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Particle dance: particle physics in the dance studio

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Abstract

A workshop using dance to introduce particle physics concepts to young children is presented. The workshop is realised in the dance studio, the children assume complete ownership of the activity and dance becomes the means to express ideas. The embodiement of the physics concepts facilitates knowledge assimilation, while empowering the students with respect to science. Beyond the scientific and artistic benefits of this workshop, this approach aspires to overcome the barriers between art and science; and open new interdisciplinary horizons for the students.

1. Introduction

The 2015 Nobel Prize in physics was awarded 'for the discovery of neutrino oscillations, which shows that neutrinos have mass' [1]. This was the starting point of a fruitful collaboration between the authors, a deeper look at the respective practices and exchange of ideas, that culminated in the 'Neutrino Passoire' performance [2]: following the elusive and omnipresent neutrinos, from their birthplace in the Sun, travelling through space and oscillating between flavours imperceptibly. In this journey, the neutrinos transverse matter, the Earth, our bodies, continuing unimpeded. This provides for the opportunity to explore the idea that the human body is not a fortress as one might think; it is rather perceived as a sort of passoire, the french word for colander, letting neutrinos pass through without trauma or memory of the event itself. From that point on, the performance naturally questions notions particularly prevalent in the public discourse and leaves it to the audience to provide answers.

The performance was presented for the first time at the University of Birmingham Arts and Science Festival 2016, and in several venues since. An extended version was presented at the Midlands Arts Centre in March 2018, while the final version of the performance was presented in Paris in October 2019. The overwhelmingly positive feedback received from the audience compelled the authors to go beyond the performance by taking particle physics in the dance studio, allowing school students to approach the subject matter through an experiential approach. This mirrors, to a large extent, the process followed by the authors during the development of the performance.

Through the 'Particle Dance' workshop, we aspire to make particle physics more accessible, support students in developing self-confidence in relation to science and research, and generate an interest in science, as an inherently creative subject, that would persist for a long time after the workshop.

2. Workshop development

The 'Particle Dance' workshop was developed, initially, as part of the CREATIONS project, a Horizon 2020 support and coordination action across eleven EU-member countries, aiming to develop art-based creative approaches towards a more engaging science classroom [3]. The workshop design was informed by the creative pedagogical features established within CREATIONS [4], similarly to reference [5] which was developed in parallel.

The core idea is to bring particle physics in the dance studio. This encourages informal learning, avoids any student pre-conceptions regarding the science classroom, and allows for interdisciplinary connections to be made. Furthermore, it allows students to appreciate that dance is not only a means to express oneself in relation to feelings and emotions, but also to convey ideas, even on topics that are not usually perceived to be connected with dance. Thus, another benefit of this approach, is the bridging of art and science subjects, that are currently disconnected in the school curriculum. For this reason, it is important that at the end of the workshop the students have a complete artistic creation, a final product that they could perform and discuss.

The workshop consists of two parts. In the first part, students learn about fundamental particles that make up matter and mediate interactions, as well as about the Higgs boson. At this stage, students connect particles to dance through short choreographic movements, proposed by themselves, inspired by the particle properties, name, etc. In the second part students learn about particle interactions, scattering, pair-production and annihilation, and, in teams, produce a choreography of an interaction. They are given complete responsibility both for the development of the choreography and the choice of music.

During the workshop two main props are used:

(a) the 'subatomic plushies' [6], a cloth model for each particle, used to provide a visual anchor to the discussions; and
(b) a deck of particle trump cards, one per particle, showing the particle name and basic properties [7].

For the initial implementation phase of the workshop, reported here, the main focus was on girls in Key Stage 3 (KS3), and more specifically year 8 (12–13 years old), in the British education system. Seven workshops were delivered in schools in the West Midlands area with up to 16 students per workshop and a total of approximately 110 participating students.

3. Learning about the particles

Some students in KS3 may be familiar with the idea that matter is made out of atoms. However, it is very rare to find students that know the details of the atom consisting of a dense nucleus made of protons and neutrons, and electrons around them. At the beginning of each workshop, students sit in a circle on the floor and each one is presented with a card, randomly drawn from a deck of particle trump cards. These cards, originally developed for the 'particle physics in primary schools' workshop [7], present each particle and its properties in a simplified manner, appropriate for the age of the students, and codify the interaction properties in terms of 'likes' and 'dis-likes' between the particles. At this stage 16 cards are used, representing the matter particles, interaction carriers, and the Higgs boson.

Subsequently, a model of the atom consisting of 'subatomic plushies' [6] is presented and following discussion about the atom consisting of a dense core of protons and neutron with electrons orbiting around, the students are invited to 'open' the proton and the neutron to find that they are made up of up- and down-quarks, along with gluons that keep them together.

Having completed this basic introduction with the atom, a discussion begins between the physicist and the students. The physicist introduces one-by-one the particles of the Standard Model, and the students are asked one-by-one to read out loud the content of their the trump card, as the particles are being presented and the 'plushies' are arranged in familes, as shown in figure 1. For each particle, after the trump card is read, the physicist adds a funny or interesting fact about the particles on top of the description read out from the card, for example how they were discovered, how they got their name, etc. The use of these trump cards was found to be very effective in engaging the students, as each of them has 'their own particle', and provides a natural opportunity for each student to add something to the discussion. Thus, it also acts as an ice-breaker, and allows for active participation in the ensuing discussions.

Having introduced the particles of the Standard Model, a discussion which lasts for about 25 min including questions and answers, the warm-up begins. Each student holds a cloth model of a particle. Students start walking in the dance studio, changing direction freely, engaging in eye contact with their classmates. When two students simultaneously look at each other, they exchange their particles by throwing them to one another, an activity that links to particle interactions in the microcosm. Progressively, walking becomes faster, almost running. Students are asked to move through space constantly being aware of the presence of the others. Eventually this includes jumps, change of levels, and balance exercises. The 'plushie particles' in dance exercises provide concrete support and a movement reference to the student who is warming up while playing. At the same time they provide an excuse for the students to interact with one another. The warm up ends in a circle with some stretching and exercises performed in tandem.

Following the warm up, the first exercise begins. Each particle is associated with a dance move, inspired by its name, its properties, or anything else that may have drawn the interest. Initially, the dancer provides a set of moves associated to the particles, and subsequently each of the students in turn adds a move for the particle in their card. The students are asked to guess the particle, when the dance teacher is showing a move. The students succeed in guessing most of the particle moves, as they have read the particle identity cards in the beginning of the workshop. The teachers use simple, almost theatrical moves to embody the particles, and the students are encouraged to do the same. An example choreography is given in figure 2. When a student is hesitant to propose a movement, the teachers take this unconsciously produced hesitant movement and put it into the choreography. The choreography is repeated with the dance teacher naming the particles at the beginning of every movement. This way the students assimilate the name, together with a body movement.

In this exercise, the primary role of the music is to support the developping choreography. However, the presence of the musician and the interpretation of the evolving choreography through improvised music, adds another layer of dialogue, between the dancers and the musician.

Figure 1. Introducing the particle of the standard model using a 'plushie' for each particle. Photo credit: Dimitra Spathara.

This way, the musician, seeing the evolving choreograph, can add or propose surprise music elements that enrich, and potentially guide, the process. This way the imaginative space created between science, dance, and music is expanded.

4. Learning about anti-matter and particle interactions

In the second part, the students are introduced to the idea of anti-matter. The physicist demistifies anti-matter: there is nothing mystical or apocryphal about it and it is routinely produced in cosmic ray collisions in the atmosphere and high energy particle colliders. The key element of particle annihilation is presented. This is very exciting for the students, they show visible interest in the discussion, and they ask several questions trying to grasp the nature of these anti-matter particles, and the process of annihilation where photons appear where matter and the, respective, anti-matter particles meet. At this point also the notion of pair-production of particle is introduced, and this, naturally, leads to the possibility of scattering between particles.

Subsequently, the students are split in teams, with each team tasked to produce a choreography for a given interaction. Particle scattering is choreographed by a team of three students (two particles and a force carrier), the annihilation and subsequent pair production by a team of five students (particle and anti-particle in the initial state, force carrier, particle and anti-particle in the final state). A team of seven students may produce a choreography of the atom (three quarks,

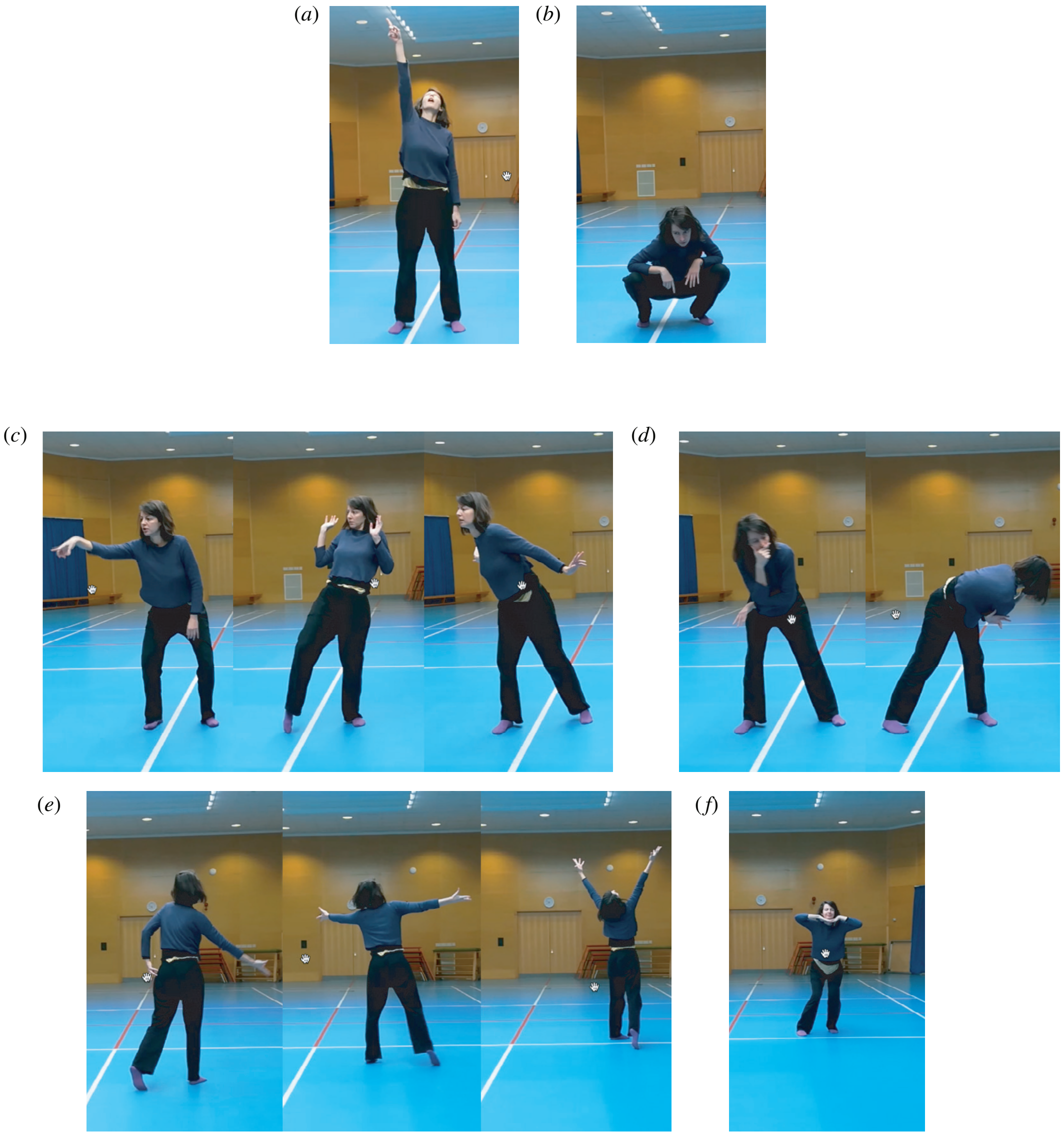

Figure 2. Example choreography for the quarks by Mairi Pardalaki. Extracted from video by Daniela Ámbar Gayoso-Miranda. (a) Up quark. (b) Down quark. (c) Charm quark. (d) Strange quark. (e) Top quark. (f) Beauty quark.

two gluons, one electron, and a photon). Initially, the team should decide which particles they are going to use. A requirement is that at least one of the moves developed in the first part should be retained. It is interesting to observe how the students humanise the inanimate particles by giving them facial expressions, funny interactions, and by using dance techniques they are familiar with, for example ballet, jazz, or modern. First, they imagine the interaction and then translate it and enrich it through dance, see figure 3.

It is crucial that the students not only decide on the particles to use and the choreography, but also the music itself. Each team, once they have an initial plan for the choreography and the music, discusses directly with the musician on the music they would like to use for their performance. This has been proven to be a key point for the students to take full ownership of the final product. In most cases, it was the first time that they have this kind of freedom during a dance class.

(a) (b)

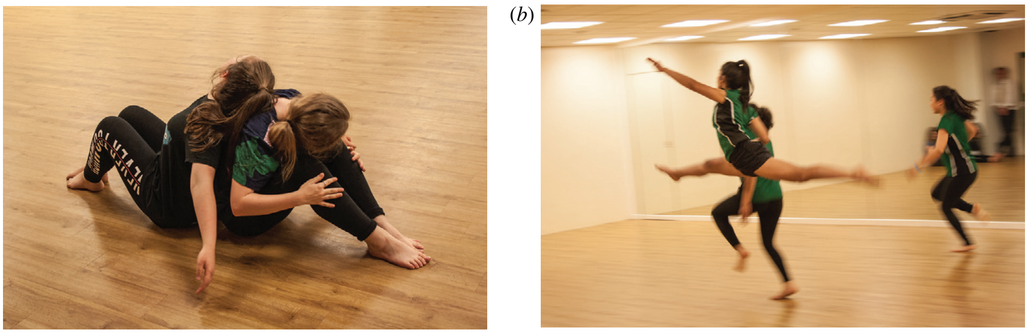

Figure 3. Choreographed interactions by teams of students. Photo credit: Dimitra Spathara.

5. Particle dance and open questions in particle physics

At the end of the session, both parts are presented as a whole, the 'Particle Dance', and the choreography is completed and the students feel particularly excited about performing.

Finally, the students sit again in a circle on the floor and a discussion takes place. This opportunity is used to introduce elements of open questions. The students are confronted with the idea that the Standard Model particles, all those discussed during the workshop, make up only about 4.6% of the matter-energy content of the universe, and that the majority is attributed to Dark Matter and Dark Energy. The reaction of the students to this varies, most of them are excited and interested, some are disappointed. One student actually got upset, almost angry, not being able to accept the relevation!

6. Evaluation

At the end of each workshop a round table takes place were students are invited to provide feedback on the session, and comment on things that they did or did not enjoy about it, and suggestions for improvements. At the same time feedback is requested from the teachers accompanying the students to the workshop. Overall, the received feedback has been particularly encouraging.

Based on the above the workshop seems to hold promise in achieving its aspiration to make particle physics more accessible, help students build confidence in themselves in relation to recent scientific developments, and—eventually—create images that the students will carry in their mind long after the workshop has been completed.

The students were found to be particularly excited about the creative aspects of the event and how they developed their own dance. Prior to the event the students had little idea of what it would involve and they expressed surprise at how physics and dance came together so naturally They found the event different and unusual. The use of 'plushies' was positively noted as it made easier to visualise certain aspects of the particle properties. The collaborative aspects, and working as a group, were positively noted.

Obtaining a final 'end product' combining both parts of the workshop in one choreography, proved a powerful concept appreciated by the students. It was though that interleaving physics with dance parts was beneficial for their understanding.

One of the students mentioned that they appreciated how the dancers would take their suggested movements in the first part, and turn them in actual dance moves. The aspect of having live music, and in particularly chosing the music on their own proved extremely powerful, to the extend that it was thought to be the cornerstone in the process of the students taking ownership of the choreography. Usually, in dance lessons the students are given a song or a piece of music to dance to, and the approached used in this workshop was ground-breaking for them.

Regarding the learning outcomes, students indicated that they learnt what is inside the atom. Most of them thought that the atom is indeed the smallest division of matter, and they were particularly excited to find out how many different particles there are and that they can be created or disappear through their interactions.

'I always thought it was just one atom and there were just electrons going around it. But actually there is so much more to it'. one student commented.

The interdisciplinarity aspect was highlighted. Students, were very keen to respond to the questions at the end of the workshop, a striking difference with their relunctance at the beginning of the workshop. They definitely had increased confidence in relation to both expressing their opinion, likes and disklikes of the workshop, but also on discussing the bits and pieces they have learned during the day. In a scientific context this is used to explain that particle physicists work collaboratively, nowadays in very large teams from different countries, and that collaboration, and the ability to communicate and exchange ideas is crucial for progress.

7. Summary

With the development of the 'Particle Dance' workshop we aspire to bring particle physics in the dance studio, and to stimulate the students' curiosity towards particle physics and science in general. The workshop builds on the CREATIONS creative pedagogical features Integral part of the workshop is the introduction of novel for the students particle physics concepts. The evaluation of the pilot phase is encouraging regarding the effectiveness of the workshop. Future steps involve focused implementation and expansion to different ages to allow for larger classrooms, and the training of science–art teachers.

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Kostas Nikolopoulos is a particle physicist who was strongly involved in the Higgs boson discovery and now tries to complete our understanding of mass generation for matter. He is also interested in inspiring the new generations of scientists and citizens.

Mairi Pardalaki is a dancer and a choreographer based in France. She works for dance-theatre performances, for the opera, in music videos and also collaborates with visual artists. She has created "The Neutrino Passoire" performance and its workshops, imagined together with physicist Kostas Nikolopoulos, in order to inspire the audience on fascinating recent scientific discoveries.