DIGITAL TECHNOLOGIES, MOTION RECOGNITION AND ANALYSIS OF BASIC MOVEMENTS FOR IMPROVING THE TEACHING OF BALLET DANCE

THE DIGITAL DOUBLE OF THE PASSAY PROJECT

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DIGITAL DOUBLE
EDUTAINMENT
DANCE

The paper will describe the PASSAY project, an educational system that helps ballet teachers conveying basic movements to young students thanks to the use of optical tracking devices and the development of a digital double to check and validate movements. The project brings a significant innovation in a discipline that could sometimes look anachronistic in relation to today's social context in which the technology has a fundamental role. Moreover, its use can help in overcoming distances, like the pandemic is imposing, and engaging more people and young students in particular.

INTRODUCTION

The concept of teaching ballet has changed very little during the years, mainly because its effectiveness depends on the dedication and discipline, bearing boredom of repeated and long exercises to fix in mind the basic moves of ballet.

This initial phase is essential for a student to create the basis of the classical ballet techniques but is also the most frustrating and long part, where new technologies can mitigate difficulties.

Since this art is well described and codified by various methods, it is very easy to understand if a movement is correctly executed or not.

Therefore, technologies and algorithms, that uses machine learning and motion recognition, are a good vector to analyze, record and give feedbacks based on these methods.

The possibilities of now-a-days technologies are endless; thus, to be effective, the focus has to be strictly on helping the users. For these reasons, the PASSAY project, developed within the Master Degree in Innovation Design at the University of Ferrara, tried to give a consistent answer, through experimentation, to two main problems:

1. Helping both teacher and young dancers during the lesson, to improve proprioception;

2. Helping a dance student during the phase of memorizing the choreography.

For both, several techniques have been used to create a digital double, a replica of the dancer's body and his/her movements, assembled by the use of image tracking, motion analysis and other numerical outcomes, for achieving the best accuracy and effectiveness.

Thus, the paper will dig deeper into learning processes and teaching methods at first, and then will focus on how new technologies can be applied to that, stressing users and stakeholders' benefit from these advancements.

MATERIALS AND METHODS: ANALYZING LEARNING PROCESSES AND TEACHING METHODS OF BALLET DANCE

Learning or Playing?

The area studied by this research is the classical dance lessons, which is an easily involving subjects because who is interested is also entertained by it. Every time young dancers enter in the dance venue, they feel immersed almost in a different reality. The moment of the class is very similar to the concept of the 'magic circle' depictured by Huizinga (2002): "All play moves and has its being within a play-ground marked off beforehand either materially or ideally, deliberately or as a matter of course.

Just as there is no formal difference between play and ritual, so the 'consecrated spot' cannot be formally distinguished from the playground.

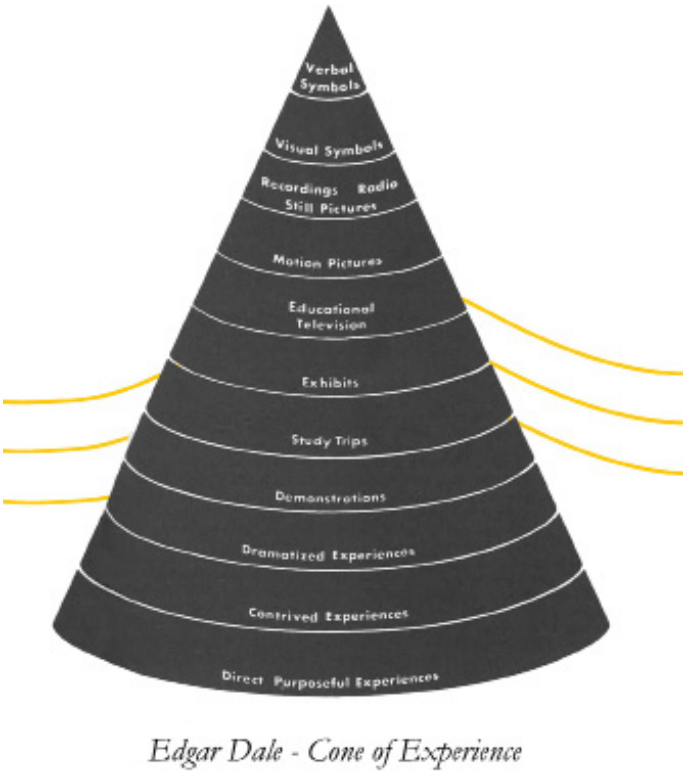


Fig. 1 Edgar D., *The cone of experience*, 1969. The cone shows how people are keener to learn and remember that they do and play instead of what they see or say. Retrieved April, 22, 2020 from https://innovedtech.com/blog/tag/meshing+hypothesis.

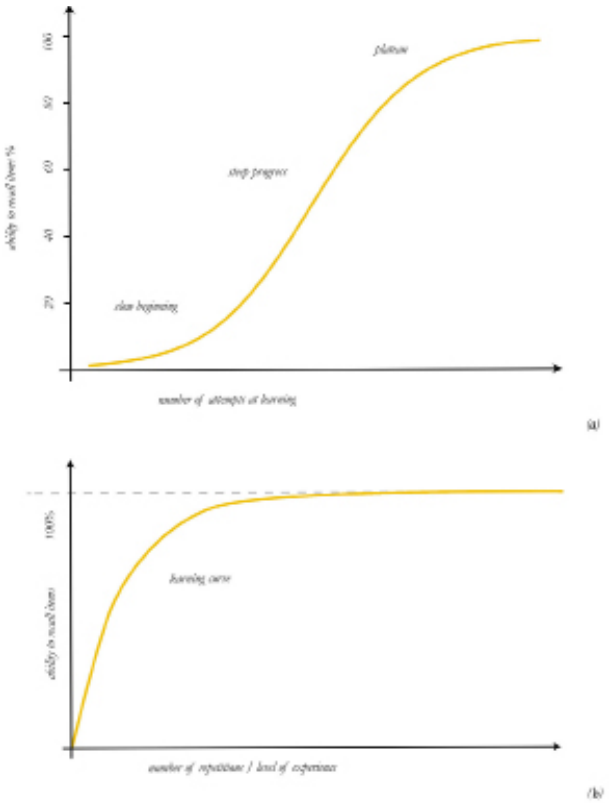


Fig. 2 Zambonini A., a representation of the learning curve (a) that divide the process into three sections (slow beginning, steep progress and plateau) and another one (b) that instead shows how repetition of several recalls of the same element exponentially increases the retention percentage, 2019. Retrieved April, 22, 2020 from https://kaylaslearningcurve.wordpress.com/2011/04/01/what-is-a-learning-curve-anyway/. https://www.valamis.com/hub/learning-curve.

The arena, the card-table, the magic circle, the temple, the stage, the screen, the tennis court, the court of justice, etc., are all in form and function play-grounds, i.e. forbidden spots, isolated, hedged round, hallowed, within which special rules obtain. All are temporary worlds within the ordinary world, dedicated to the performance of an act apart" (p. 10). The lesson of ballet has several elements that can let this be described as a playful moment: it has pre-chosen rules, the participants have different roles that sometimes can be changed, every 'player' mainly has a voluntary approach to the game and most importantly the art of the dance is itself a good representation of the concept of mimicry and ilinx described by Caillois (2001). For the first concept –mimicry– is clear that during plays, the actor or the dancer assumes a very specific role that has to be portraited during every act

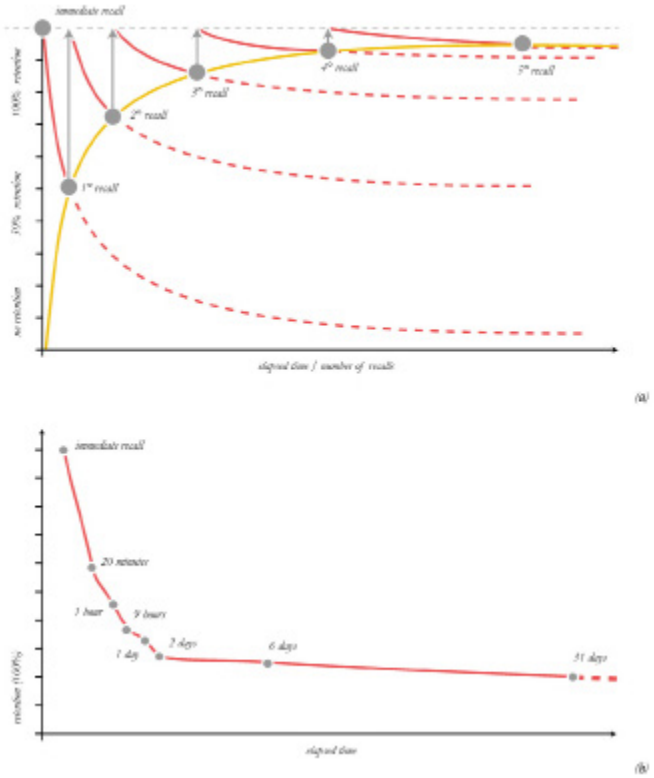
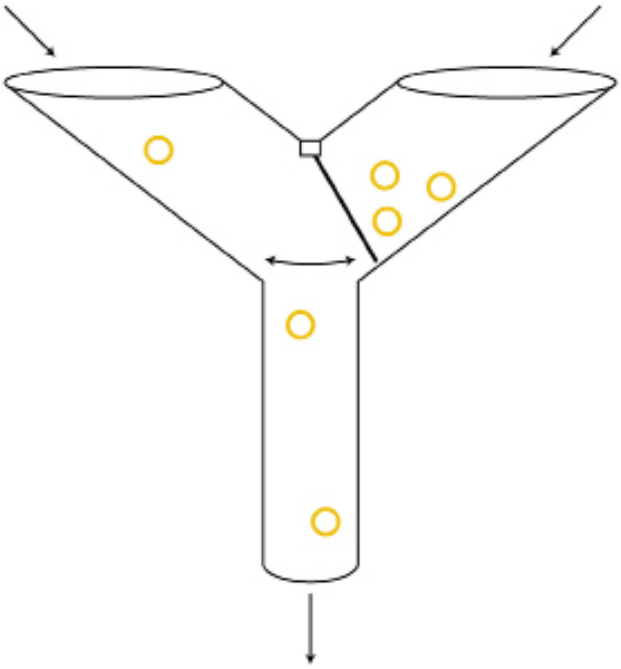


Fig. 3 Zambonini A., the graph (a) shows the correlation between each recall and the retention percentage, while the graph (b) represents the Ebbinghaus forgetting curve, 2019. Retrieved April, 22, 2020 from https://qz.com/1213768/the-forgetting-curve-explains-why-humans-struggle-to-memorize/.

of the play. "Each game presupposes temporary acceptance, if not an illusion of one closed, conventional and, under certain aspects, fictitious universe. The subject denies, alters, temporarily abandons his personality to make another" (Caillois, 2001, p. 24).

The second concept of the game classification, ilinx "it is the search for vertigo; an attempt to destroy for a moment the stability of perception and to make the conscience, lucid, suffer a sort of voluptuous panic" (Caillois, 2001, p. 23). This is mostly present during the parts of the lessons where the students can execute freely the moves that they've learned. Even if it is entertaining, one of the first learning gesture, that is essential to execute correctly a '*plié*', is the motion of the head that prevents this dizzy/funny feeling and to secure the balance during the rotation.



Broadbent's filter model of attention

Graphical elaboration of the Author based on Broadbent's illustrations.

Fig. 4 Zambonini A., the Broadbent's filter model of attention. A graphical elaboration of the author based on Broadbent's illustrations, 2019. Sinico, M. (2012), p. 21, Fig. 1.2.

There are several schools and ways to conduct a dance class, some more rigid, other more tolerant, applying approaches close to the concept of "paidia" or the opposite "ludus" (Viti, 1998). Considering the lesson as a form of role-playing within the magic circle of the venue with a duration of usually an hour, it's important to understand the 'sacrality' of the game for the students and to maintain this playful quality of the lesson (Joyce, 1984).

In our contemporary world, the teaching of dance is more common, especially to children, as a form of entertainment and physical expression of music. This view, however, as shown by Plato's quote in Huizinga's text, already belonged to antiquity: "The young creatures cannot keep the body and the voice at rest, they must make step and noise, jump, jump, dance with joy and emit all sorts of sounds" (Huizinga, 2002,

p. 159). This quote reveals an interesting insight into the ballet student: the activity of the dance is totally volunteered and entertaining for the student. According to the cone of experience (Figure 1), theorized by Edgar Dale (1969) people are keener to learn and remember something that they do and play instead of what they see or say. In fact, the active contribution to a lecture, in this case to a workshop or regular dance class, is the most effective tool that a student has to be able to learn the subject in a faster and correct way.

Experiencing something in the first person and been asked to perform something forces the student to be ready at any time. Furthermore, it has been shown that there is a strong correlation between the 'environment' and the results of the students. In every real-life lesson, the student will encounter colleagues, teachers, dedicated rooms provided with technical tools. All of this could be indicated as 'environment' according to the vision of Huizinga.

Every teaching subject has different needs and different layout/spatial arrangement. Vygotskij (1973) described how much the environment is important for the student: a welcoming space with the correct tools, a stimulating team/competition, and a motivating and competent teacher are essential to overcome faster the zone of proximal development.

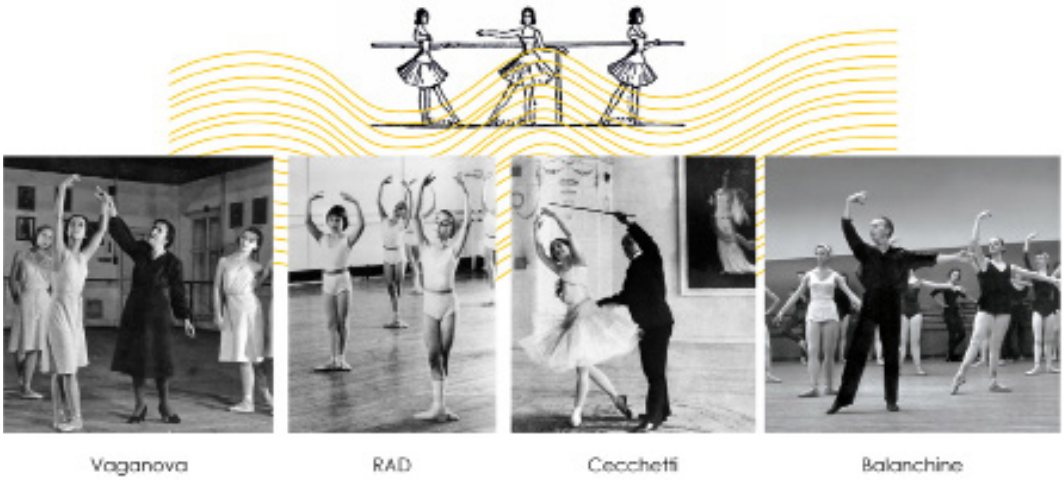


Fig. 5 Zambonini A., Several teaching methods for ballet were analyzed in order to consistently develop a smart system in line with teaching requirements, 2019. Vaganova, A. (2007), p. 57, Fig. 10 - Retrieved April, 22, 2020 from: (Vaganova) www.alisonsstudioofdance.com/single-post/2017/01/21/Spotlight-Agrippina-Vaganova; http://www.diomedia.com/stock-photo-lady-sarah-armstrong-jones-during-a-ballet-class-royal-ballet-school-1974-image4235388.html; (Cecchetti) http://cecchettiusa.dutcher-design.com/about/who-was-enrico-cecchetti/; (Balanchine) http://www.dancespirit.com/these-are-some-of-the-legendary-ballet-dancers-that-you-should-know-2476166676.html.

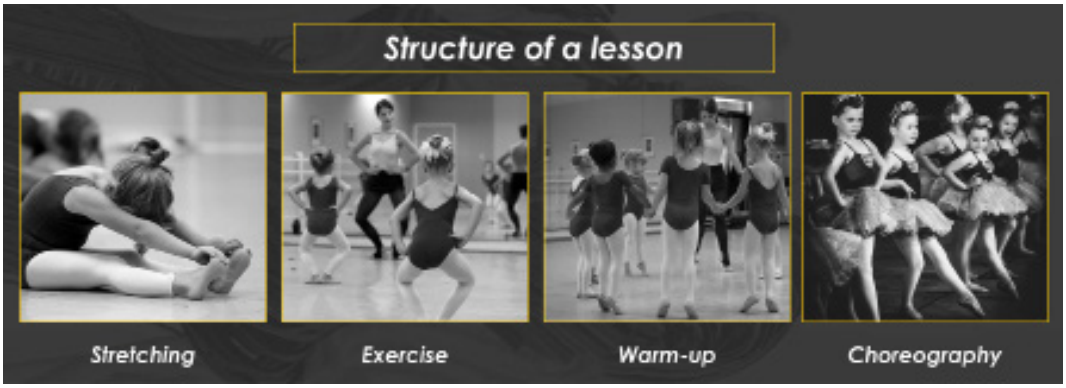


Fig. 6 Zambonini A., even if methods significantly differ one among the other, a main definition of the lesson structure can be summarized in 4 steps, 2019. Retrieved April, 22, 2020 from (from left to right): http://www.richardcalmes.com/"; http://www.pbase.com/rcalmes/image/66226008; http://www.theodysseyonline.com/dancers-arch; http://matinlumineux.blogspot.com/2012/11/richard-calmes.html.

The Human Factor in the learning process

Since the topic of the ballet has a deep connection with body and motion, it's important to understand that this physical-human factor is essential for the learning process. "When it comes to 'human factors', in design, we refer generically to the scientific knowledge on human factors that affect the design and which are particular objects of investigation in ergonomic research" (p. 11). This opening quote from Michele Sinico (2012), summed up the definition of ergonomic, considering both the physical and the cognitive sphere of perception. The most important elements considered for this study are the one related to the factors that allow a human to learn and forget elements and the cognitive perception of physical stimuli to improve the learning and the execution of the steps, maintaining unaltered the joyful factor. The main topic is inquired because this research aims to provide an effective learning experience that considers the attention of the students, their learning curves and their retention curve.

Remembering and Forgetting

In 1885, Ebbinghaus published *Über das Gedächtnis*, a great research that, for the first time, studied the unexplored field of learning and memory through empiric experiments. In this work, he defined the 'learning curve' as "a correlation between time and capacity of absorbing exter-

nal information" (Ebbinghaus, 2014, p. 67). In other words, it refers to how fast one learns information and it is described by an exponential curve. The learning curve of a person could be different from someone else because this ability depends on several factors, first of all, what is happening the life of the experimental subject: a job promotion, a new technology to develop with, a new car are all different events that could make better or worsening the ability to recall an element. Usually, a learning curve (Figure 2a) can be divided into three sections but the most important for this research is the beginning, in which the student has to overcome the first touch to properly lay the foundations of the new knowledge.

Analyzing different learning curves is easy to understand not only the progress of the student but also the efficiency of the learning system. The learning curve is related to the forgetting curve, which is exponential too because it describes the time that it takes for not recalling anymore something learned. The L.C. (Figure 2b) instead is created by the repetition of several recalls of the same element, and based on the number of recalls, the retention percentage will increase exponentially. For example the graph (Figure 3a) shows that the first time that the learning is recalled, one has the 50% of retention, instead of at the fourth recall, it is the 80% of retention.

The Ebbinghaus forgetting curve (Figure 3b) also shows the retention of learning over time where the experimental subject does not try any effort to recall it. If an item is recalled after 20 min the retention is around 50% and after one day is 33, but most importantly if something is retained after one day, most probably it can be recalled even after a month. Ebbinghaus divides also the memories between voluntary and involuntary to understand whether the retention of the information derived from a willing act of study or a spontaneous one. It is essential for an educational system to work on the latter, focusing more on the experience as a tool to convey information.

Focusing and keeping the attention

For a concept to be learned (especially if it is transmitted verbally) one of the fundamental elements is the attention. In this case, attention is referring not only to the actual attention that the student pays to the instructor but on the human capacity of attentivity. In particular, Broadbent, carrying out several tests, theorized the attention as a filter (Figure 4): the information reaching the person could be several, but only one at the time is actually perceived by the brain (Broadbent, 1958). There is a boolean correlation between different channels, the filter model will shift the attention from one channel to another but it will never accept information from both sides at the same time. It needs a bit of time to shift the attention from one side to the other, depending on the time of stimuli and the channel involved. This is related to the types of content that are perceived by the user, in any case, it is very important not to overlap different or opposite information.

This study helps in the definition of which type of feedback needs to be designed in this research and what timing has to be applied to the feedback to make the experience efficient for the students.

Ballet teaching methods and notation systems

Several teaching methods for ballet were analyzed (Figure 5), including the Vaganova Method, the RAD - Royal Acacemy of Dance method (Trevisan, 2017), the Cecchetti Method (Cecchetti, 1997), the Balanchine Method and the eurythmy art of movement (Poplawski, 2020), but this research mainly refers to the Vaganova's one (Vaganova, 2007). Different methods imply also different approaches to the lesson even if in the Vaganova method the structure of the lesson is not as rigid as the sequence of which step has to be taught at a certain age of the student. However, a main definition of the lesson structure can be summarized as follows (Figure 6).

- Warm up: is one of the most important parts of the lesson in which the students warm up their bodies to be pre-

pared for stretching and performing difficult moves without harming themselves;

- Stretching: consists in different exercises dedicated to stretching the body of the students to better their extension. Usually this part of the lesson can be performed in groups of two people where one is stretching the other forcing the stretch;

- Practice: is the actual dance lesson, where the instructor will teach different moves so the students can execute them several times. It is also useful, for very young students, to simply keep a rigid position to improve their balance and proprioception. The training part is composed by three interchangeable parts: center, *barrè*, floor *barrè* and diagonals.

- Choreography: is the moment where the student will learn to merge the different steps in a unique performance designed by the instructor. The choreography is taught in several days, based also on the ability of the students to learn the consecution of moves or the single gestures, and repeated many times. It is common to do this in preparation for a public show. This phase is mainly done for students of

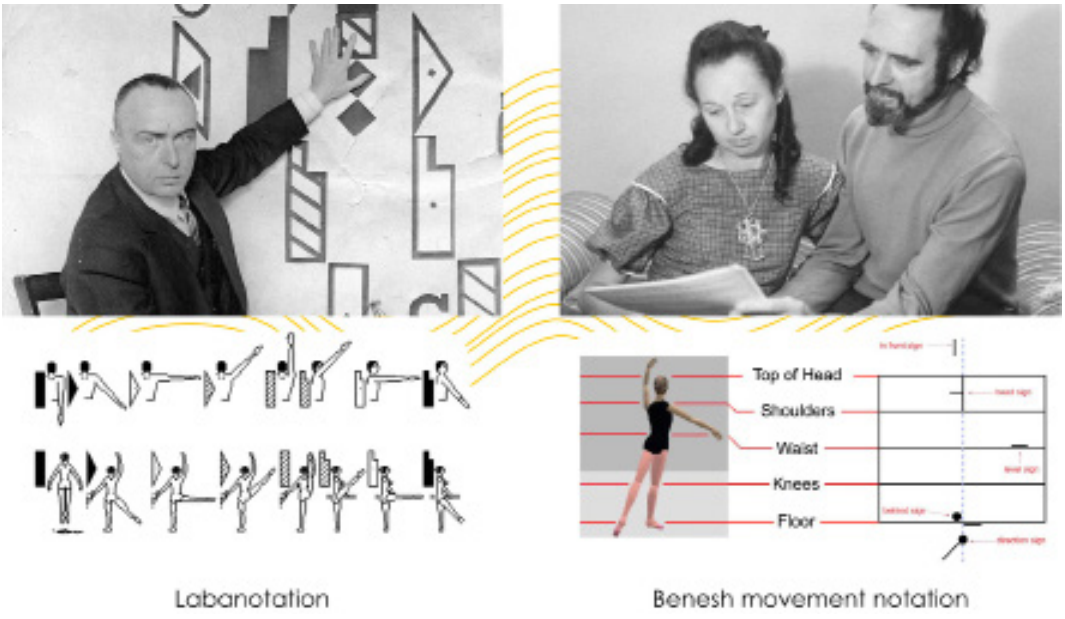
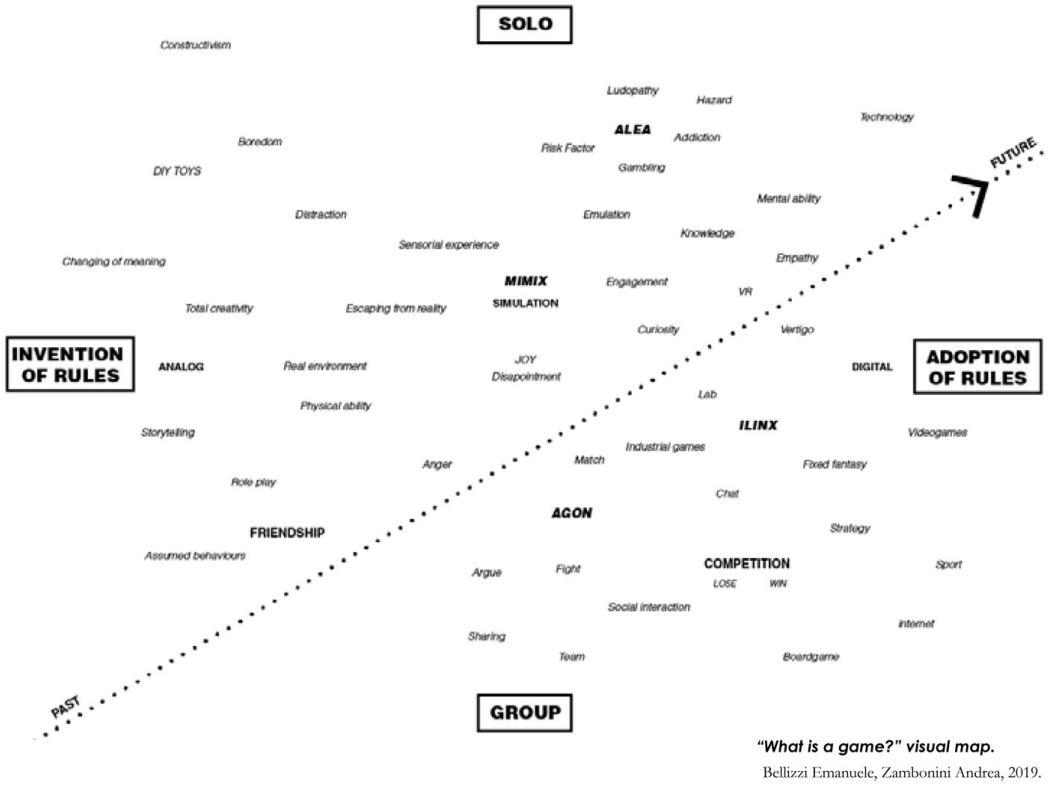


Fig. 7 Zambonini A., photocomposite, the two main notation systems analyzed and used for the development of the PASSAY project: Labanotation and Benesh (BNM), 2019. Retrieved April, 22, 2020 from https://en.wikipedia.org/wiki/Labanotation; https://owlcation.com/humanities/what-is-choreology; https://en.wikipedia.org/wiki/Benesh_Movement_Notation.



"What is a game?" visual map.
Bellizzi Emanuele, Zambonini Andrea, 2019.

Fig. 8 Bellizzi E., Zambonini A., graphical elaboration. The schema is a visual map on what is a game. It's based on two variables: on the vertical axis is represented the number of players and on the horizontal axis there is the difference between 'ludus' and 'paidia', 2019.

at least 8 years old. When it comes to ballet and its teaching methods, a common question is how something intangible and temporary as this form of expression was described and recorded in the past to be passed on to future generations (Figure 7). In the second part of the XX century, the dancer, choreographer and theoretician of dance Rudolf Laban drown up a written method for record choreographies (Labanotation) (Watts, 2015). His purpose was to fix something ephemeral, as the dance choreographies are, in something eternal (at that time there weren't video supports).

Thank to this method anyone, in particular future generations, could have the possibility to understand and reproduce choreographies designed in the past. He studied the movement with a physical-mathematical approach, with the purpose to eliminate every subjective aspect of the

motion and create a universal interpretation of the scores. He considered, for the analysis of the movement, three variables: direction, height, duration. After, he translated the results in a graphical language, with vertical reading (from the bottom to the top). It's divided in two parts with a central axis of symmetry that represents the left and the right part of the body. For the movement he used, as main symbol, a rectangle and modifying its color, form and size in relation, respectively, to height, direction and duration of the movement of arms and legs. In addition, he used other symbols to integrate other kinds of steps.

An alternative method is the Benesh Movement Notation, or BMN for short. It was invented in late 1940s by Joan and Rudolf Benesh (Watts, 2015) and it uses abstract symbols based on figurative representations of the human body. It is used by the Royal Academy of Dance to teach ballet: formerly the Benesh Institute, since 1997 it has been incorporated within the RAD (Trevisan, 2017). In the Benesh notation, the symbols are recorded over a five-line staff that will indicate, bottom-up floor level, knees, waist, shoulders and head. It's readable from left to right, indicating the sequence of moves marked on the time. Benesh (Ryman, Singh, Beatty, & Booth, 1984) notation can be displayed alongside and in synchronization with musical accompaniment, because of its similarity to modern staff music notation.

RESULTS: AN EDUCATIONAL GAME TO IMPROVE THE TEACHING OF BALLET DANCE THROUGH THE USE OF MOTION RECOGNITION TECHNOLOGIES

The analysis of educational game theories, learning processes and ballet teaching methods opened up to the definition of the PASSAY as a smart system, intended as a set-up of capturing devices and data analytics as seen in sports since the late 90s (Filippeschi et al., 2017).

The requirements of the educational game

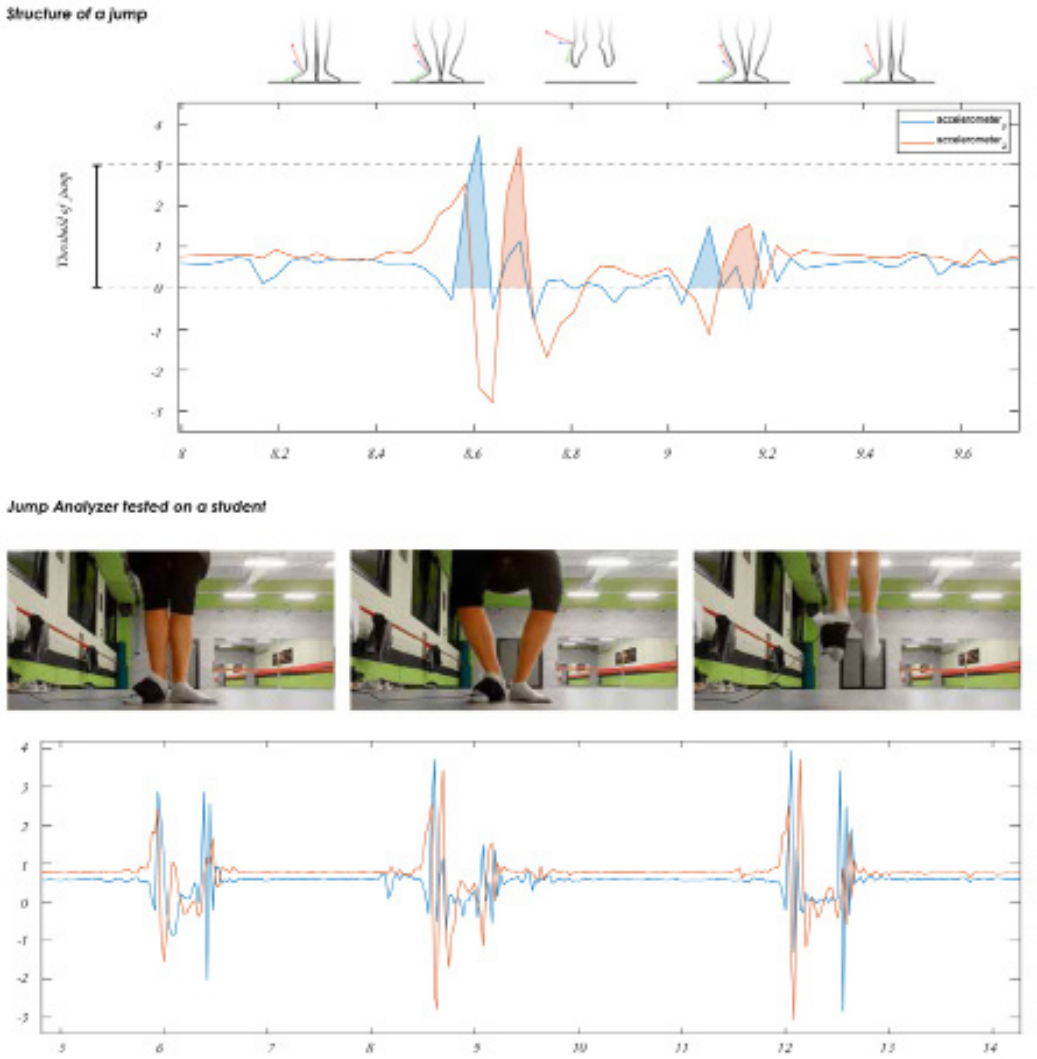
Many pedagogist gave their vision of what a game could be: the differences are useful to understand all the possibilities and values that the project could take into account. Based on Huizinga's theory, "Each game is a free activity standing quite consciously outside 'ordinary' life as being 'not serious', but at the same time absorbing the player intensely and utterly" (2020, p. 13).

While Callois adds that a game is not only uncertain but is also unproductive. This means that a ludic activity, even if does not have any ultimate productive aim, can definitely transmit content and knowledge to the users. One possible first step to successfully design games with educational purposes could be defining a reward-based logic related to challenges with different levels of difficulties. This makes the users learn how to test themselves and to never stop learning or improving their abilities. If the tests are based on the capacities of the player, winning them could be both possible with the right amount of challenge. Another element that limits any learning-by-playing activity, is the voluntary intention of the player.

In this case, dancing is itself a voluntary action that the user executes to gain a sort of pleasure. It is essential to maintain unaltered the joyful factor of it, allowing the players to completely dedicate themselves to the challenges that should not be felt as forced (De Beni, 1997). Last factor could be to design an experience that doesn't make the players perceive that they are actually practicing something. To do this it is important to put the layer of educational content benight a graphical, narrative layer with an involving storyline or a breathtaking game dynamic that hides from the user the real aim of the experience. After having exposed different theories on the theme of the 'game', it is important to classify the types, adopting a reference model producing a summary map. The scheme showed in (Figure 8) is based on two variables: on the vertical axis is represented the number of players and on the horizontal axis there is the difference between

Fig. 9 Zambonini A., photocomposite. An Inertial Sensors (IMU) has been used for recording and analyzing the structure of a jump, understanding whether there is a jump, for a maximum of three jumps and if the toes are pointing correctly during the elevation, 2019.

'*ludus*' and '*paidia*'; two radically different types of games. '*Ludus*' has the characteristic of having pre-designed rules and elements, '*paidia*' is the free expression of a joyful act, a game in which the rules, if existing, are created on the fly by the one that is playing. Introducing the time variable, we can see how this influenced the change of the 'game' experience. We can perceive a shift from a team-based game without rules to a self-centered game with pre-designed rules. Cause of this



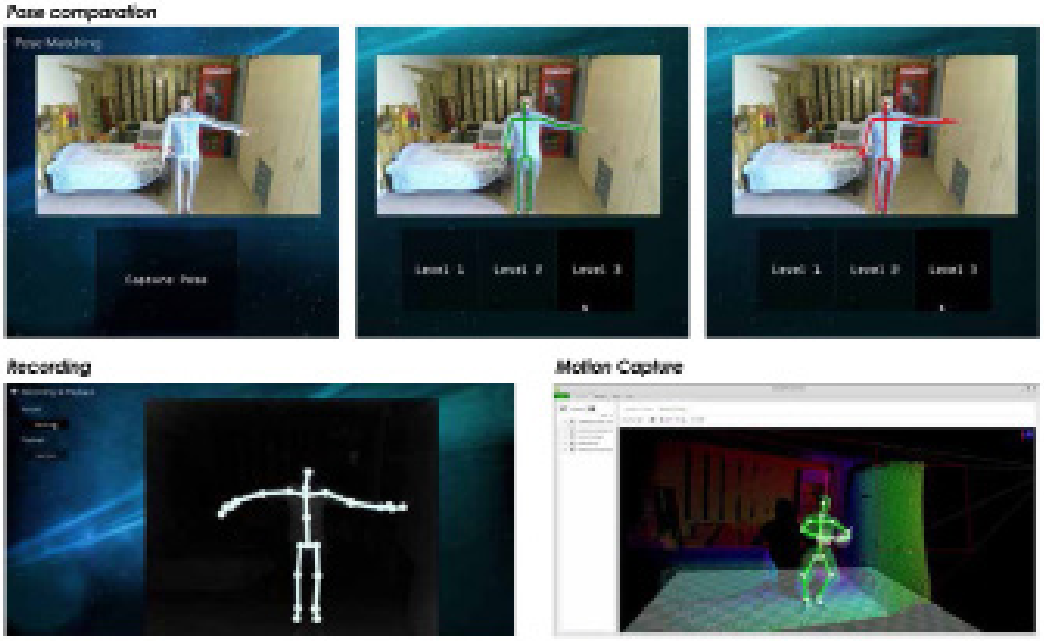


Fig. 10 Zambonini A., photocomposite. Motion capturing technologies and devices have been used for capturing a pose. In the left image the button "Capture pose" will fix the pose of the user. The central image shows the correct position being respected by the user, the image on the right instead is reflecting a possible distraction by the user, 2019.

shift could be the diffusion of mobile videogames and greater accessibility to the masses with the lowering of the costs for VR systems. Now children that keep on playing with physical toys are lessening.

The PASSAY technological layer

Based on the research described before and in order to allow the development of a smart system that could results in an effective educational game, significant efforts were aimed at the definition of the right technologies for tracking motion (Van Der Kruk, & Reijne, 2018), the primary input for merging the real and the digital world. For this purpose, two different technologies have been mainly tested for this purpose, developing two prototype experiments.

An Inertial Sensors (IMU) to record and analyze the motion

For this experiment, it has been used the development platform 'Freedom-K64F' with the compatible shield board 'Freedom STBD AGM04' (Perales, Barrero, & Toral, 2016).

This hardware has been wrapped up over the right foot of the experimental subject (dancers and not) with an elastic band always with the X-axis switched with the Y.

The software used to record the motion using this technology is 'Freedom Sensor Toolkit' (Suma, Lange, Rizzo, Krum, & Bolas, 2011), more precisely the program ran was the 'Out of Box Sensor Demonstrations/ 9 Axis Orientation Sensor demo'. The outcome of the recording is a spreadsheet with information on all the 9 Axis and an indication of the time. The sampling frequency is 36Hz. Following other experiences in sports and the need for a feedback (Kos, Umek, & Tomazic, 2015), the program designed for this experiment is a 'jump analyzer' (Figure 9) that understands whether there is a jump, for a maximum of three jumps and if the toes are pointing correctly during the elevation.

The program was written in Matlab 2019. To define if a jump has been executed with the proper strength, the value of vertical acceleration is around 3G (this value may change based on the subject analyzed). If there was a jump but the energy but it didn't go beyond the threshold, this will not be considered by the program. It was also found a correlation between the values of the Y-axis and of the Z-axis: if the jump goes over 3G, if the values of the Z-axis tend to be similar to the values of the Y-axis, then this can

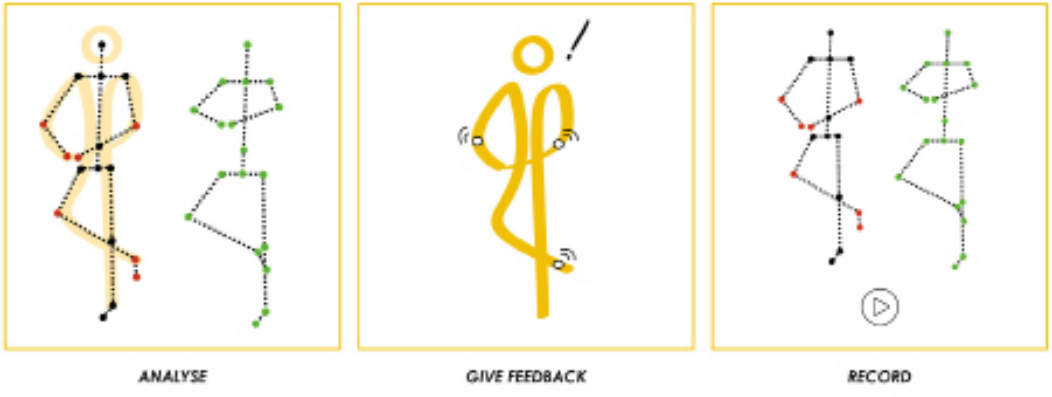


Fig. 11 Zambonini A., thanks to the application of motion capturing technologies and wearable devices, the PASSAY can provide the dance classes with 3 main features: analysis, feedback and recording, 2019.

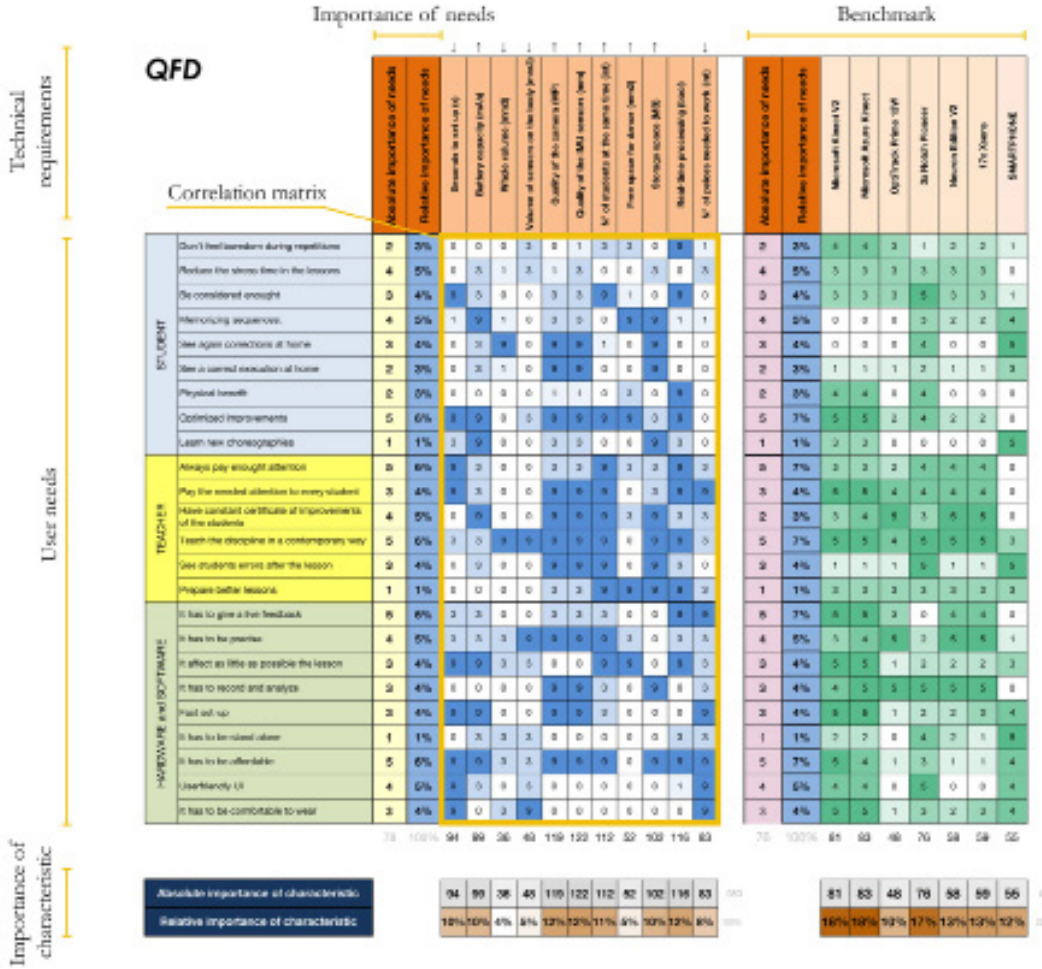


Fig. 12 Zambonini A., the Quality Function Deployment QFD matrix based on the users, stakeholders and technologies suggested the best development choices, prioritizing needs, 2019.

be defined as a good jump. This experience made me understand the complexity of programming this kind of tools and the possibility of integration with other technologies. The outcome of the program will be given after the execution and will result in an image indicating the good and the bad jumps.

This method is very useful to have precise information, but the application on the body of the students of at least 14/17 of these could be frustrating and limiting. Maybe the integration with a motion capture technology could optimize the result.

Motion capturing technologies and devices

The second prototype produced was based on a motion capture technology. The aim was to create a platform that could integrate various functionality of the motion sensor, including pose comparison, and recording. For this experiment, it has been used the hardware Kinect V2 SDK (Papadopoulos, Axenopoulos & Daras, 2014) and the software Visual Studio 2017 and Unity 3D. The position in the room of the sensor has been defined by empirical tests.

The final distance chosen was around 2,5 meters away from the user and at a height of 1.5 m.

Based on the Vitruvius SDK (O. F. Ince, I. F. Ince, Park & Song), the aim of the Pose comparison was to prove the efficiency of this state-of-art technology for this kind of application. In the first image (Figure 10), the user is in the correct pose and clicking on the button 'Capture pose' will fix that pose.

The central image shows the correct position being respected by the user, the image on the right instead is reflecting a possible distraction by the user. In this case, the feedback is just visual changing the color of the skeleton.

The buttons below the preview define three different levels of threshold based on the experience of the students. The last part of this application has a function of record and playback three-dimensional motions. This was implemented to have the possibility for both the students and the teachers to re-watch a lesson or a specific choreography.

The PASSAY smart system

Once solved the technological feasibility of capturing movements, the PASSAY features has been developed for improving the teaching of ballet dance altering as little as possible both the dynamics of the classes and the setting of the ballet room. Thanks to the application of motion capturing technologies and wearable devices, the PASSAY can provide the dance classes with 3 main features (Figure 11):

- Analyze: analyze errors in the motion during the lesson by a recreation of a skeletal model of the student

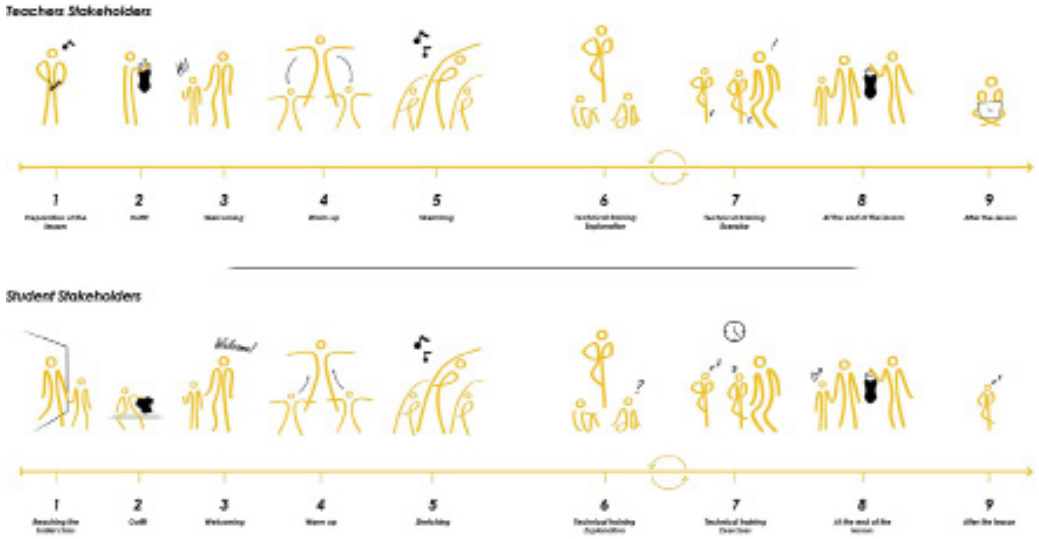


Fig. 13 Zambonini A., the User Journey Maps (UJM) of teachers and students highlights how a proper app development, covering the entire learning process as an educational game, is highly needed, 2019.

and confronting it with an ideal model (motion capturing technologies analyzing data from capturing devices installed in the room – requirements: Kinect Azure).

- Give feedback: the system can send feedback (using graphical elements on screens or by the use of vibrating wearable devices – requirements: PC and wearable devices) directly to the student augmenting the efficiency of the exercise and engaging the student through a more gamified lesson.

- Record: after the lesson, both the student and the teacher could see, in a personal application (requirements: PC, tablet or smartphone), a 3D reproduction of the moves to remember corrections, memorizing choreographies and analyze improvements.

These set of functions could be both use in person, within a traditional dance class improving the effectiveness, or for opening up to an online class, where the teacher can see, real-time, the student and vice-versa. Furthermore, these capabilities can be exploited for the creation of an 'educational-game', where different approaches to the topic, such as learning-by-doing, role-playing and board-game can be applied.

DISCUSSION

The Quality Function Deployment QFD matrix (Figure 12) based on the users, stakeholders and technologies suggested the best development choices. This method was indeed fundamental for better understanding the relation between user needs and technical requirements of the design, in order to avoid common mistakes in the development of final product already seen in other experiences. For instance, valuable commercial product, such as Babolat Play in tennis (Büthe, Blanke, Capkevics, & Tröster, 2016), can result in non-effective selling performances in a market not yet ready for these IoT (Internet of Things) implementations. User needs were analyzed thanks to the involvement of both students and teachers resulting in the following order of importance.

For the students, needs are: (1) reducing the stress time in the lessons, (2) memorizing sequences, (3) being considered enough, (4) watching again corrections at home, (5) not feeling bored during repetitions, (6) playing correct execution at home, (7) physical benefit, (8) learning new choreographies.

While, for the teachers, need are: (1) paying enough attention to students, (2) teaching the discipline in a contemporary way, (3) having constant supervision of improvements, (4) better noticing students errors after the lesson, (5) preparing better lessons.

These are the needs that the PASSAY project tried to answer, balancing them with the technical requirements. In fact, the QFD also highlighted the software and hardware had to be (1) affordable, (2) user-friendly, (3) precise, (4) the UI intuitive, (5) the wearable comfortable, and (6) the whole system had to affect as little as possible the lesson.

Last but not least, it had to offer (7) a record and analyze feature and be installed as a (8) fast and (9) standalone set-up. The QFD analysis showed how important was that final result offered a high-quality of the tracking system to help the teacher and the real-time processing was essential to not alter too much the lesson.

Fig. 14 Zambonini A., mock-up of the graphic interface of the PASSAY educational game: phase "preparation of the lesson", 2019.

In fact, once developed the system on these multiple requirements, it was tested against its using within the User Journey Maps (UJM) of teachers and students (Figure 13), highlighting not only the need for a hardware-software set-up but for a proper app development that could cover the entire learning process as an educational game.

The PASSAY app: an educational game

This paragraph will explain the educational game app step-by-step, as teachers and students will encounter in along their UJM.

1. Preparation of the lesson (Figure 14). The app has a dashboard that allows the teacher to have a general overview of the improvements of different courses, re-watch the last lessons. The teacher can also modify all the classes and their members.

2. Welcoming (Figure 15). When a new student is subscribed to the school, the teacher, before presenting the new member to the whole class, will record the new user in the multisided platform of PASSAY. In this phase, the student will choose which personal 'decoration' he/she prefers. This

illustration (ID) will be applied on the outfit and will work as an identifier symbol for the system to associate the body analyzed to a specific profile of a user.

3. Technical training (Figure 16). During the description of the movement, the teacher will say the name of the movement and this action will be considered by the Kinect as a call to action to wait for this move to be executed by the users. After the description, the students will be divided into groups composed by 3 'players'.

The teacher will ask everybody to execute statically a position. The instructor, when is sure about the position of the student, will say '[name_of_the_student] is ready'. When the three people in front of the sensor have been prepared, the teacher will say again the name of the movement, asking everybody to execute it. During this phase, the instructor will correct the other group. During the exercise, with defined length decided said to PASSAY by the teacher, every time the analyzed ones will diverge from their original state, they will receive vibration feedback, in real time, in the parts of the body holding the wearable. The wearable will react only when the assigned point on the skeleton scheme will go beyond the threshold of error shown in the previous scheme.

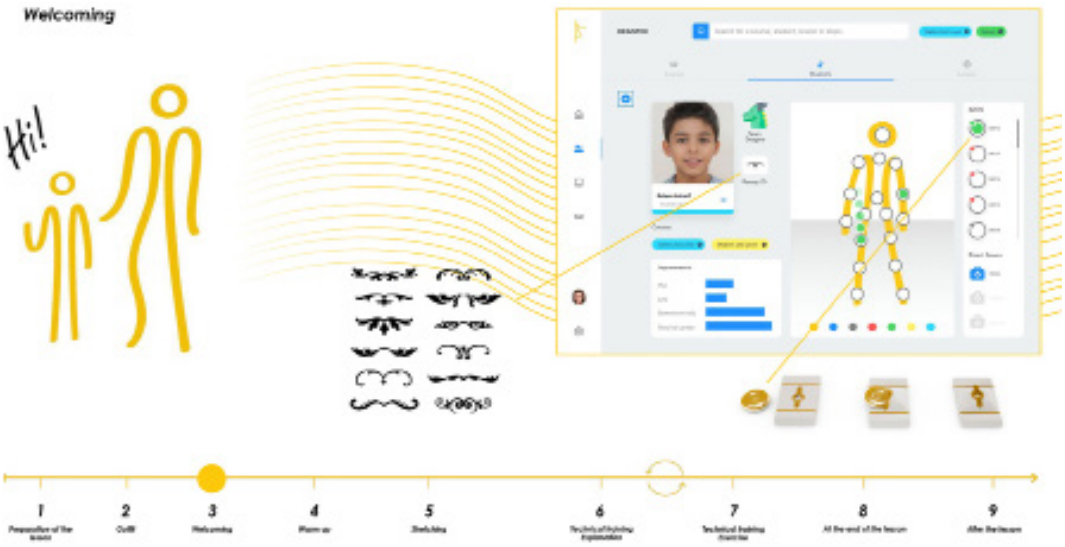


Fig. 15 Zambonini A., mock-up of the graphic interface of the PASSAY educational game: phase "welcoming", 2019.

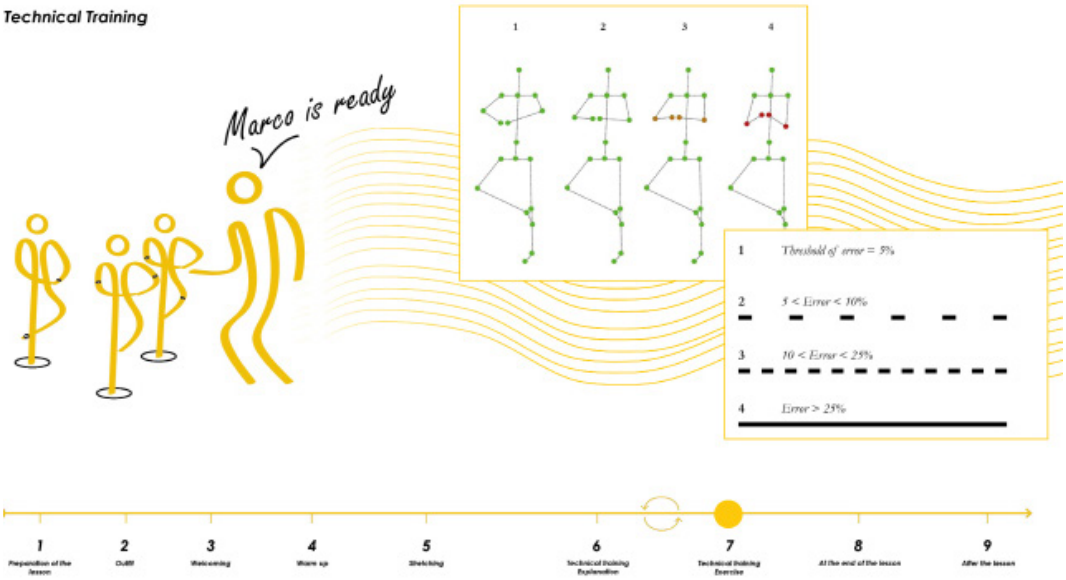


Fig. 16 Zambonini A., mock-up of the graphic interface of the PASSAY educational game: phase "technical training", 2019.

The more the student diverges from the ideal position in the analyzed body part, the more the vibration will be annoying. The more the students will not diverge from the desired state, the more they will gain points that will be summed up with the rest of the team. After the repetitions, another group will be positioned in the same place as the first group. At the end of the lesson or the exercise, the teacher will say 'Stop', then a team leaderboard will be shown with the best three teams. 4. After the lesson (Figure 17). After the lesson, the teacher can watch again the whole class in 3D and check specific clips for every student. In the section of the student, he/she can also see the improvements and highlights.

CONCLUSIONS: ANALOGUE VS DIGITAL TOWARDS NEW POSSIBILITIES

The teaching and learning of classical dance are still faithful to an ancient model, based on the standardization and transmission of knowledge in a mainly analogical meaning. Digital technologies are considerably different from this

concept because they offer a way of transmitting knowledge that is not only handed down but also shared, creating a non-linear learning pattern. However, new technologies provide children enormous potential in terms of motivation, empathy and confidence growth.

Despite these aspects would seem positive, the degree of resistance to the introduction and to the possible use of new technologies for the learning of classical ballet has proved, in the research phase, to be still quite rooted in the beliefs of some teachers. This resistance is not profitable, because the fracture with the current digitalized social context risks making this discipline incapable of attracting students and maintaining them over time: these 'digital natives', who from a very young age possess typical skills and 'forma mentis' of those who use new technologies, prefer a dynamic, personalized and inclusive type of communication.

The technologies integrated with a more traditional methodology, as illustrated in this project, would make it possible to enhance the lesson by making it more effective, certified and at the same time more motivating and satisfying: the typical concepts of game design, in fact, make it possible to expand the scope of the teaching far beyond an hour of lesson in the gym, promoting a real self-regulation in the movement. The role of the teacher remains central to the learning of the student because the technological integration will always be conducted directly by the person who manages the courses and the lessons.

However, there's still room for improvements. The low-resolution digital prototype of the 'Pose matching' algorithm, illustrated above, has been tested on different dancers and dance students. This 'proof of concept' has revealed that there are both some limits and potentialities for this new type of learning. In particular, basing each movement on a single ideal model seems to be restrictive in relation to the conditions of application of the movement; for example, in choreography, the dynamism could prevent us from giving a certain answer on the execution of a particular step of

the sequence. Nowadays, however, artificial intelligence systems, and in particular machine learning, allow us to clearly analyze even dynamic moves without renouncing the personalization of positions. The system, in order for the computer to recognize these steps, needs a very large initial dataset that is gradually enriched by the additional data generated by the users of the system. A further step, necessary to be actually exploit the potential of PASSAY in the best possible way, would be to directly involve early adopters for this technological system. The target could be users very favorable to the use of technologies, i.e. young professionals in the sector, who are interested in improving themselves by exploiting innovative and qualitatively valid products.

The relationship between arts and technology foreseen by this project is indeed so close to the same envisaged by Oskar Schlemmer (Trimingham, 2017), Master of Form at the Bauhaus theatre workshop since 1923 (Schlemmer & Hildebrandt, 1951, p. 36): "If today's arts love the machine, technology and organization, if they aspire

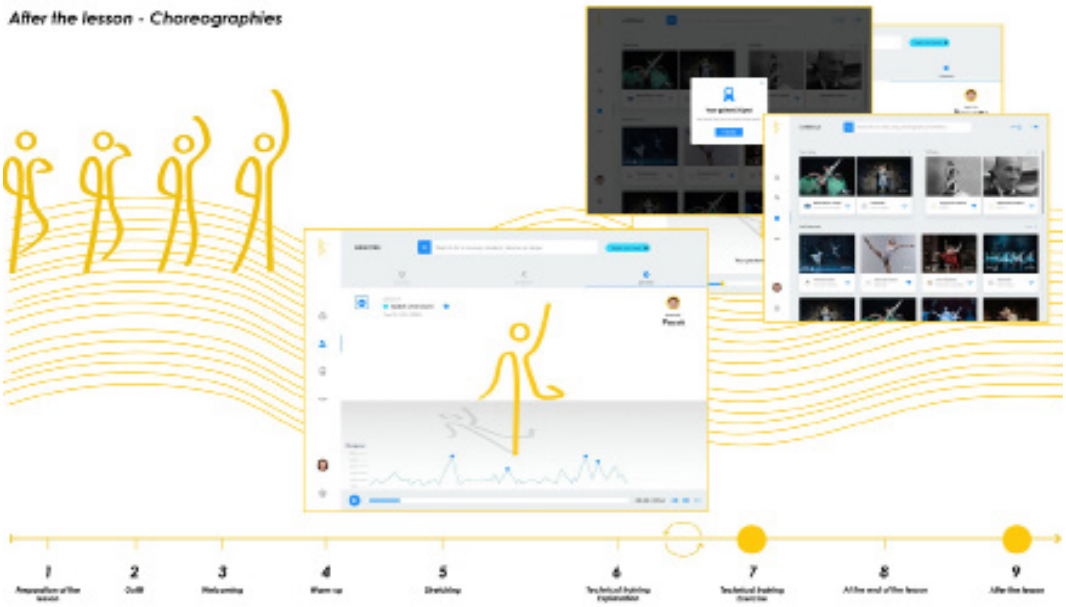


Fig. 17 Zambonini A., mock-up of the graphic interface of the PASSAY educational game: phase "preparation of the lesson", 2019.

to precision and reject anything vague and dreamy, this implies an instinctive repudiation of chaos and a longing to find the form appropriate to our times" (Schlemmer, 1990, p. 43).

After World War I, during his workshop dedicated to dance and acting, Schlemmer developed the famous *Triadic Ballet* (Lahusen, 1986) which was born from the perceived necessity to re-evaluate the figure of the men within the new world, reconciling arts and techniques.

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