Dance & Robots: Designing a Robotics-enhanced project for dance-based STEAM Education Using ENGINO

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Abstract. The emerging domain of robotics provides a creative tool for engaging young children with the engineering and artistic components of STEAM. Educational activities based on dance can captivate student interest in arts while exploring foundational technological ideas. The paper describes vignettes of dance-based activities utilizing the ENGINO E30 kit. The objective of this work is to explore ways to use a robotic kit to create a science-art integrative STEAM project, named DancENG. The DancENG project has been designed by creatively integrating dance, music, engineering, and math concepts, aiming to cultivate aesthetic sensitivity in parallel with problem-solving and engineering-thinking skills of elementary school students. It has been implemented to 20 5th graders of a Greek elementary school to indicate the practical use of the framework.

Keywords: Education, STEAM, Mathematics, Art, Dance, Educational Robots, ENGINO.

1 Introduction

Several studies show how STEM education, a multidisciplinary integration of Science, Technology, Engineering and Mathematics, enhances the development of convergent abilities in students curriculum [1, 2]. Art in its various forms (painting, music, theater, dance, etc.) can provide different innovative ways to interact with STEM and expand it into STEAM (A for Art), increasing the efficiency of learning and motivation as depicted in recent research [3-5]. However, art-based STEAM program has not been diversely established because Arts has only played a secondary or marginal role and, moreover, there are only a few cases concerning the utilization of emerging technologies as robots in science-art integrative education [6, 7]. The robotics-enhanced project for art-based STEAM education suggested in this study is expected to provide educational tools to enhance creativity and ingenuity through the natural integration of arts and robotics.

Among these art forms, dance, as an embodied cognitive medium [8], constitutes an expressive approach for creating educational activities including STEAM disciplines [9-12]. Dance can be depicted as a social event that expresses artistic and communicative elements through movement, helping in releasing experimental students' inspiration and transferring creative thinking and behavioral outcomes into everyday environments [3]. Thus, dance-based educational activities emerge as appropriate inventive method in the comprehension of concepts from math, physics, engineering, etc. [3, 11]. There is no doubt that art can play an important role when exploring technology and science, but how teachers combine these domains effectively can be a challenging task. Especially during the elementary school years when educators are already dealing with a large load of teaching curriculum [13].

One of the aims of this paper is to explore how robotic kits (like ENGINO) can facilitate STEAM education using dance activities in a natural way that can easily integrate with traditional subjects [13]. Additionally, STEAM education has a place in the proposal of solutions to overcome the well-studied and identified gender concerns, such as absence of female role models, relevancy of curricula, socio-cultural beliefs and expectations [14], aiming to encourage and retain females in the domains of science and technology. The same applies for other often-excluded groups of students, such as immigrants, lower social-economical groups, disabled.

To this end, our work attempts to aid towards establishing a more inclusive formal and informal STEAM education by suggesting **DancENG** (abbreviation of Dancing ENGINO) approach that is meaningful not only for technological-oriented students (mostly boys) but also for students with various levels of technical ability and interest such as girls, immigrants, students with disabilities, etc. DancENG is a proposal for a STEAM environment which includes dance performances where educators, students, and technologies work together to implement artistic tasks to learn STEAM concepts [3] through hands on, collaborative projects with educational robots [15].

2 DancENG Educational Framework

Composing dance choreography is very similar with problem solving, including notions such as ideas, experimentation, patterns, holistically organization of the structure and form [16]. A meaningful assumption of the DancENG approach is that the incorporation of specific supporting technologies enhances knowledge construction and learning procedures within a STEAM curriculum. In this context, DancENG attempts to create the methodological framework for the realization of dance-based activities supported by educational robotic kits that use dance sequences as embodied STEAM notions to cultivate the creation of parallel abstract notions. The body and its movements have a pivotal role in the DancENG project, both as the artistic discipline of dance and as the physical embodiment of the robotic technology.

In this study, ENGINO E30 [1] robotic kit was used as a representative example of educational robotic kits for primary and secondary school students [17]. ENGINO models are built by assembling small blocks or bricks together, with the aim of assisting students to create technological models easily and creatively so that they can ex-

[1] https://www.engino.com/

plore and learn in a playful way [17]. Studies [18] have validated that the ENGINO products create the suitable circumstances for developments of creativity and novelty, indicating that the ENGINO kit is well-suited for exploring a variety of STEAM concepts. Even though there are many remarkable educational robotic kits that can be used in this project, they are mostly divided into two categories. They are either constructional kits to build your own models, but they require computer programming, such as LEGO WeDo, VEX, Popy Ergo Jr, etc. [19, 20], or they provide tangible programming but they are ready-made robots, such as Probot, Bee-Bot, etc. [20, 21]. ENGINO E30 kit combines both since it is a constructional kit offering tangible programming. Another example that we can say that it also combines the two categories is Cubelets [20], but cubes restrict the variety of models and its tangible programming doesn't provide the required flexibility. However, DancENG project can be also implemented with other educational robotic kits after some necessary modifications according to the technology used.

Basic buttons of PRO 2.0 controller

1. "Program" button to start recording.
2. Button for clockwise movement to the motor in port A.
3. Button for anti-clockwise movement.
4. "Program" button to save the program in the memory (after the sequence).
5. "Play" button (If you press it continuously for 3 seconds, the program will be played in an infinite loop).
6. "Pause" button.
7. "Buzzer" button.

Fig. 1. Basic buttons of ENGINO PRO 2.0 controller for manual control and record.

These are some of the important advantages of ENGINO robotic kit that makes it suitable for the proposed project. First of all, ENGINO's technology has the ability with very few components to allow the connection in all directions of the three-dimensional space facilitating the students to build very easily and quickly their own models as well as to modify them within a few minutes. This allows a great degree of possible variations.. This degree of variations enhances students' creativity and engineering design thinking. Additionally, the ―PRO 2.0 controller‖ (See Fig.1) provides tangible and unplugged programming, which is preferable for the age of elementary school students and it is more appropriate for the dance-based approach of this project, since the no-screen programming permits the unhindered movement all over the space[2]. Furthermore, the ―buzzer‖ and ―pause‖ buttons provide a perfect tool for the teaching of notes length, pauses, and measures (Activity 2) and the ―play‖ button allows playing a sequence in an infinite loop which is well-suited for the repetition of dance sequences.

In the implementation of the proposed project participated 20 children aged 10 years old that were students in the fifth-grade class of a public elementary school in Athens, Greece. The children were grouped in teams of 3-4 pupils. A few children had some previous experience in dance (mostly girls) or in robotics (mostly boys), but generally the class had little experience in the STEAM objectives that this project introduces. The pilot project lasted two weeks (June 2020) and its duration was approximately 10 hours, two hours per activity 1-3 and four hours for activity 4 (of course the time duration can vary and it depends on pupils' level and the complexity of dance combinations. Activities can repeat with more complex combinations).

The proposed activities are team-based and the teacher has mostly a supportive role. This means that in the beginning the teacher describes the activity, the concepts included and what pupils should do, and then each team works independently. The teacher moves from group to group and only intervenes when a team needs help. At the end, each group presents to the other groups the results of their work.

The activities took place after the construction of an ENGINO robotic model, which can be different in each activity based on students' preferences. In the implementation the ―Bumber car‖ (See Fig.3) was used utilizing the ―PRO 2.0 controller‖ for direct tangible programming of the robot. Even though in the beginning the students found some difficulties in combining the components together, after a few minutes they started creating their own combinations without any problem and they explored the ways the parts should be connected to create the desirable outcome.

The mathematical concepts and vocabulary practiced in the sample activities had been previously introduced (the concepts used in this project are included in the national curriculum[3] of the 5^{th} grade) and they were reviewed, enhanced, and connected with notions related to dance and engineering. In our pilot implementation, the first author of the paper was the teacher of the class and the person [4] that carried out the project, thus she was familiar with the background knowledge of the students and their needs. During this project they had the chance to revise the acquired knowledge and enhanced it with the new concepts creatively.

In the following section, the illustrative activities for the proposed STEAM framework are presented.

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[2] The ―PRO 2.0 controller‖ offers also other interconnected ways of programming, code, flow diagram, etc. for more advanced programming based on the children's age and experience.

[3] Greek Curriculum – Primary School – Mathematics: http://repository.edulll.gr/1926

[4] The teacher had previous experience with STEAM-related teaching (dance and math), but if it is possible, a multi-disciplinary team of educators is also proposed.

2.1 The Proposed STEAM Activities of the DancENG approach

DancENG proposal aims to link concepts from dance with maths and engineering within a unique educational framework. Some basic elements of dance [16, 22, 23] used as a base in this proposal are:

- **Space**: *where* is movement performed, related to directions, floor pattern, etc.
- **Time**: *when* is movement performed, related to rhythm, duration, phrases, etc.
- **Energy**: *how* is movement performed, related to force and flow.
- **Form**: how is dance *structured*, related to recurring theme, abstract geometrical form, repetition, and other choreographic devices.

In the DancENG activities below, the description and the didactic implication are described, as well as the related topic and the goals [24] of each discipline in Table 2.

Activity 1: Move in the Space
Description/Implication: In this activity, pupils explore the classroom's **space, directions, and floor patterns** [16] by creating lines and shapes through movement, first by themselves (following the context of embodiment [8]) and then by programming the robot to do the same movement. Children mention the different shapes they are familiar with and practice moving in *straight lines, squares, circles, butterfly-shape*, etc. in the classroom (see Fig.2), which is a common practice in dance lessons for understanding of space. Then, they examine which of these shapes ENGINO robot can or cannot do with its controller's programming language by testing and correcting the engineering design process to make the robot move in the different shapes and even in curves and circles, either all over the class space or by drawing them in a paper after adjusting a pencil on ENGINO robot.

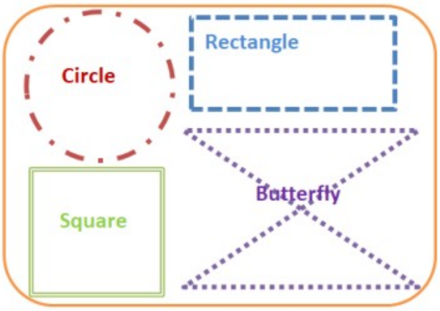


Fig. 2. Shapes from ―Move in the space‖ activity.

During the pilots, students managed to demonstrate all the proposed shapes after several trial and error attempts and they had fun by competing each other team on who will be the first to succeed. One of the important things that they had to explore is which buttons and for how long should they press in order for the robot to turn (e.g. it requires a 90 degrees turn for the square and a 45 degrees turn for the butterfly) The robots can provide instant feedback—they either do the correct shape, or they do not. Making mistakes and troubleshooting are fundamental steps for developing problem-solving skills thus they provide a unique learning opportunity. The dance practice also provided an important help to understand how the robot should move analogously with their own body movement (in terms of embodied programming).

Note that in all activities, once the sequence of the program has been inserted manually by pressing the onboard offline keyboard on the PRO 2.0 controller, it is saved on the robot instantly. No connection with a computer or tablet is necessary for programming with ENGINO (however, ENGINO provides the ability to also program the robot with a computer/ tablet/ smart phone, using a simulator or a flow diagram or code, enabling this project to be suitable for older students as well).

Activity 2: Feel the Rhythm

Music is an essential part of dance lessons, which require understanding of concepts such as **beats, bars (or measures), notes length, and rhythm** [22]. Music is divided into beats and bars. Beats are similar to single dance steps, while taking a few beats together creates a bar, just like a few steps give you a pattern. Bars combine to give phrases, such as a few dance patterns build a small choreography.

Rhythm work in dance most of the times use a **4/4 time signature** and the steps are usually counted up to 8, i.e. *two bars counting by 1,2,3,4 - 5,6,7,8*. Music is read in a similar way as math symbols. The lengths of notes are indicated by mathematical **fractions**. Each note has a different shape to indicate its beat time. There are whole notes, half notes, quarter notes, and eighth notes. Teaching notes length is the same as teaching math fractions, thus they can be combined (see Table 1).

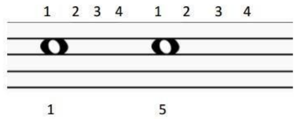
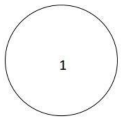
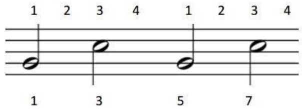
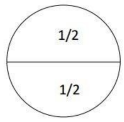
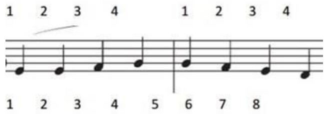
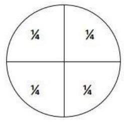
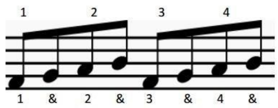
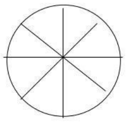
After teaching the notes length, the teacher gives to the pupils a set of rhythm, (*e.g., a whole note, two crochets and a minim*) and they can do the following variations:

1. Clap the set of rhythm to a 4/4 marching piece of music.
2. Step the set of rhythm to a 4/4 marching piece of music.
3. Program the robot to play the rhythm using the ―buzzer‖ button (or also the ―pause‖ button if there is pauses in the set of rhythm).
4. Program the robot to dance the rhythm using the ―movement‖ buttons.
5. A group of pupils program the robot to their own set of rhythm and the other groups of pupils try to understand the set of rhythm and clap it.

The teacher can try using different sorts of 4/4 music, different speeds, and different styles (such as jazz, classical piano, orchestral, etc.) and the children should try not only to play the rhythm by themselves, but also program the robot so that it follows the rhythm correctly. Pupils can also propose their own song choices.

In the implementation, there were some difficulties in following the correct counting of the music (especially in songs with quick tempo), which required spending some time in the beginning of the activity only to count the music into 2 bars. Students really enjoyed this inter-disciplinary activity, which combined elements of dance, music, math and technology, and give them an insight of how different disciplines can be closely related. The variation 5 is proposed to be done after working for 2-3 times the other variations.

Table 1. Combination of fractions, note lengths and dance in the activity ―Feel the rhythm‖.

Activity 2: "Feel the rhythm"		
	Dance counting	**Math Fractions**
Semibreve A Semibreve is *whole note* (= four counts).		
Minim A minim is a *half note* (= two counts).		
Crochet A crochet is a *quarter note* (= one count).		
Quaver A quaver is an eight note (= half note).		

Activity 3: Synchronize Rhythm with Dance.
In this activity, the children synchronize a small dance sequence on the set of rhythm that they learned in Activity 2 and then they ―teach‖ the same sequence to the robot. Based on children's dance level the dance sequence can be created with the following variations. In all levels, **first the pupils learn the sequence to dance it by themselves and then they teach the same sequence to their robots**, aiming in both cases to synchronize the dance sequence with the rhythm of music.

- *Level 1*: The teacher provides to the pupils a pre-arranged dance sequence.
- *Level 2*: The pupils develop the dance by putting a floor pattern (from Activity 1) on simple steps of the rhythm. Pupils must count the note values as they do each step. The teacher makes sure they can repeat it. Then they add arm movements on the dance steps or even add other steps (such as turns or leaps). This level introduces the student to a more creative approach. The movement of the robot should be kept simple (it cannot jumb or use hands!).
- *Level 3*: The children make their own combination. They think of 3-4 dance steps (including arms, directions, counting, etc.), write them down together with their note lengths, and dance them out.

Dancing the sequence helps the children to separate a complex task into smaller, executable steps, which is similar with the sequential nature of programming [25]. Programming involves specifying each movement independently in the right order. When the children have captured the dance sequence, they try to ―teach‖ the dance sequence to the robot (mostly regarding to floor patterns, note lengths, and simple movements). For example, in the set rhythm used as example in Activity 2, they can program the robot to do the following sequence. ―Move forward for four counts, turn left for two counts, move backward one count, and turn right for one count.‖ Teaching the robots to dance, teaches children how to control and move their robot (Fig.3).

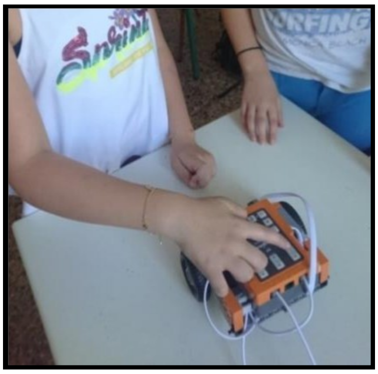


Fig. 3. Pupils ―teaching‖ a dance sequence to the ―Bumber car‖ from the pilot implementation.

Dance sequences usually repeat, so making the robot to repeat a sequence of executable steps is the next stage. With a loop, the robot can repeat the sequence. The ENGINO robot, by simply pressing the ―start‖ button for 3 seconds, repeats the last sequence in an infinite loop. By doing so, it helps children explore foundational programming concepts such as sequence and loops, and engages them in robust programming and mathematical learning.

A series or sequence that repeats creates also a math pattern. Besides geometry and time, everything in dance has to do with patterns. Students memorize patterns as they act out dance sequences executed in the space. Additionally, the set of rhythm contains patterns in the form of beats, which is usually synchronized with the dancers' movement. Indicating this connection in class, can make the students see and understand mathematics as a part of everyday life [10].

In the implementation, the class made a few examples all together (practicing both students' movements and robot's movement) and they proposed what moves can be added to each note length. A main difficulty in this exercise is the ―turn‖ movement, since it takes specific time for the robot to turn. In this case we either use a slow tempo and we count how much time it takes for the robot to make a full turn or we agree with the students that the robot will turn as much as the note length permits (e.g. half circle). Additionally, in level 2, if we want the robot to follow the floor pattern we should keep two empty bars between the repetitions of the set rhythms in order to change direction. Generally, keep the dance sequences very simple in the beginning (it can be just steps) and level up only if the pupils have mastered the previous level.

The quick and tangible way that ENGINO can be programmed to repeat loops was very helpful to show the difference between a single sequence and a repeating one. In the pilot project, children spontaneously played a game where they were trying to guess in which direction the robot will move during the loop and see if it was going to find obstacles in the class (like tables and chairs). Generally, during this project, pupils can and should be encouraged to find their own creative alteration of these activities.

Activity 4: Make Your Choreography.
In the last activity, pupils became choreographers and directors as part of their STEAM exploration [13]. Children chose songs from the class's music collection and programmed their robots to complete dance sequences synchronized with the songs' tempo. After their robot was arranged in the way they desired, pupils choreographed their own movements to dance out along with the robot. Some of the elements that they should take into consideration are the synchronization of dancers, the directions in space, and the rhythm of music. The outcome of this work can then be shared with other students of the school or demonstrated to parents, since the main concept of dance is to communicate thoughts, feelings, and ideas. In our pilot, the teams demonstrated their choreographies between them as well as to the other fifth-grade of the school.

Fig. 4. Dance choreography with human and robot dancers from the pilot project.

During this activity, children explored features of stage production, as they experienced being live performers, directors of the dance show, and even the engineers who checked that the technology (i.e., the robot and program) are all set for the performance (Fig.4) [13]. The idea of integrating dance and stage performance into robotics education provided the potential to accelerate the development of problem solving, communication and critical thinking skills in pupils through the procedures of *inspiration, planning, creation* and *performing* of a dance play in parallel with the *programming* of robots as dancers.

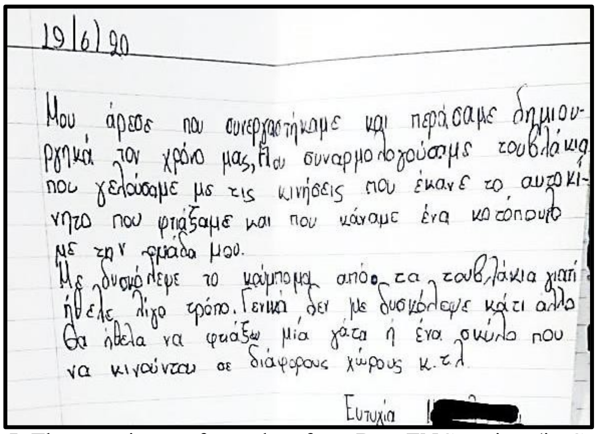
Table 2. Topic (T) and goals (G) of the activities in connection with STEAM fields.

Activities		STEAM fields: Dance	STEAM fields: Mathematics	STEAM fields: Engineering
1. Move in the space	T	Space	Geometry - Shapes	Basic engineering
	G	-Experiment and identify how the different movements define the use of space in dance.	-Recognize standard concepts as shapes. -Imaginary drawing and real drawing of geometrical shapes.	-Learn the basic programming actions and the procedure of commands and program the robot.
2. Feel the rhythm	T	Rhythm	Fractions	Basic programming - Sequencing
	G	-Learn about rhythm, beats, bars and tempo and note lengths and how they are used in dance. - Exercise different set of rhythms.	- Understand a fraction 1/b as the quantity formed by 1 part when a whole is partitioned into b equal parts.	- Make a —buzzer‖ and —pause‖ sequence. - Combine the note length and pauses (time) with the robotic movements' commands.
3. Synchronize	T	Synchronization	Time	Sequencing - Repeat Loop
	G	- Synchronize the dance movements with the set of rhythm and develop musicality.	- Understand that time is used to quantify, or measure the duration of (dance) events or the intervals (pauses) between them and even, sequence of events.	- Make the robot to repeat a sequence of executable steps. - Combine key computational concepts as identifying phases and orders within a set of rhythm.
4.Choreography	T	Choreography	Patterns	Combined program
	G	- Divide a task into a series of interconnected sub-tasks. - Create a performance, including music, dancers and robots.	- Learn progression patterns, by making alterations of the same sequence.	- Develop the ability to program group lines of code into a unit and combine different parts in a whole.

After the activities, the pupils were asked on their impressions from the project (the intentions of this assessment weren't on the learning goals rather on their experience). The general impression was that the pupils had the chance to cooperate, to solve together the problems that they encountered, to be creative and to have fun at the same time. To quote the words of a student (Fig.5):

—*I liked that we collaborated and spent our time creatively, that we assembled bricks, that we laughed at the moves made by the car we made (i.e. the robotic "Bumber car"), and that we made a chicken with my team. It was difficult for me to assemble the bricks because they need a specific way. General, I did not find anything else difficult. I would like to make a cat or a dog that dances in different directions."*

While in the current state, this implementation included a small number of pupils, future work is required that will involve more students and more explorations to test and validate the impact of the DancENG framework.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Μου άρεσε που συνεργαστήκαμε και περάσαμε δημιου-
ργηκά τον χρόνο μας, που συναρμολογούσαμε τουβλάκια
που γελούσαμε με τις κινήσεις που έκανε το αυτοκί-
νητο που φτιάξαμε και που κάναμε ένα κατόπουτο
με την ομάδα μου.
Με δυσκόλευε το κούμπωμα από τα τουβλάκια γιατί
ήθελε λίγο τρόπο. Γενικά δεν με δυσκόλευε κάτι άλλο
Θα ήθελα να φτιάξω μία γάτα ή ένα σκύλο που
να κινούνται σε διάφορους χώρους κ.τ.λ

Ευτυχία [redacted]

Fig. 5. The experience of a student from DancENG project (in Greek).

3 Conclusions

In this paper, an original proposal for a STEAM educational framework that combines dance and robots, called DancENG, has been presented. The aim was to show that the introduction of dance (and art in general) in teaching procedures of STEAM can enhance embodied learning, increasing at the same time students' creativity, motivation, and engagement. We have also proposed that the use of robotic kits (such as ENGINO E30 kit) as a technological medium for the engineering part in the accomplishment of the activities, offers unique possibilities for artistic, mathematical, and engineering learning. Assembling and programming a robot encourages children to use their creativity and engineering-thinking skills in a playful, engaging learning environment. While this project was tested with a small group of pupils, future work is needed that will involve the further implementation and experimentation with more students and classes to check and validate the impact of the suggested STEAM framework. In the INBOTS project[5], we work towards a highly accessible and sustainable framework in robotics education [26] to promote the broader use of robotics as a tool to teach and learn STEAM subjects and the DancENG approach comes to contribute to this end.

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[5] http://inbots.eu/

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