Move Your Mind: Creative Dancing Humanoids as Support to STEAM Activities

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Abstract. Educational activities based on dance can support interest in comprehension of concepts from maths, geometry, physics, bio-mechanics and computational thinking. In this work, we discuss a possible use of a dancing humanoid robot as an innovative technology to support and enhance STEAM learning activities.

Keywords: Cognitive architecture · Embodied Cognition · Enactivism · STEAM · Humanoid robots · Computational creativity

1 Introduction

Several studies show how STEM education, a teaching paradigm based on a multidisciplinary interaction between Science, Technology, Engineering and Mathematics allows the improving convergent skills in students curricula [1,3]. At the same time, there is a growing interest in investigating the role of Arts as a glue between these disciplines to improve also divergent skills. This leads to the growth of a new interdisciplinary paradigm called STEAM that, in recent research [4–6], seems to be an approach to increase the efficiency of learning and motivation for STEM concepts. According to these study, the inclusion of liberal arts and humanities in STEM curricula can be described as not a simple addition of an A in a STEM area but as an integration of Arts in STEM education with the

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aim of creating an expanded transdisciplinary perspective [4,7]. Such a perspective rejects the idea that Art is creative but not logical and scientific disciplines are logical but not creative. Art in its several variations (painting, sculpture, theater, dance, etc.) can represent different ways to interact with STEM for creating and expanding the mentioned transdisciplinary area. Among these variations, dance, if it is analyzed within an embodied cognitive paradigm [8], represents an excellent perspective for analyzing teaching/learning processes and activities involving STEM disciplines [9–12]. Namely, according to the Embodied Cognition approaches and in particular to Enactivism [13] and sensorimotor theory [14], that define intentional movements as a primary modality of thought [15], the sensorimotor interactions of the body with the physical world can be read as key elements of the process of cognition, learning and knowledge construction. Taking into account this point of view, dance can be described as a social practice which, relating to movements - primary modalities of thought - and integrating physical and motor aspects with aesthetic, active, communicative and social elements, allows investigations on the different skills. Moreover, it helps to unleash experimental performers' creativity, allowing it to spread and also facilitate the transfer of behavioral outcomes into everyday contexts and experiences. Learning activities (LAs) based on dance, therefore, emerge as suitable in the understanding of concepts from maths, geometry, physics, biomechanics and computational thinking (e.g. symmetry, reflection, acceleration, motion, equilibrium, self-similarity, progression patterns, compositional patterns, iteration) [9,16,17], suggesting an original dance-based STEAM approach.

In this work, we describe MoveYourMind (MYMi), a proposal for a STEAM Smart Learning Environment within which learning activities are conceived as educational practices where dance performances involve teachers, students, and technologies working together to implement creative ways to learn and teach STEAM notions at different levels.

2 Proposed Approach

Although within the STEM research field, several educational experiences of teaching and learning scientific concepts through dance can be reported, each experience can be described as an individual attempt to account for some concepts of a specific scientific discipline. There is a common intrinsic shortcoming that emerges within the context of this kind of studies: they appear as unrelated educational experiences of teaching and learning that exploit dance as a mere educational instrument.

MYMi proposal takes into account these several unconnected educational experiences of teaching and learning scientific concepts through dance and aims to create a learning framework able to connect these experiences within a unique educational framework. In this context, MYMi, using new technological integrations [18], proposes the realization of new tech-based and dance-based activities that exploit dance compositions as embodied STEAM concepts and foster the creation of abstract concepts from concrete activities [11]. Specifically, the created learning framework aims to be the theoretical/methodological/educational background for connecting in a whole coherent perspective educational the dance-based experiences that have explored:

- standard concepts as circles, squares, triangles, rectangles, lines and line segments, angles, exemplifying points [19];
- the classification of polygons according to the number of sides [19];
- geometrical concepts as shapes, patterns, angles, symmetry, reflection, rotation, rescaling [10];
- platonic solids, duality, self-similarity, regularity [20];
- the relationships between Math and Dance for teaching and learning fractions [21];
- the relationships between Math and Dance for teaching and learning progression patterns and matrices [22];
- the possible relationship between Physics and Dance to teach and learn concepts as equilibrium, motion, rotation, acceleration, mass of a body [12];
- modalities for creatively improving logical and computational thinking through computer programming [23–25].
- modalities for teaching and learning key computational concepts as identifying phases and orders within different tasks (sequencing), reiterate procedures to reach different goals (iteration), combine different parts in a whole (modularization), divide an activity into a concatenation of sub-activities or recognize parts (decomposition), fixing mistakes (debugging) [26].

An important assumption of the MYMi approach is that the integration of specific enabling technologies supports knowledge construction and educational processes within a dance-based STEAM (science, technology, engineering, arts, and mathematics) curriculum. Such an integration brings out the MYMi Smart Learning Environment (SLE) as the physical realization of the MYMi Learning Framework. This SLE, equipped with some key technological features [27], aims to involve students in learning paths within which the different possible connections between dance and technology are the essential cornerstones. As regards to these connections, the MYMi approach takes into account some crucial points such as the behavioral investigation about body perception and action recognition carried out through the use of motion-capture technology [28,29], the 3D human body motion tracking based on inertial sensing to record the trajectories of movements during learning activities and reconstruct the kinematics of a dancing body and its parts [30,31], the reconstructions with different modalities of representations and tools - e.g. a Serious Game context [32] - fitting for the MYMi specific educational goals, the corporeal interaction with the Smart Learning Environment during learning activity by means of the constant learners relation with a humanoid dancing robot with an active role. In the next section the key role of the humanoid robot will be examined in depth.

2.1 Dancing Humanoid Robots as Catalysts of Knowledge Construction

Within the MYMi perspective, the interaction with humanoid robots can enhance STEAM learning activities. A humanoid robot can act as a smart and amusing learning assistant and can help the students in performing some specific and ad-hoc developed learning activities. The knowledge management and reasoning mechanisms modeled in the robot can guide students in their learning experiences by acting as a captivating cultural mediator and fostering their creativity.

The body and its movements have a key role in the proposed STEAM setting, either in the choice of "dance" as the artistic discipline and also in the physical embodiment of the chosen technology. The robot is able to exploit its physicalness to perform dancing choreographies designed for the learning activities. It is able of reproducing real dancer movements and it is also able to creatively compose elementary movements by following the typical design steps of a choreographer. The behavior of the robot and the performed choreographies depends on the specific LA and the ongoing interaction with the students. The different typologies of LAs require behaviors of various complexity for the robot, from the reproduction of basilar movements to the performing of more complex choreographies and also the automatic generation of novel movements and choreographies. This last ability, obtained using a computational creativity approach, is exploited for introducing some variations in the LAs, with the result of stimulating the students and helping them in identifying possible mistakes. Besides, students can also deepen the cognitive model of the robot and exploit the coding interface of the robot to train the robot to perform specific activities or simulate some human behavior. The design and implementation of the robot behavior, therefore, represents itself a powerful component of LAs. In fact, some LAs can be based on the study and the use of the cognitive architecture on which the robot is based on, with the aim to train the robot to perform specific activities or simulate some human behavior.

According to this perspective, the robot is exploited not as a passive technological tool, but it has an active role in the STEAM learning setting.

3 MYMi STEAM Activities

In this section, we discuss possible activities for the proposed STEAM framework. The activities are aimed to review and practice mathematical concepts previously introduced in a third-grade class in a primary school. The concepts and their related vocabulary have been already introduced to the students. The learning purpose is the improvement of what learned in class and the student's abilities of observation and analysis of forms (passive observation of the concepts), expressing verbally and with the body what is observed and also the answers to the teacher questions (active expression of the concepts). Tree samples of ad hoc designed dance-based STEAM learning activities are proposed below. For each LA, at least the following key information is reported:

- The topic of the activity;
- The learning outcome of the activity (goal);
- The role and the number of participants;
- The description/implementation of the LA;

– The cognitive implication of the LA
– The didactic implication of the LA

All this information will be text based and will be used as a starting point to formal describe the learning activities. All the activities in the proposed framework require the exploitation of cross-sectional competencies from dancers, teachers in different fields (e,g math, geometry, physics and PE) and researchers during the design, implementation and assessment phases.

3.1 Sample Activity 1: PERMUDANCE

– Topic: Permutations (Math)
– Goal: arranging all the members of a set into some sequences or orders
– Participants: Teacher, a small group of students (2–3) and the robot.
– Description of the learning activity: The teacher proposes to students to play a role in the PERMUDANCE game. Both student and robot are placed in a row (side by side). Each position is marked by a number in ascending order. Students are the coaches of the robot and have to teach it a sequence of rhythmic movements to allow each member of a group to occupy, shifting rotation, the position number 1. Within this context, students collaborate to create and plan the sequence of movements and steps that robot has to learn. Then they execute the performance repeatedly to test the sequence of movement they created. At the end of the activity an avatar of the robot in a mobile platform suggests some exercises recalling the real situation (e.g. students have to find possible combinations/permutations rejecting repetitions).
– Cognitive implications: PERMUDANCE as learning activity involves memorization processes. Referring to the codification of sequences of movements in to be remembered movement tasks it involves both working memory (sequencing online) and long-term memory (sequences stored through corporeal patterns).
– Didactic implications: PERMUDANCE as learning activity allows students to acquire the ability to arrange all the members of a set into some sequence or order. Moreover, it can be adapted to different target groups modifying the number of participants and the complexity of spatial relationships.

3.2 Sample Activity 2: ORIGIN OF SYMMETRY

– Topic: Symmetry
– Goal: Ability to symmetrically/asymmetrically reproduce movements and actions and transfer (generalize) symmetrical and asymmetrical relationships to different contexts.
– Participants: Teacher, students of a classroom, robot/avatar
– Implementation: Imitation, Role-Changing, Creative configurations (3 Steps).
– Description of the learning activity:
  • Step 1 Imitation: The teacher involves students in a learning game in which the robot plays the role of tutor/coach. Introducing the robot as a dancing coach, the teacher asks students to place themselves in front

of the coach. After checking the accuracy of students disposition teacher reveals the goal of the game: each one is the mirrored image of the robot and has to exactly duplicate its actions to create several mirrors of the dancer coach.
  - Step 2 Role-Changing: The teacher organizes different groups of students that have to create and design n-movements. They will teach robot these movements within an imitation game similar to Step 1 activity.
  - Step 3 Creative Configurations: The robot, sequencing the learned movements by similarity, will propose to students a new dance. In this step, students will have to recognize the different movements created by each group and evaluate the accuracy of the performance.

  At the end of each step, within a virtual learning environment an avatar of the coach, monitored by teacher, suggests some exercises and activities recalling the real situations (e.g. students have to distinguish symmetrical and asymmetrical movements, symmetrical in opposite/same direction and in/out of phase).
- Cognitive implications: ORIGIN OF SYMMETRY as learning activity involves motor skills related to posture and visual-motor imagery (spatial and kinaesthetic). Referring to the imitation step, synchronizing with movements of other people stimulates attentional processes. Moreover, this activity affects long-term memory that stores information as non-verbal grammar or movement vocabulary that can be employed in contexts other than dance practices.
- Didactic implications: ORIGIN OF SYMMETRY as learning activity allows students to acquire the ability to recognize symmetrical and asymmetrical relationships starting from a real situation. Moreover, it can be adapted to different level of complexity: e.g. within the exercises suggested by the avatar, modifying the number of different objects in symmetrical/asymmetrical relation or extending/generalizing the concept of symmetry to other connected element of other branch of knowledge (e.g. the logical concept of same as).

3.3 Sample Activity 3: BODY-SCRATCHING

- Topic: Scratch (programming).
- Goal: Learn to program in a virtual or a mixed reality to convert a simple sequence of movements into a creative embodied goal-directed action.
- Participants: Teacher, students, avatar/robot.
- Implementation phases: Body-scratching learning activity can be implemented through several levels of complexity and across different levels of generalization starting from two possible points: (1) from abstract STEAM concepts to real situations and (2) from real situations to abstract STEAM concepts.
- Description of the learning activity:
  - Starting point 1 From abstract STEAM concepts to real situations - Students learn to program by scratch in a virtual learning environment where the avatars actions need to be created and programmed. Within this event-driven programming context, using a mobile platform or a PC, students have to select from a database movements and dance steps fitting

with a specific proposed rhythm. After movements and dance steps selection, with teachers support, students learn to create a regular sequence of movements having a starting and an ending point (choreography). Each choreography will be embodied in a real learning context by the humanoid robot. During this phase, the teacher can highlight how the scratch activities are translated into concrete movements and how programming a choreography allows implementing actions with a specific goal.

- Starting point 2 From real situations to abstract STEAM concepts - Students equipped with specific technological tools (e.g. inertial sensors) learn to program an agent (the avatar) in real-time by means of their body. They implement an innovative body-scratching with the aim of creating a combination of rhythmic movements within a dance context. During this activity, the teacher will manage the avatar ability to recreate, within a virtual environment, students movements combination highlighting regular repetitions and possible errors emerging from the designing process. Moreover, teacher stresses the importance of movements iteration and rhythmic consistency in a choreography creation activity and emphasizes how real movements can be translated into a combination of scratch processes.

At the end of the body-scratching activity, the different choreographies can be implemented in a real situation by the robot.

– Cognitive implications: BODY-SCRATCHING as learning activity can be described as an embodied and enactive participatory sense-making activity and involves cognitive skills connected to creativity. It specifically involves long-term memory that is stimulated thanks to the learning of sequences coded in corporeal patterns. Moreover, it stimulates logical skills as inference and generalization and allows to evaluate heuristics processes within a computational learning activity.
– Didactic implications: BODY SCRATCHING as learning activity allows students to acquire knowledge connected to STEM disciplines and skills belonging to logical reasoning, especially the ability to generalize programming concepts starting from real situations (inductive and abductive reasoning) - POINT 2 - and the ability to reason involving inference (deduction) POINT 1.

4 Abilities of the Humanoid Dancer

A cognitive architecture [2] underlies the autonomous cognitive and creative processes of the artificial agent and supports the STEAM activities. The main modules of the architecture allow the robot to perceive the stimuli of the external environment, to understand its internal state, to learn through experience, to execute and coordinate its movements and to create new dancing choreographies.

The robot learns the basilar movements, postures and gestures designed in the learning activities. The robot behaviors are organized in modules, each one having a proper learning goal. The modules can be re-used during the definition of other LAs, with consequent advantages regarding the extensibility of the system.

The robot can also learn associations between music patterns and suitable motion sequences through an internal mechanism of evaluation, as in a dance school. The dancing repertoire is stored into the long-term memory (LTM) and used as input by the planning and execution module.

During the planning and execution phase, the humanoid dancer estimates the best sequence of movements to produce, choosing time to time the best movement according to the previously executed movement and the perceived sound.

Moreover, the robot is able to create new dancing steps in real time, by means of an artificial creative process, relying on the combination of an interactive genetic algorithm and a Hidden Markov Model (HMM).

The main parameters of the HMM are the states, the possible observations and two stochastic processes governing the system through a Transition Matrix (TM) and an Emission Matrix (EM). Briefly, in our model [2] the states correspond to the possible movements that the robot can perform whereas the observations are the perceived music.

The Transition Matrix of the HMM represents the correlation between the different movement; it has a key role in the composition of the movements, and it is built to select those that suit better each other. The Emission Matrix is used to link the movements to the rhythm perceived by the system; it is set up to select some movements rather than others in the presence of specific musical patterns. The HMM is employed by the robot to estimate the best motion sequence associated with the perceived music. The robot also employs an interactive genetic algorithm to learn different dancing styles under the guide of a human teacher producing original and harmonized movements in relations with the perceived music.

5 Conclusion and Future Works

In this work, an innovative proposal for a STEAM Smart Learning Environment, called MYMi, has been discussed. The assumption is that the introduction of art in teaching processes of STEM disciplines can increase the efficiency of learning, improving at the same time students' motivation and engagement.

The aim is to exploit body movements and dance in the definition of the learning activities since it is possible to obtain several connections with STEM concepts. We also propose the use of a humanoid robot as an amusing assistant in the accomplishment of the activities. Future works will regard the effective implementation and experimentation of the proposed SME.

References

1. Kanematsu, H., Barry, D.M.: STEM and ICT Education in Intelligent Environments, vol. 91, pp. 3–198. Springer (2016)
2. Augello, A., Infantino, I., Manfrè, A., Pilato, G., Vella, F., Chella, A.: Creation and cognition for humanoid live dancing. Robot. Auton. Syst. **86**, 128–137 (2016). Elsevier

3. Cotabish, A., Dailey, D., Robinson, A., Hughes, G.: The effects of a STEM intervention on elementary students' science knowledge and skills. Sch. Sci. Math. **113**(5), 215–226 (2013)
4. Land, M.H.: Full STEAM ahead: the benefits of integrating the arts into STEM. Procedia Comput. Sci. **20**, 547–552 (2013)
5. Madden, M.E., Baxter, M., Beauchamp, H., Bouchard, K., Habermas, D., Huff, M., Plague, G.: Rethinking STEM education: an interdisciplinary STEAM curriculum. Procedia Comput. Sci. **20**, 541–546 (2013)
6. DeSimone, C.: The necessity of including the arts in STEM. In: Integrated STEM Education Conference (ISEC 2014), pp. 1–5. IEEE, March 2014
7. Spector, J.M.: Education, training, competencies, curricula and technology. In: Ge, X., Ifenthaler, D., Spector, J.M. (eds.) Emerging Technologies for STEAM Education, pp. 3–14. Springer International Publishing (2015)
8. Shapiro, L.: Embodied Cognition. Routledge, London (2010)
9. Schaffer, K., Stern, E., Kim, S.: Math Dance. MoveSpeakSpin, Santa Cruz (2001)
10. Wasilewska, K.: Mathematics in the world of dance. In: Proceedings of Bridges 2012: Mathematics, Music, Art, Architecture, Culture, pp. 453–456 (2012)
11. Schaffer, K.: Math and dance windmills and tilings and things. In: Bridges Proceedings, pp. 619–622 (2012)
12. Capocchiani, V., Lorenzi, M., Michelini, M., Rossi, A.M., Stefanel, A.: Physics in dance and dance to represent physical processes. J. Appl. Math. **4**(4), 71–84 (2011)
13. Di Paolo, E.A., Thompson, E.: The enactive approach. In: The Routledge Handbook of Embodied Cognition, pp. 68–78 (2014)
14. Bishop, J.M., Martin, A.O. (eds.): Contemporary Sensorimotor Theory. Springer, Heidelberg (2014)
15. Smith, L.B., Thelen, E.: Development as a dynamic system. Trends Cogn. Sci. **7**(8), 343–348 (2003)
16. Leonard, A.E., Daily, S.B.: Computational and Embodied Arts Research in Middle School Education. Voke (2013)
17. Wilson, M., Kwon, Y.H.: The role of biomechanics in understanding dance movement: a review. J. Dance Med. Sci. **12**(3), 109–116 (2008)
18. Parrish, M.: Technology in dance education. In: International Handbook of Research in Arts Education, pp. 1381–1397. Springer, Netherlands (2007)
19. Moore, C., Linder, S.M.: Using dance to deepen student understanding of geometry. J. Dance Educ. **12**(3), 104–108 (2012)
20. Parsley, J., Soriano, C.T.: Understanding geometry in the dance studio. J. Math. Arts **3**(1), 11–18 (2009)
21. Watson, A.: Engaging senses in learning. Aust. Senior Math. J. **19**(1), 16–23 (2005)
22. Mui, W.L.: Connections between contra dancing and mathematics. J. Math. Arts **4**(1), 13–20 (2010)
23. Hamner, E., Cross, J.: Arts & Bots: techniques for distributing a STEAM robotics program through K-12 classrooms. In: Proceedings of the Third IEEE Integrated STEM Education Conference, Princeton, NJ, USA, March 2013
24. Oh, J., Lee, J., Kim, J.: Focus on 6th graders science in elementary school. In: Multimedia and Ubiquitous Engineering, pp. 493–501. Springer, Netherlands (2013)
25. Yanco, H.A., Kim, H.J., Martin, F.G., Silka, L.: Artbotics: combining art and robotics to broaden participation in computing. In: AAAI Spring Symposium: Semantic Scientific Knowledge Integration, p. 192, March 2007
26. Soh, L.K., Shell, D.F.: Integrating computational creativity exercises into classes (2015)

27. Augello, A., Infantino, I., Manfrè, A., Pilato, G., Vella, F., Gentile, M., Città, G., Crifaci, G., Raso, R., Allegra, M.: A personal intelligent coach for smart embodied learning environments. In: Intelligent Interactive Multimedia Systems and Services 2016, pp. 629–636. Springer International Publishing (2016)
28. Hove, M.J., Keller, P.E.: Spatiotemporal relations and movement trajectories in visuomotor synchronization. Music Percept. Interdisc. J. **28**(1), 15–26 (2010)
29. Neri, P., Luu, J.Y., Levi, D.M.: Meaningful interactions can enhance visual discrimination of human agents. Nat. Neurosci. **9**(9), 1186–1192 (2006)
30. Sevdalis, V., Keller, P.E.: Captured by motion: dance, action understanding, and social cognition. Brain Cogn. **77**(2), 231–236 (2011)
31. Loula, F., Prasad, S., Harber, K., Shiffrar, M.: Recognizing people from their movement. J. Exp. Psychol. Hum. Percept. Perform. **31**(1), 210 (2005)
32. De Gloria, A., Bellotti, F., Berta, R.: Serious games for education and training. Int. J. Serious Games **1**(1) (2014)