authors' experience with the European Commission funded PERFORM project. We summarise the results of the project, outline lessons learned, and consider how PERFORM processes can be implemented more widely – particularly under the framework of the new 'myPERFORM' concept. Parts of this paper closely follow the authors' previous work in their PERFORM policy briefs [Vizzini et al., 2018a; Vizzini et al., 2018b].

PERFORM explored innovative ways of combining performing arts and STEM education, bringing together teachers, students, early career researchers and science communicators in an interdisciplinary and participatory learning process.

The PERFORM project reflects the increasingly common view that there are opportunities to innovate in approaches to science education. New and varied pedagogical approaches can play a key role in bridging the gap between current science research and the classroom. Using performance art can be a way to connect young researchers with students of all ages.

It is well established that there is no single and correct way to teach science. Rather, an effective strategy is to use a variety of approaches, catering to various senses and multiple intelligences [Shams & Seitz, 2008; Gardner, 1983). A number of theatrical techniques are able to cater to an impressive number of senses and intelligences at the same time. Many traditional classroom approaches make use of only one sense at a time (e.g. reading only uses vision; listening only uses audition). Combining vision and audition can lead to more effective learning and retention, such as in the use of videos, analysis and discussion. Adding a tactile element, through doing or acting can further increase the effectiveness of instruction [Dale, 1954]. Encouraging students to create performances so that they can themselves teach and share can bring the classroom experience to the pinnacle of Dale's "Cone of Learning", which claims that most students will retain upwards of 90% of what they teach others. Improved techniques can yet further increase the effectiveness by focusing more active attention.

Drama is also a powerful tool to encourage inclusivity, bringing together learners with various languages and backgrounds in a shared, creative and partly non-linguistic endeavour. This can help to both 'level the playing field' and teach language skills as a secondary curriculum. Several decades ago, Jean Piaget noted the critical role of dramatic play and creative movement for young children to

construct meaning [Piaget, 1962]. Drama can be a powerful and universal tool with which learners of all ages can begin to understand new concepts. Being relatively non-language dependent, physical gestures and movement can be meaningful ways to enable students to engage with content independent of their language skills. In doing so, it also becomes a great tool for the development of new language skills [Greenfader et al., 2013).

Arthur Glenberg has studied the embodiment framework, whereby all psychological processes are influenced by body morphology, sensory systems, motor systems, and emotions [Glenberg, 2010]. This extends to processes involved in learning scientific concepts and acquiring language skills [Greenfader et al. 2014].

Recent work in neuroscience and cognitive science has shed new light on topics in education, and increasingly we are re-evaluating traditional ideas that meaningful and long-term learning is the product of focused attention over a period of time [Kahneman, 2011; Gladwell, 2008]. New information stimulates neural pathways to be formed, and through repeated, focused attention, these pathways are strengthened. The focus of the attention can be thought of as the traffic of nerve signals through these pathways, and the more traffic that occupies these pathways, the easier they become to use. This can be seen as the automation of tasks, or as Daniel Kahnemann puts it, shifting the responsibility from System 2 (short-term working memory, thinking hard to perform a task) to System 1 (long-term memory, performing tasks automatically without need for much conscious thought) [Kahneman, 2011]. This mechanism can explain the 'ten-thousand hour rule', popularised by Malcolm Gladwell in his book Outliers [Gladwell, 2008], according to which 10,000 hours of focused practice in any particular activity should result in the practitioner becoming a world-class expert in their activity.

These findings are relevant to the PERFORM project in two distinct ways. First, the idea of active attention – the more focused a learner's attention, the more likely they will retain the content. Active performance is an effective way to draw and focus a learner's attention, and this is compounded through the use of early career scientists and effective role models. Second, the idea of duration, or repeated practice, comes into play when students are involved in creating and practicing their own performances. The anticipation and pressure of performing for an audience adds an element of focus to the practice, thus making it the meaningful, focused repetition needed to strengthen neural pathways for deep learning to occur.

UNESCO was responsible for PERFORM's 'Sustainability and Project Legacy'. Gender equality is a central priority for the Organization, especially in light of the 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals – in particular Goal 5. PERFORM helps to promote women in STEM and science by providing contexts for young scientists to showcase their research, showing the human side of young scientists, and adapting instruction to be more engaging and accessible for all.

Women continue to be underrepresented in STEM careers, despite their high achievement in academia and other fields [Modi et al., 2012]. A key strategy to

increase the number of young women in STEM fields is to showcase the work of female scientists. Historical and famous examples are useful to highlight the achievements of female scientists, and to inspire the youth of today. By providing a framework for early career researchers to share their work with students, PERFORM helped put a face to modern research, including excellent female role models. The importance of this exposure to women in STEM fields is highlighted by a study done by the Girl Guides of America, which found that girls who know a woman in a STEM career are 50% more likely to be interested in STEM [Modi et al., 2012].

As suggested above, there are reasons to support active and participatory approaches to science education. In more traditional education systems, there can be resistance to innovation and new techniques, which can be seen as a less efficient use of classroom time. This resistance often comes from a short-term perspective that prioritizes curriculum coverage over knowledge retention. The approach suggests that a teacher stating facts to a group of students counts as teaching, regardless of whether the facts are understood or retained. A number of factors can give rise to this approach, from the demands of standardized curricula, inspection and reporting pressures, and most significantly, resistance from teachers and parents themselves.

Everyone has attended school as a student, so one might suspect that this contributes to cases where adults consider themselves 'experts' on schooling, regardless of whether or not they have any experience or training in planning or designing learning experiences. These results in a tendency for parents to judge their children's school experience based on their own experiences in school. Thus, parents with memories of sitting in lecture-style classes for hours on end will tend to expect the same from their children, and may be susceptible to resisting new approaches like PERFORM.

This resistance to new techniques can be grounded in a concern for the quality of education given to their children, and so it is important to demonstrate the effectiveness of any new technique, in order to gain the support of all stakeholders involved. Simply inviting parents to see performances created by their children in collaboration with science communicators and researchers can be a powerful way to include them in the learning experience and gain their support.

One next step that we can take is to connect early-career researchers with teachers and schools, and with science communicators – professionals in performance-based approaches to communicating science. In so doing, we would be following the framework of the PERFORM project. We outline this framework in more detail in the next section of this article.

The PERFORM Framework - Implementation and Achievements

In this section we describe the authors' experience with the PERFORM project, outlining its structure and achievements. Based on this experience, we suggest ways forward for implementing performance-based education processes elsewhere, including in Ukraine.

PERFORM was a three-year pilot project funded by the European Commission's Horizon 2020 Framework, centred on the development of science communication tools in the performing arts. At the heart of the project was an ambition to explore innovative and new ways to inspire and motivate young people to pursue STEM, both academically and professionally, while encouraging young people to develop a more reflective and holistic understanding of science.

PERFORM held performance-based science education workshops in three countries - Spain (Barcelona), France (Paris) and the UK (Bristol), with students from twelve selected secondary schools. All schools came from low and medium socioeconomic backgrounds. PERFORM employed different performance practices, using improvisational theatre in France, stand-up comedy in Spain, and science busking in the UK.

Central to the project was the European Commission's framework for Responsible Research and Innovation, which seeks to align scientific research with broader social values, emphasising ethics and transparency in research, gender equality, and more widely, the importance of public engagement and responsible political governance of research and innovation.

These values were deeply embedded into the project. PERFORM emphasised three RRI values: critical thinking, inclusiveness and ethics integration [Heras et al., 2018: 7]. Within the framework of performance, young people considered philosophical and ethical issues pertaining to science, as well gender equality issues and the 'human elements' of scientific research. They were encouraged to consider science from a 'critical' perspective, considering questions such as: 'what are the principles that scientific investigation relies on? What kind of ethical dilemmas do scientists find themselves facing?' The PERFORM framework is one which is intrinsically inclusive: by its nature, it aims to reach out to diverse groups of young people with different profiles and approaches to learning. It then constructs an inclusive environment in which all actively participate as equals, in an honest and transparent process which targets multiple senses and learning preferences.

Encouraging young people to develop a reflective and holistic understanding of science was considered to be an end in itself, but PERFORM researchers were also interested to see whether 'widening' the approach to science education in this way could itself contribute to fostering motivations and positive views about science.

PERFORM placed value on making science appear 'real' and relevant. It achieved this through the 'contextualisation' of science learning, framing scientific issues as connected to real global and local issues, and demonstrating applications within local contexts [Vizzini et al. 2018a: 9]. This brought into focus the relevance and applicability of science and scientific research. PERFORM also aimed to convey 'transversal competences' to young people through workshops: skills like collaborative and social skills, communication skills, self-confidence and an accompanying sense of initiative, and 'learning to learn' – an ability to independently identify research questions, find relevant sources, and critically assess evidence [Heras et al., 2018: 13-14].

One defining element of the PERFORM process was its combination of four sets of actors: workshops brought together students, teachers, science communicators, as well as early career researchers. These stakeholders would then work together to construct scientific performances. In view of research which shows that young people are influenced by negative stereotypes and problematic cultural images of scientists [Ruiz-Mallén & Escalas, 2012; Cheryan et al., 2015], early career scientific researchers (ECRs) were included in the PERFORM process as a way of helping to nullify these stereotypes. The ambition was that, interacting directly together, scientists could show just in being themselves that people of all genders, ages and ethnicities are and can be scientists. Early career researchers also acted as intermediaries between students and science communicators; students could turn to them informally to ask questions about their research, and for more general guidance. In this way, the goal was for early career researchers to develop relationships of trust and empathy with the students, contributing to the goal of challenging stereotypes [Vizzini et al., 2018a: 4].

In improvisational workshops in France, 10 or so students per group worked with an early career researcher, a science communicator and an artist to create a final performance with the students as actors [Heras et al., 2018: 8]. In busking workshops in the UK, students used demonstrative props, combining music, magic, humour and theatre to inform imagined passers-by about a topic in science, primarily based on the research area of a mentoring early career researcher [Heras et al., 2018: 8]. In stand-up comedy workshops, students developed humorous scientific monologues based on group reflections and activities which involved an early career researcher [Heras et al., 2018: 8].

Training for Early Career Researchers and Teachers

In the PERFORM programme, early career researchers and teachers were included in performance-based education workshops after receiving bespoke training. PERFORM designed and implemented two rounds of training courses for early career researchers and teachers, preparing them to collaborate effectively with young people on performance-based activities. From this experience, PERFORM developed two open access training toolkits, one aimed at early career researchers and the other at teachers, which are available for download online [PERFORM toolkits, n.d.]. The early career researchers' toolkit can be used by higher education institutions to help train early career researchers, or by early career researchers independently.

Training for early career researchers reflected PERFORM's RRI values, encouraging them to build a more reflexive, interdisciplinary and holistic understanding of their own research practices. Training also aimed to help early career researchers develop their leadership and communication skills. These skills and this awareness could then be transferred from researchers to students in PERFORM workshops. PERFORM found that for many early career researchers, the training sessions provided them with their first formal opportunity to develop essential

communication skills, and to consider RRI questions and values. Outside of the PERFORM framework, it is rare for universities to provide early career researchers with opportunities for this kind of reflection and skill-building. Certainly, it is not an obligation to build these skills at PhD level. As we write in one of our policy briefs, early career researchers "reported that they had developed conceptual frameworks to look at science and their own research with 'a new lens', improved their linguistic and listening skills, and benefited from developing meaningful relationships with students" [Vizzini et al., 2018a: 5].

Training for teachers had a different emphasis. Training aimed to provide teachers with tools and resources to provoke classroom discussions on science and society, and to help teachers convey transferable competences to students using performance-based approaches and classroom activities. The skills targeted included social and civic competences, analytical skills, and personal competences such as the capacity to manage time effectively. Both training toolkits emphasise narrative and storytelling as a way of bringing science to life.

We found that "teachers' and educators' responses to the training indicated that they perceived that techniques from drama would engage students, inspire their curiosity and interest, encourage them to direct their own learning, to remember content of lessons and to link what they were learning about to wider, social worlds that were personally meaningful" [Vizzini et al., 2018b: 5]. These benefits do not come without constraints, however. Teachers raised some concerns about the confidence of teachers to use the techniques, the constraints that are brought by school curricula deadlines, the confidence of students to perform, as well as pupils' behaviour in the classroom.

Summary of Results

In this paragraph we provide a brief overview of PERFORM results, summarising researchers' assessments. Please refer to PERFORM's publications for detailed results and quantitative data [Heras et al., 2018; PERFORM Deliverables n.d.].

PERFORM assessed how young people reacted to its workshops both quantitatively and qualitatively. A questionnaire was given to students before and after workshops, and also to a control group who did not attend workshops. We reported that young people showed increased levels of engagement and interest with science and science-related issues, and there was an improvement in their understanding of RRI values and the role of science in society [Vizzini et al., 2018a: 7].

The project reported that the workshops "created a relaxed and supportive learning atmosphere and a sense of connection with pupils. Students in the three case studies perceived this playful environment not only as motivating to get involved, but also as an invitation to do so without feeling judged" [Heras et al., 2018: 9]. Workshops allowed for the "contextualisation of learning and the sharing of science as a practice involving ethical values" [Heras et al., 2018: 11].

Workshops helped participants develop transversal skills. Researchers found that "the collaborative nature of the project was a way for students to develop teamwork skills...with students equally sharing tasks and roles according to their own motivations and capabilities" [Heras et al., 2018: 13]. Performance-based work supported development of communication skills, and "when properly accompanied and supported by the science communicators, the performances provided a platform for students to enhance their self-confidence and self-esteem" [Heras et al., 2018: 14].

With regards to thinking more broadly about science, PERFORM found that "many students identified a much broader field of topics within science after the workshops, realising that science is more than just 'clearly defined categories in a textbook'" [Heras et al., 2018: 17].

PERFORM found that "data show a differentiated impact" [Heras et al., 2018: 19] with regards to encouraging scientific vocations. PERFORM "seemed to reinforce the willingness of those students with an existing interest in science or a certain hesitation, but those who did not initially identify with science still did not consider it to be an option after" [Heras et al., 2018: 19].

The bringing together of early career researchers and students "within a creative learning environment had a positive impact on students' perceptions of scientists" [Heras et al., 2018: 19].

Expanding the PERFORM Framework

How can we implement the PERFORM framework more widely? We recommend a 3-step process [Vizzini & Lewis, 2018]: first, early career researchers and teachers must be trained, to collaborate effectively with students in workshops; connections and networks must be established between early career researchers, teachers and science communicators; and finally, performance-based pedagogy must be encouraged and promoted.

More specifically, as recommended in a PERFORM position paper [Vizzini & Lewis, 2018], policymakers should:

- *Provide funds and create mechanisms to support higher education institutions in offering programmes of professional development for early career researchers which include training on: communication, performance, reflexivity, and Responsible Research and Innovation (RRI).*
- *Incorporate the above elements into teacher-training curricula.*
- *Encourage early career researchers to undertake programmes of professional development through incentives, such as public recognition and subsidies for development programmes.*
- *Promote and disseminate resources to support development programmes. Raise awareness of Responsible Research and Innovation at all levels in higher education institutions.*
- *Establish connections and official channels of communication to*

facilitate and encourage interactions between early career researchers at higher education institutions, teachers in secondary schools, and science communicators, creating a common-culture of reflective performance-based participatory learning.

- *Encourage higher education institutions to build on the progress that they have made with outreach and engagement, particularly with schools operating in low socio-economic contexts.*
- *Encourage and promote the use of performance-based pedagogy and activities that stimulate thinking about Responsible Research and Innovation issues in school curricula, fostering students' reflective engagement with STEM* [Vizzini & Lewis, 2018].

UNESCO aims to implement PERFORM processes on a wider scale under the concept 'myPERFORM'. myPERFORM projects will adapt the PERFORM framework to different regions around the world, utilising different performance-based approaches, highlighting different scientific themes, and emphasising transversal skills relevant to local regions. The myPERFORM concept is currently in development.

The PERFORM and myPERFORM projects may be well-suited to implementation in Ukraine, which began reforms to its education system after gaining independence in 1991, and has been improving the curriculums and educational structure of schools since then. However, many components of the old framework remain in place and certain schools do not have the resources or technical equipment to implement the new requirements into their curriculum [Stetsevych n.d.]. Since the 90s, there has been a string of initiatives to decentralize and standardize the quality of the Ukrainian education system. Most notably, the initiative of the "New Ukrainian School" was recently proposed and has gained significant traction. The project was launched by the Ministry of Education and Science in 2017 and aims to adapt a more engaging and activity-based approach in the classrooms. The goals, such as an increased competency in STEM subjects and a school environment that incites learning beyond the classroom, go hand-in-hand with the mission of the myPERFORM project [Ministry of Education and Science of Ukraine n.d.].

Conclusion

In this paper we have reflected on broader research which has implications for performance-based approaches to science education; we have outlined the framework and processes of the PERFORM project; and we have looked ahead to implementing PERFORM-inspired processes more widely, under the 'myPERFORM' concept.

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