Dance Interactive Learning Systems: A Study on Interaction Workflow and Teaching Approaches

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Motion Capture and whole-body interaction technologies have been experimentally proven to contribute to the enhancement of dance learning and to the investigation of bodily knowledge, innovating at the same time the practice of dance. Designing and implementing a dance interactive learning system with the aim to achieve effective, enjoyable and meaningful educational experiences is, however, a highly demanding interdisciplinary and complex problem. In this work we examine the interactive dance training systems that are described in the recent bibliography, proposing a framework of the most important design parameters, which we present along with particular examples of implementations. We discuss the way that the different phases of a common workflow are designed and implemented in these systems, examining aspects such as the visualization of feedback to the learner, the movement qualities involved, the technological approaches used as well as the general context of use and learning approaches. Our aim is to identify common patterns and areas that require further research and development towards creating more effective and meaningful digital dance learning tools.

1. INTRODUCTION

According to recent scientific literature and documentation of various research efforts, in the past decade, digital environments and motion capture technologies have been used in the field of dance practice through different perspectives, such as artistic creation and experimentation, research, education and other. Specifically, in the field of dance education, recent technological advances have led to the design and development of tools to support dance teaching and learning through different technologies such as interactive whole-body experiences, motion capture, virtual and augmented reality, as we highlight also in our previous work [35]. These tools attempt to enhance and support dance learning and teaching, as well as in some cases to innovate the analysis and reflection on the movement itself. This contribution includes investigating bodily knowledge, innovating the teaching of dance, preserving cultural heritage, revolutionizing choreography, widen the access and practice of dance and augmenting the experience of performing. In addition, techniques applied in this domain can be extended and applied to other areas where movement plays a central role, such as sports, rehabilitation, performance and artistic creation, etc.

Taking into account this research background as well as current relevant research projects such as WhoLoDancE EU project [81], this work attempts to provide an overview of existing approaches for interactive dance learning systems that are designed specifically for dance education purposes. These approaches are categorized based on a proposed framework that can inform on the current conceptual and technological gaps in the field and guide subsequent research initiatives.

Apart from the purely educational systems for dance, there are also several other approaches that support dance practice in various contexts such as dance creation, analysis and research, through a variety of interactions, ranging from web-based and desktop to stage applications. Some of these tools such as Laban Dancer [11] and Life Forms [13], which were introduced by Calvert et al. and extended by Wilke et al. [83], benchmark the start of a dialogue between computer science and choreographers like Merce Cunningham, introducing tools for generating movement on 3D avatars and using computers in choreography as reported and investigated by Thecla Schiphorst [71]. Recently, many interdisciplinary projects have explored the use of technologies for movement analysis and creation. These

examples include Motion Bank [43] and Choreographic Objects [44] which are the result of a collaboration between the choreographer William Forsythe, dance scholars, interaction designers and computing researchers, Moving Stories [72], an interdisciplinary collaborative project and research group that focuses on movement within technology design, and "TKB, A Transmedia Knowledge-Base for the performing arts" [41] which investigated the intersection of choreography, linguistics and computer sciences. In addition, EU funded projects such as i-treasures [50], Dance EU [29] and WhoLoDanceE [81] investigate and apply the use of technologies for capturing and analyzing dance movement both from an educational and a creative perspective, as well as a tool to preserve intangible cultural heritage. The aforementioned efforts have resulted in a number of systems and tools, which vary in terms of the type of experience (e.g., desktop, mobile, AR, VR), context and purpose. More specifically, these outcomes include annotation tools for movement analysis like Choreographer's notebook by Singh et.al [73], Piecemaker by Delahunta et.al. that was developed in framework of Motion Bank project[32], and previous work of our team such as BalOnSe [36][37] which focuses on ontology based annotations for ballet and WhoLoDancE annotator[34]. Similar tools consist online applications for collaboration purposes and distant co-working like the BlackBox which is proposed by Fernandes et al. [42]. Although annotative tools, fall out of the main scope of this survey, they can show a great potential as teaching tools [34][68].

In addition, augmented performance settings and interactive technologies have been designed and developed to create augmented and virtual spaces within the context of performance and scene production such as the works of Instituto Stocos[1], K. Danse[2] and similar dance artistic companies, which also developed systems which transform movement and its qualities into a variety of modalities for performance like in the work of Palacio and Bisig [64]. All these applications present several similarities or overlaps with dance learning systems and environments, and they directly feed into the analysis of movement, in terms of conceptual modeling, representation, multimodal visualization and transformation. For this reason, they have been examined to inform the framework of this work, however they will not be presented in detail as our focus is on purely whole-body interaction educational systems.

Another category of dance related applications is commercial games, such as "Dance Dance Revolution" [28][48] "Dance Central Spotlight" [82], and "Just Dance"[51] video game series . Although these applications have many similarities with learning environments, and have attracted large audiences, their purpose and context of use is entertainment rather than education. More specifically, in these cases, as Chan et al. [22], indicate "the input data is greatly decimated to facilitate the analysis of the movements and although such decimation is acceptable in an entertainment setting, the system is not able to provide sufficient feedback for the whole-body movement for training purposes". According also to the results presented by Charbonnau et. al [24], dance games do not seem to offer much in improving dance performance and learning, as usually the feedback is just a judging overall score, which do not however, indicate what went wrong nor suggests improvements. On the other hand, it is worth mentioning that such games present interesting design paradigms and metaphors that facilitate engagement and to this end they have been included as a category of interactive environments in Table 1. In addition, another point which is interesting about those systems is the use of available hardware and fact of playing with other users online, compare scores etc.

Despite the fact that the use of interactive technologies to support dance learning and education is still a relatively unexplored domain, as we point out in our previous work [33], it is certain that it can contribute significantly to the field of mastering expressive movement, as well as in applications where embodied interaction plays a key role such as sports, informal learning environments for children and adults, rehabilitation and health applications etc.. Many researchers have highlighted the importance of embodied cognition in HCI [31][55][59] and presented paradigms that can be applied in both ubiquitous computing, as well as MR, VR and AR environments. Thus, the main contribution of this work, extends from the boundaries of dance learning systems to other areas of computing. Dance as human activity cultivates a wide range of physical, cognitive and emotional skills such as precision, musicality, creativity, expression, mastering of space and time, social awareness, as well as synchronization and coordination with other bodies, music and the environment. In addition, compared to other physical activities, it is usually highly related to cultural assets such as clothing, music, cultural values and behaviors, history, geography, perception of time and space, etc.. In fact, dance learning systems, to work effectively require a deep understanding of human

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[1] http://www.stocos.com/
[2] https://www.k-danse.net/en/

behavior and constitute a demanding area to apply computational methods. Based on the examined systems. in our work, we show that a wide range of computing areas are challenged in order to offer and effective DILS, such as pattern recognition and similarity search, high-level features extraction and signal processing, management of multimodal data, semantic & conceptual modelling as well as machine learning and artificial intelligence. The recent collaboration of Google Art with the choreographer Wayne Mc Gregor [56] is one good example of investigating AI technologies and machine learning. The same algorithms and research results can be applied to a variety of domains that require the analysis of human behavior. For the scope of this survey we mainly focus on the existing efforts and systems which satisfy the following characteristics, referring to them as Dance Interactive Learning Systems (DILS): 1) They are designed and implemented targeting dance teaching and learning, thus being educational tools, according to their explicit self-characterization. 2) They adopt whole -body interaction and motion capture technologies, either for creating a database of pre-recorded movement to be shown to the students, or for capturing the students' movement to be analyzed and compared with an ideal movement - or for both reasons, thus being whole-body interaction tools. 3) They can potentially adopt augmented, mixed or virtual reality technologies to include visualization of the movement of the teacher, the student or both. An example of such a system is Choreomorphy [78], shown in Fig.1 which was developed and evaluated in our previous work [38] within the framework of the WhoLoDancE project [81].

Table 1. A categorization of digital tools based on their objective and purpose of development and use

Category of tools	Description
Choreographic tools	Tools that support the creative process of dance composition
Augmented Performance tools	Digital technologies that are applied on stage to augment performance through different modalities (e.g., visualizations, sonification)
Educational tools	Digital environments that aim to support the learning, teaching, and continuous practice of dance
Research and Analysis tools	Digital technologies that aim to support the documentation, analysis and reproduction of movement within a research context.
Dance Games	Digital games that use dance as the theme of the experience.

Fig. 1. "Choreomorphy: a whole-body Interaction System used for dance improvisation and movement experimentation"[38] using inertial motion capture technologies, used in the Lab left, and during a workshop with dance students (photo by K. El Raheb)

In Section 2, we present the advantages of the use of DILS, as well as relevant requirements stemming from the particularities of dance education, in comparison to other fields, based on existing literature. In Section 3, we situate the existing DILS within the broader map of tools for movement and dance, outside the scope of education, and we propose a categorization based on their characteristics. In Section 4 we describe a generic workflow for the DILSs and we present the critical issues that accompany the different phases of this workflow, proposing a conceptual framework for categorizing existing DILS. While in this Section (Introduction) we presented a short categorization of digital systems applied to dance to differentiate DILS, in Section 5, we analyze existing systems and we categorize them based on the proposed framework. Section 6 presents the potential of DILS as virtual environments for collaboration and tele-presence through examples and, finally, Section 7 presents a discussion of the results, while Section 8 concludes the paper.

2. REQUIREMENTS AND POTENTIAL OF DANCE INTERACTIVE LEARNING SYSTEMS

The fact that, since many decades, dance movement is not considered as a limited subset of defined sequences and structures, but as the field of deeply understanding and researching bodily knowledge, opens new opportunities in the domains of Human Computer Interaction, Movement Computing and Artificial Intelligence. Seeing dance education from a broader perspective, as a field of exploring and mastering bodily knowledge, the digital environments of learning can be informed by various interactive technologies which have been widely used in the context of artistic performance and creativity, as well as computational methodologies for the analysis and measurement of movement qualities such as in the works by Fdili et al. [2] [40], Camurri [17], Piana [66] amongst others. As we described in the previous section, there are several projects and efforts towards introducing effectively digital technologies into contemporary dance and choreography. On the other hand, different technologies have been proposed in the context of interdisciplinary research, and experimental artistic creation since many decades, producing examples such as LabanDancer [12], LifeForms[13], and Cochoreo [18] and others introducing the idea of "sketching movement" [19]. At the same time other efforts propose the use of digital environments not for learning dance per-se but to introduce young students to both artistic expression and engineering (RoBallet), [21], for other physical tasks [25] or to learn computer science thinking through choreography and movement in a VR environment[65]. Soga et al. [74] propose Web3D, a system in progress for generating 3D animations for classical ballet choreographies. Nevertheless, technology is still absent from the dance studio where practitioners learn and rehearse, as Molina-Tanco observes [60], dance has probably been the slowest of all the art forms to adopt technology as part of everyday life and practice, as Calvert et al. also note [12]. This is partly due to the fact that dancers and choreographers are reluctant to let anything get between them and the physical kinesthetic experience. But although useful tools have been slow to emerge in a market with a reluctant and demanding customer group, the area of dance practice reveals a new field with a strong commercialization potential. As dance program director Marsha Barsky, claims [27], technology can help dance educators to enhance their classes as well, providing an example of using "Annotative tools," as defined above by Alaoui et al. [1] and video platforms. Calvert et.al. explains: "There are many examples of the use of all forms of multimedia in conjunction with live dance performances. In some cases, a pre-planned animation sequence or digital video with appropriate sound is played as a backdrop and live dancers interact with the preprogrammed display"[12]. A more technically complex system is required to sense a dancer's movements real-time and modify the visual and/or audio presentation. In other cases, there is a need for joint rehearsal and/or performance amongst dancers in remote locations, where video conference technologies are applied, possibly combined with the use of immersive or stereo VR displays. All kinds of variations and combinations of available technological means are possible. There has been also substantial research on the use of movement qualities, a concept inspired by dance, to design and develop whole –body and touch-based interaction experiences [40]. In recent years, the domains of dance, music composition and movement analysis, visual and media arts and Human Computer Interaction appear to be in a constant cross-fertilization dialogue [1][2][15][17][18][33][72]. In all these cases cooperation and co-creation with practitioners is essential to achieve a high-quality user experience and an effective learning one, if this is the goal. The rest of the section focuses on how to support the teaching and learning of dance in different educational contexts through the current state of the art in technological solutions.

2.1. Characteristics and Requirements of Dance Learning

Systematic dance education can be hard and demanding and also require the development of critical and analytical skills on one's own performance of the movement. Dance is a field of mastering movement literacy, conceptualization, self-reflection and creativity. Different techniques may apply as well as different learning objectives, teaching approaches, and often philosophies on movement [35] and perception of the body. Taking into account the variety and diversity which exists in the field of dance, stemming from the variety of 1) dance genres e.g., ballet, folk dances, contemporary, etc., 2) dance practices and learning approaches e.g., mimesis vs. reflection, traditional methods, improvisation, 3) context and objectives of practitioners e.g., choreography and creation, movement analysis and focus on details, enhancing creativity, learning new steps, enhancing technique, but also 4) profile of the practitioners e.g., amateurs, professionals, choreographers, dance researchers, children vs. adults, it is clear that even if we focus on dance learning it is impossible to evaluate technological tools and experiences, outside these contexts.

On the other hand, "if there is one field where education and learning need to be continuous this is the field of dance. As we mention in our previous work [33][35], the fact that advanced or professional dancers never quit practicing, attending classes and seminars in daily or frequent basis the experiential and practice-oriented nature, multimodality, combining both cognitive and bodily processes, and its diversity in relation to contexts, differentiates dance learning from any other subject of "book" learning .

For physical education in general, several models have been proposed and applied [61]. In the case of dance, however, existing teaching approaches can be summarized as follows [16][33][35]:

1. Mimetic method: In this method the students mainly imitate or copy the teacher's movement or sequence of movements. It is also known as "see and do" approach.
2. Traditional method: where the teacher makes all the decisions and the learner follows these decisions. The method requires precision and accuracy of performance and the right/wrong paradigm is strongly applied. Also known as command style teaching.
3. Generative method: the teacher gives the student an exercise/phrase/sequence as a starting point to achieve technical and creative goals;
4. Reflective method: the student is given a movement task/image to work with, improvising without trying to achieve a specific phrase/sequence and the teacher provides feedback. The aim is more on mastering or exploring specific aspects of movement (principles, qualities, etc.), rather than reproducing specific moves.

During the last decades, the teaching and learning of dance has evolved from more traditional approaches to embracing generative ones, improvisation and creativity. In parallel with the related technological advancements, this evolution in dance teaching, and its opening into somatic practices, should be taken into account during the design and development of technologies for dance education [80]. The orientation of dance education towards more generative and creative teaching approaches have also paved the road for adopting a variety of technological tools from desktop and mobile apps, to more sophisticated digital environments. In what follows, we will present the advancement of digital environments in this field, through analyzing particular efforts, and through matching the characteristics of the interaction and technologies used, with the context and approach of dance learning. The effectiveness of learning and the quality of the user experience rely strongly on a successful match of interactive experience and learning approach and/or context.

2.2. Is mimicry the best paradigm for dance learning?

Although, the common scenario for applying dance teaching is through mimicking the movement of an avatar, recent advancements in dance practice and neuroscience suggest that learning through seeing a movement cannot be achieved without having previous experience, thus might not be ideal for all levels of dance students. Calvo-Merino et.al. [14], have used functional magnetic resonance imaging (fMRI) in an experiment investigating whether observing someone performing an action, our brains simulate this action. The experiment studied differences in brain activity between watching an action that one has learned to do and an action that one has not, in order to assess whether the brain processes of action observation are modulated by the expertise and motor repertoire of the

observer. The fact that although all the subjects in the study of Calvo-Merino [14] saw the same actions, the mirror areas of their brains responded quite differently according to whether they could do the actions or not, underline the importance of providing effective instructions and feedback throughout the learning process especially for not experienced dancers. The aforementioned research results imply that while the mirroring or mimetic approach is widely used effectively in many dance practices and adopted also in many DILS, might not be always the best way to learn and improve movement.

2.3 Advantages of using digital and interactive systems in dance practice.

This section highlights the importance of interactive dance training systems in dance learning and refers to other aspects of dance practice they can also contribute.

2.3.1 New perspective on movement.

Motion capture technologies can play an important role on capturing, reproducing and self-reflecting later on the details of one's movement and dance performance. According to reports on an experiment in Stanford University by Rosanne Spector [67], dancers from the Merce Cunningham Dance Company who were recorded through motion capture sensors placed directly on their skin expressed their enthusiasm. The quote of one of them highlights the impact of using technologies in the learning process: "I know what I think my body is doing. But is it really doing that? I do not really know, but I'd like to". The use of technologies like motion capture and biomechanical visualizations can support deep understanding of the movement mechanisms and provide objective data about one's movement for self-evaluation and further reflection: "While movement is something humans do constantly without thinking, the members of this class are giving it a lot of thought: By analyzing movement from both scientific and aesthetic perspectives, they are trying to gain a deeper appreciation of why people move their muscles and bones in a particular fashion. In other words, when you actually quantify something artistic, even if it seems obvious, you often learn something" [67]. Therefore, capturing and analyzing the motion can be very helpful in enhancing dance learning and understanding and, as we will see in the following paragraphs, is widely used in interactive dance learning systems. In comparison to using video recording where you can see the movement from one perspective, the one of the motion capture technologies and 3D presentation have the advantage of three -dimensionality. In addition, the 3D display through a digital avatar allows the students to distance themselves from their own image as recorded on camera, including their body, clothing, etc., and focus only on the movement and its qualities. Castaner et al. [20] have compared the aesthetic appraisal of contemporary dance movement using optical motion captured movement vs. observing videos and the differences are significant depending on the particular movements. Nakamura et al. [62], have proposed a multimodal information presentation for teaching dance to beginners and that proved to be more effective comparing to watching videos. This comparison is a good example, where a training system has been designed, implemented to potentially substitute an existing used technology, in this case video, and not the physical experience itself.

In all the aforementioned examples, the technology is used to observe, reflect or mimic the teachers' movement. In dance learning however, the dance practitioner is always at the same time an observer of her teacher's ideal movement as well as an observer of her own movement, visually, using the mirror or through visual imagery. Related to the relation between movement and observation, Loke et al. [55] propose a non-prescriptive design methodology which is "structured around the three perspectives of mover, observer, and machine". As the author describes, "the three perspectives are designed to make clear the trajectory between the perspective of the mover (in the act of moving), the perspective of an observer (such as the designer or the mover during reflection on design), and the perspective of the machine (because ultimately if movement is to be effective input to a computer system, the machine

must be able to detect and interpret it correctly). Each perspective offers orientation, guidance, methods, and tools at each stage of designing". As we note in our previous work [38], visualizing teachers' movement (student is an observer), and visualizing students own movement (student is mover and observer) are two different, complementary important aspects in designing DILS.

2.3.2 Distant and online and/or collaborative learning.

One reason for designing and implementing interactive dance learning systems is to provide the option for distance training. But is online learning a viable option when it comes to dance teaching? Online dance learning can share the same characteristics with online physical education. Daum [30] argues that dance and physical education face similar issues with other topics of on-line learning courses. These include academic honesty, learner readiness and motivation, student retention, technology issues, etc. Additionally, these movement-oriented topics pose to the learner the unique challenge of enhancing motor skills, movement principles and qualities, as discussed by Camurri et al. in the framework of WhoLoDancE [16]. Buschner [10] documents some of the potential advantages and disadvantages of online physical education, which could also apply to online dance education. The main advantages include the fact that students in some cases could be motivated by technology as a novelty and, most importantly, the concrete offered benefits for students who live in remote areas without easy access to dance schools.

2.3.3 A means to practice without the pressure of a regular class.

Usui [79] introduces another point to support interactive dance learning, that of "using technologies as supporting tools to overcome anxiety and lack of experience, especially for young teachers. Motion capture and animation technologies could potentially lead to the development of new and exciting methods to help people learn dance". Although we do not propose the DILS as a replacement to a physical dance class, one cannot ignore the added value of creating tools for self-practice to support people who cannot afford attending classes regularly or suffer from anxiety when performing in front of other people, teachers or fellow students.

3. TOWARDS A CATEGORIZATION OF DANCE LEARNING SYSTEMS

As already mentioned, the objective of this paper is to provide an overview of the domain of DILS and to present and analyze the most crucial characteristics which define the digital learning experience, aiming at providing a handbook for comparison among systems, to foster understanding of the state-of-the art, as well as the identification of open issues which require further research.

This section firstly presents a categorization of technological tools designed for dance, which is the broader category interactive dance training systems belong to (Fig. 2), and, secondly, it proposes a framework and system workflow, highlighting design questions on the different phases of the interaction, that can then be used to categorize existing systems.

A significant point during the design of interactive tools for movement analysis in creative, educational, scientific and other contexts, as Alaoui et al [1] also suggest, is to describe the relation between the dancer's movement and the digital response. This link which is in fact the mapping between input and output modalities of the system is crucial for generating expressive cause-effect relationships that allow for a richer exploration of movement.
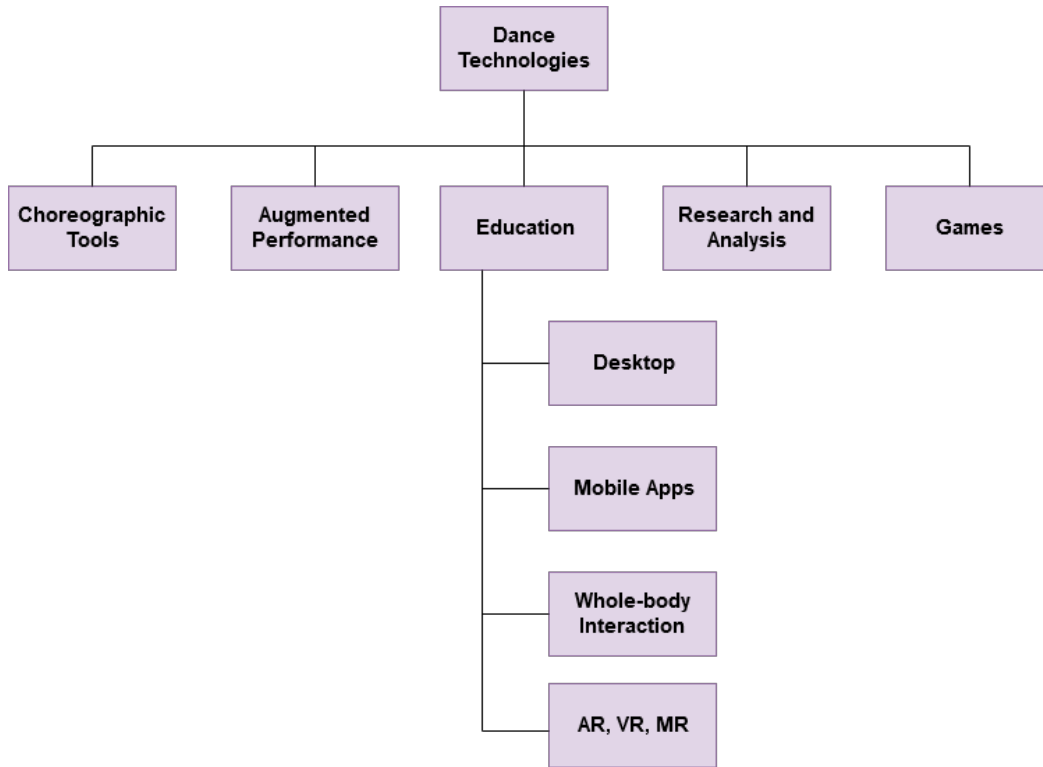
Fig. 2 A categorization of dance technologies, focusing on educational ones.

Table 2, focuses on digital technologies for learning and dance practice from an educational perspective and categorizes these tools depending on the mode of interaction and the devices used to facilitate the learning experience, including also examples of desktop web-based experiences like the one shown in Fig. 3. For the scope of this survey, we mainly focus on digital learning environments for dance which include whole-body interaction experiences and augmented/mixed and virtual environments, since they are the more complex to implement and require advanced and state of the art hardware, software and design of interaction. Although in this work we focus on learning environments, these categories apply in any of the aforementioned categories of dance technologies for different objectives (creative and artistic production, research and analysis, choreography, or gaming).
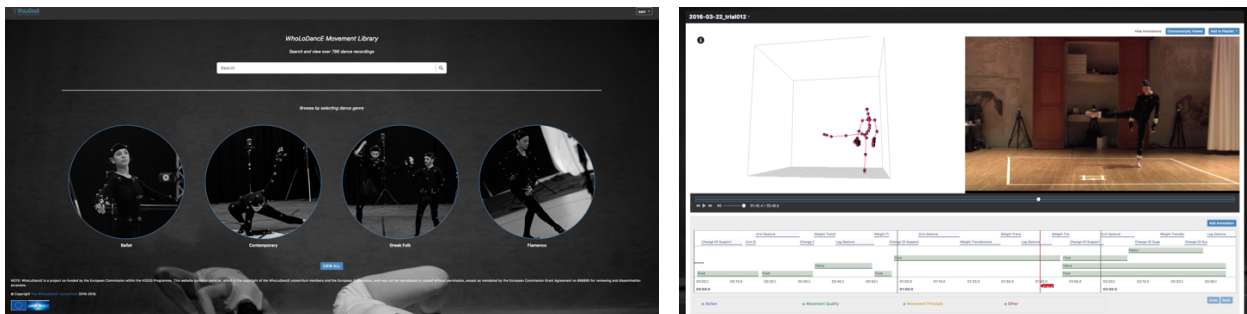

Fig. 3. WhoLoDancE Movement Library and Annotation tool in an example of a desktop & web-based technology tool for analyzing dance for educational purposes using semantic search of movement descriptors (such as turn, jump, symmetrical, fluid, light, etc.)

Alaoui et al. [1], propose a categorization of tools for dance from a more generic and artistic perspective into Reflective, Generative, Interactive, and Annotating tools. According to the authors, depending on their use and purpose these tools can be categorized as follows:

- Reflective tools, that apply various approaches to visualizing movement or structures, including systems that provoke reflection on shapes and structures of movement to enhance the user's perception.
- Generative tools that generate movement material either autonomously or manually.
- Interactive tools, that allow dancers to interact with a digital media that responds in real-time to their performance. In this case, the tools can be designed for assisting choreography, but also learning process by facilitating improvisation or exploration of the creative process through behaving as the dancer's virtual partner.
- Annotative tools, that allow to annotate (or describe) dance movement or structure during or after the rehearsal or a dance class and have a strong potential for assisting the learning process.

Although this categorization is focused on what the users do with these tools rather than the mode of interaction as in Table 2, depending on the teaching approach, all of the aforementioned categories could also be applied to dance education depending on the specific goal of each learning experience. Dance learning is usually perceived as an educational experience limited to learning moves and enhancing sensorimotor skills and performance. However, contemporary dance education systems include a wider range of required skills related to research and analysis and the ability to reflect on movement and to generate and compose new movement sequences. In fact, a successful learning tool might require combining more than one of the aforementioned functionalities.

Table 2. Categorization of Dance Education Digital Tools based on the type of experience they offer

Tools	Definition
Desktop (pc, laptop)	Desktop apps that support the more theoretical aspects related to dance practice. Such tools can include examples in the form of videos, audio, explanations of techniques, animation, annotation tools. These dance learning apps offer a user experience which is similar to the one of a more conventional Digital Learning Environment.
Mobile apps	Apps that can be used with a smartphone. The main difference from the desktop category is the opportunity they provide to capture movement through the movement of the smartphone.
Whole-body Interaction	This category of tools includes the motion capture of students' movement in various ways, such as Kinect and depth cameras, inertial and optical full motion capture systems, etc. The difference of this category from the two categories above is that they aim at providing particular feedback on the various aspects of student's movement (shape, quality, actions and tasks, etc.)
Augmented, Mixed and Virtual Reality Environments	This category can be seen as an evolution of whole-body interaction systems for dance movement since they intent both to visualize within a virtual environment an ideal sample movement for the student to follow, and also to capture the movement of the student and provide real time feedback.

4. INTERACTIVE DANCE LEARNING SYSTEM WORKFLOW

Focusing on recent advancements and state of the art on Dance Interactive Learning Systems, using both Whole-body Interaction Technologies and/or AR/MR/VR technologies, we can identify a specific, common workflow which exists (sometimes) partially to facilitate the interactive, learning experience. The general workflow presented in Fig. 4 consists of four phases of user interaction with the system:
1) Student Moving, 2) Capturing Student's Movement, 3) Processing Movement Data, 4) Feedback
As Fig. 4 shows, for each one of the phases, which can also be seen as individual components of a system, the designer needs to answer several questions before proceeding with an implementation. Depending on how the critical questions are answered in every phase the detailed workflow might lead to different experiences, where some phases

are more prominent than others, depending on the teaching approach, the trade-off between cost, complexity and effectiveness, and the actual needs of the dance teaching example. Based on this a DILS can vary from a very simple, low end application to a more sophisticated lab setting. However, not all DILS necessarily fully develop all the phases of this generic workflow as it will be demonstrated in Section 5. Depending on the design decisions, there are DILS which seem to skip one or more of these phases. In fact, they all phases are implemented in a less prominent manner for the student and without necessarily being less effective as learning tools. For example, an Initialization phase might be less obvious for the user, in a Generative approach, where the Student is not shown of particular movement to mimic, but leave more freedom to the user to do what they will, making the system less intrusive. Another example would be a system which do not necessarily evaluate the student's movement through comparison, but only maps the movement into another modality e.g., sounds with similar quality providing self-reflection.
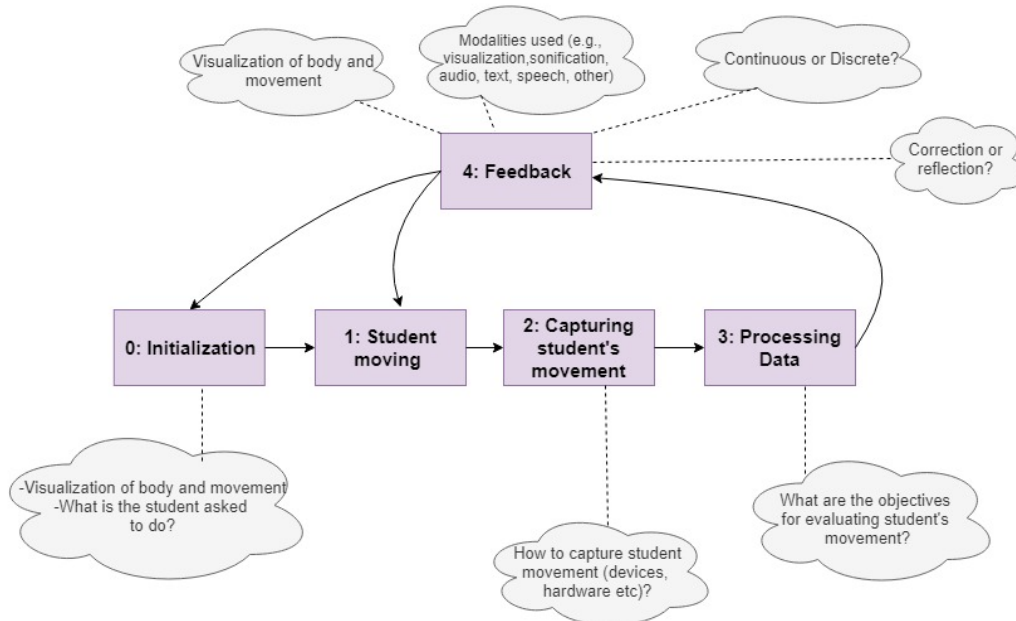

Fig. 4 Dance Interactive Learning Systems Workflow

The rest of the section focuses on the definition of each, as shown in Fig.4, and presenting the main design questions which are connected with each one of them. These questions constitute complex Human Computer Interaction challenges, some of which are presented in our previous work [33].

As we will also demonstrate in the next section, with examples of existing DILS, the most important factors which define a DILS in regards with dealing with those questions are the following:

Initialization: How the experience starts?

- Initiative (Frequency of Intervention/Timing) -What is the student asked to do?
- Visualization of body and movement.

Capturing the Student's movement: How to capture the student's movement?

- Equipment and setting (devices, hardware, etc.)

Processing (Movement) Data: What are the objectives for evaluating student's movement?

- Movement parameters to evaluate

Feedback Phase:

- Visualization of body and movement
- Modalities used (e.g., visualization, sonification, audio, text, speech, other)
- Continuous vs. Discrete
- Correction vs. Reflection

Phase-0 Initialization. In every interactive dance learning system, this is the pre-phase where the content presentation takes place. In this phase, the system invites the student to move, usually, but not always, through a demonstration of a prototype movement performance with an avatar. The movement of an expert, which is considered to be the "ideal" or "correct", is captured by a motion capture system and is used in order to animate an avatar. We will from now on, refer to this avatar as the teacher's avatar, since it is used to demonstrate the movement to the student, and sometimes also to compare the student's movement against it. However, there might also be other ways of providing the student with instructions, such as using abstract visualizations, or even other modalities, promoting thus a more *Reflective or Generative* approach on dance learning. Therefore, the presentation phase does not necessary imply the demonstration of a specific movement, but rather the way to stimulate the student's reaction and invite the student to start the experience.

Initiative. This point focuses on the initialization of the digital learning experience. In our previous work [33], this point was also described as Frequency of Intervention/Timing/Initiative. The initiative is related with how the experience is triggered and to what extent the students lead this experience or expect from the DILS to guide them with specific tasks. If this can be seen as an analogy between the Human to Human Interaction experience of teaching, the approach can vary depending on the teaching approach. So, for example a DILS which is designed after a Generative or Reflective approach is expected to leave the initiative to the student, through providing choices, and flexibility, whereas a DILS following the Traditional or Mimetic approach is expected to ask from the student to perform specific movement sequences and activities.

Visualization of body and movement. The question of how to visualize the initial move is present in both the Initialization phase and also during Feedback phase. The way of presenting the student's and/ or teacher's movement, is another characteristic to take into account at the feedback stage. The representation of the student's move individually, or in combination with the correct move (the teacher's move) is a very common way of providing corrective feedback as we will see in the next section. The way chosen for this visualization is also a characteristic to be examined for each system. Amongst the most common visualizations is a realistically rendered avatar or a skeleton avatar. This particular phase can raise many research and design decision question, as the representation of the body using 3D offers many opportunities for augmentation and abstraction of the body, as well as the risk of falling into the uncanny valley in case of using photorealistic anthropomorphic avatars. In addition, as we point in our previous work, the visualization can never be neutral, and it always somehow affects the qualitative aspects of movement [38]. On this point, we should also differentiate between the visualization of the virtual teacher body and movement, vs. the visualization of the students' body and movement. In the different DILS, there are cases where only the teachers' body and movement are visualized for giving instruction, cases where both teachers' and students body and movement are visualized side by side to provide visual comparison, and finally there as some DILS that only provide visualization of the student's body and movement for self-correction and reflection.

Two additional points on which we focus later on in this work are how the teacher's ideal movement has been captured (or generated) and how the different choices (e.g., selecting what to learn) are provided to the student.

Phase 1-Student Moving: The part that follows the initial presentation is the phase where the student reacts and starts moving. The student usually, but not always, depending on what they are asked in the initialization phase, they are trying to mimic what they see in the presentation. Therefore, another aspect to be examined is the "teaching approach". The teaching approach that is applied in each interactive system can be *Mimetic, Reflective, Generative or Traditional* (See Section 2). It is possible that there is a visualization of the student's movements already in this phase, although this mostly takes place in the feedback stage after the movements have been captured. For example, there may be a reflection of the student's image on a mirror. Some of the existing systems stop at this stage, repeating the loop of presentation and re-action and exhibit limited interaction possibilities in comparison to the ones that cover the full cycle of the interaction workflow.

Phase 2- Capturing the Student's Movement. The next phase, which is implemented in some of the existing educational systems, is the part where the motion of the student is captured through motion capture devices. The technology for capturing the student's motion is an important parameter to be examined for each system. The

technologies for capturing the student's movement can vary from full optical or inertial Motion Capture technologies, to lower-end technologies such as gyroscopes, accelerometers, Microsoft Kinect devices, etc. Most interactive systems, use capturing mainly for real time processing in order to provide feedback. Nevertheless it is important to note that this is also a mean of recording movement, and potentially create personal archive for a dance practitioner or student, either to reflect on it later, compare their progress across time, or re-use in a variety of applications that require study of human movement.

Equipment and setting. Another factor relevant with this phase is the type of equipment used and setting of motion capture, in relation to what is expected from the student in a task. Different equipment and settings present a variety of advantages and disadvantages, as Hong et al. report [47]. Several DILS described in the next section are using full optical motion capture technologies. This allows collecting high accuracy and quality data, but requires a specific laboratory setting and expensive, sophisticated equipment handled by expert personnel. On the other hand, lower cost and complexity equipment such as an individual or a combination of Kinect devices, inertial motion capture equipment or other depth cameras offer an easiest more cost-effective way to capture the students' movement, although they might present some limitations in terms of accuracy. It is also worth mentioning that each type of equipment can be considered appropriate or not, not only based on accuracy and ease of use, but also based on the characteristics of the dance genre and learning practice to be applied.

Phase 3 -Movement Data Processing. After capturing, the processing of the data is the next possible stage. There, in most cases, the movement performed by the student is compared with the one of the teachers. The most common way for movement comparison is by measuring the Euclidean distance between the two body parts and determining whether the divergence is within desirable limits. The method of comparison that each system uses is presented in the following sections. Nevertheless, depending on the context, equipment, teaching approach adopted, the aspects of the movement to be analyzed might vary (shape of movement, sequence of steps, rhythm, qualities, etc.). This particular phase, as well as the initialization phase in case pre-recorded data are stored, present a number of data related computing problems such as storage, management, semantic search, pattern recognition and similarity search, etc. Another critical question of this points is how and when the data of students are stored or shared. Monitoring one's movement across time or just record to reproduce later can offer a variety of benefits not only for dance, but also in other related to movement applications also for teachers or physicians e.g., it might be a tool for identifying common mistakes in data becoming from different users.

Movement parameters to evaluate. What are the objectives for comparing the students' movement vs. the ideal movement? Motion accuracy, rhythmicality, body balance, weight distribution between two feet, expression, effort, fluidity etc. can be some of the qualitative and quantitative aspects that describe a dance performance. We consider that the aspects of evaluation are the qualitative objective of the feedback, or in other words, what the feedback refers to, so we incorporated them in the feedback category in order to give the reader a holistic understanding. It is also worth mentioning that this aspect can be highly related to the specific scenario and context of use of a particular tool (dance genre, learning objective, age, level of expertise, etc.) as well as to the technologies used to capture the students' movement since they create a limitation. If for example the ideal movement is produced through a full motion capture optical system, with high accuracy, it is not very meaningful to compare the accuracy of movement while the students' movement is captured through a depth camera, with much lower accuracy.

Phase 4 -Feedback After the data processing phase the system generates feedback for the user that leads to a new presentation (a new call for action to the user) and therefore an initiation of a new interaction workflow cycle. Many aspects are involved in describing system feedback since it is a crucial stage for the system usability and efficiency. The "visualization of the correct initial movement in the initial demonstration", if there is one, can be considered the ideal movement that its characteristics are to be examined next and compared to the students' performance. Last but not least, this phase can also include a presentation, through more traditional means such as video, audio, oral

instruction, texts or any other output of the system which will evoke the student to start the learning experience workflow.

As mentioned above, in the phase of feedback some of the most important design questions are related to when and how to provide feedback to the student. In other words, the "Frequency timing-initialization" as well as the "way of intervention" that are also presented in our previous work [33] can be further analyzed into the following main aspects:

- Visualization of body and movement
- Modalities used (e.g., visualization, sonification, audio, text, speech, other)
- Continuous vs. Discrete
- Correction vs. Reflection vs. Judgement

Continuous vs. Discreet feedback. Another feedback categorization describing the interaction is whether the feedback is continuous or discrete. For example, visualizing one's movement in real time is a way to provide feedback continuously, without interrupting the sequential or continuous process of dancing. In the discrete mode of interaction, the user performs a movement, or a short sequence and the system responds with feedback [33]. An interactive system can use all tools that are used in corrective feedback in a continuous or a discrete way or even in a combination of both. Fig. 5 shows a WhoLoDancE project prototype of using AR devices to visualize one's own avatar real-time while wearing a motion capture suit.
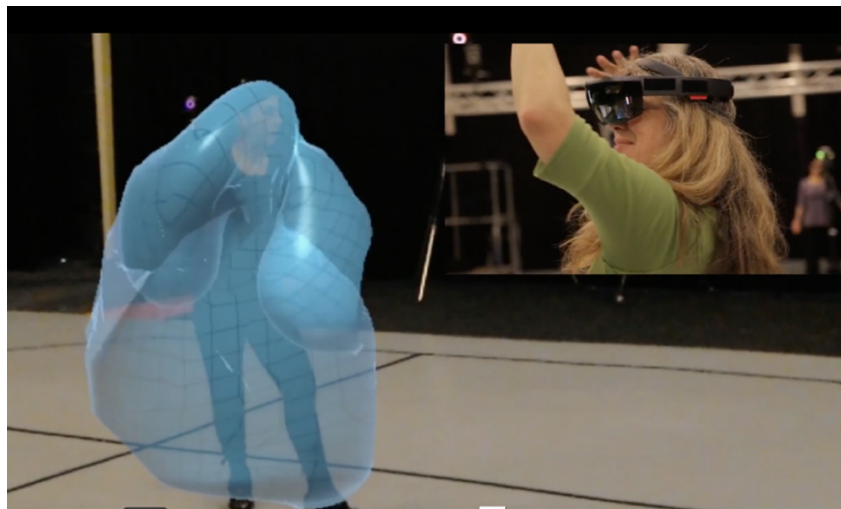

Fig. 5 WhoLoDancE prototype with HoloLens-an example of providing continuous real-time, reflective feedback

Correction vs. Reflection. A distinction is whether the system provides corrective or reflective feedback. This question is related mainly with the Feedback but the answer to it also affects the Processing of Data stage. Correction, which occurs in a traditional educational model, means that the system has set a codification in order to show to the students how close they are to the "right" movement or manner of movement. Another important point regarding corrective feedback is to differentiate between providing an overall score or judgment and providing specific corrective instruction suggesting improvements on particular body parts or aspects of movement, as Trajkova highlights [77]. The corrective feedback can be either explicit on body parts, by using techniques like color coding on body parts, overlaid avatars, etc. to provide visualizations useful for indicating the student's mistakes, or an overall evaluation of the student's performance by providing scores in numeric or graphical format. These characteristics are explained in detail in the next section.

According to the recent, and contemporary approaches to dance, especially following the Reflective and Generative approach, feedback does not necessarily need to be in the form of a "correction" or a "score" comparing student's

movement with an ideal one, especially if the tool is addressing advanced, experienced dancers and dance genres where the right and wrong way of moving can be very subjective, as is the case of contemporary dance. An interactive tool can also facilitate an effective learning experience if it provides structures and modalities for self-evaluation and reflection. This parameter differentiates the feedback given by the system, depending on the inclusion of semantic meaning. In Reflection, however, the feedback does not imply "right or wrong" semantics; the system provides open feedback on what the students do. This is usually the case when the Reflective or Generative teaching approach is applied [33].

Apart from the aforementioned characteristics which are generally relevant in most of the interactive systems in this review, there are other characteristics relevant in some of the systems, including the technical means for motion capture of the teacher's movement, devices, context of use, target group, portability, online vs. offline use, commercial or academic usage and the overall system architecture approach. These features are also very important for the description of an interactive dance training system. The type of dance, target group and whether the system is commercial or academic will be presented in the summary table of Section, but they will not be discussed in detail in this work. The rest will be further analyzed in Section 5 along with the rest of the interaction characteristics.
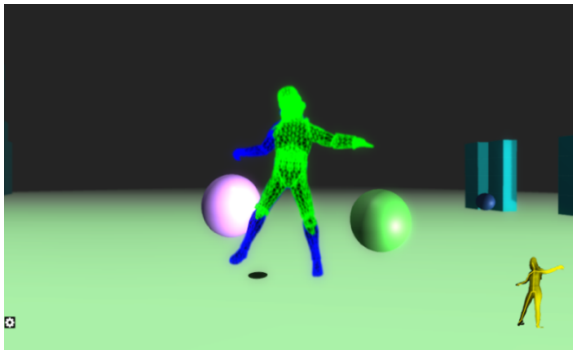

Fig. 6. WhoLoDancE prototype where reflective feedback is provided through different avatars, movement visualizations and interaction with objects
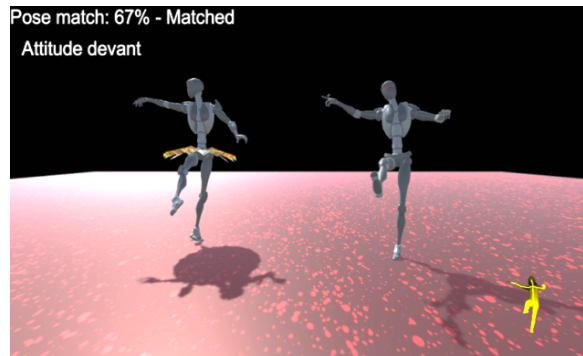

Fig. 7-WhoLoDancE prototype where Judgement feedback is provided through a score value

5. DANCE INTERACTIVE LEARNING SYSTEMS (DILS)

In this section, we present the main aspects and characteristics that describe a dance interactive learning system and examine how these characteristics have so far been implemented in such systems.

5.1 DILS in relation to workflow phases characteristics

Existing systems adopt different approaches as to which phases of the workflow presented in Section 4 they implement and how they address the various design decisions. In most interactive systems for dance education, the motion of an expert is captured and being demonstrated as the proper way of executing a move and often as a way of comparing the student's move towards an ideal or professional performance.

The most common scenario encountered is the following: During an interactive dance learning session, the user (student) is watching a demonstration from an expert (virtual teacher). Then, the student is trying to mimic the performance they watched, and her moves are recorded through a motion capture system. As in the work of Aristidou et al. [6] "the student's motion is then analyzed and compared to the teacher's motion" and therefore, an evaluation of student's performance is generated.

This type of system consists of the following parts: 1) motion demonstration through representing a stored pre-recorded motion captured movement of an expert from a database, usually using a rendered avatar, 2) the student is

asked to imitate the ideal movement, 3) the student is motion captured and her movement is compared with the ideal one in the database, and finally 4) the student is provided with a score value as feedback. This workflow can be recognized in "the virtual reality dance training system" proposed by Chan et al.[23], in the work of Essid et al.[39], as well as in the interactive dance training system of Alexiadis et al.[3]. A variation of this theme implies that the students are mimicking a movement example that has been demonstrated to them, but of their own choice.

Similarly, continuing a work presented by Sun et al.[75], discussed also by Kyan et al. [54] describe a ballet training system where the students follow the instructions of a virtual teacher. Their movement is compared with the ideal one and feedback it provided to the student. The workflow proposed by Kyan et al. [54] consists of the following stages: Motion demonstration, motion capture of the expert (motion database), motion capture of the student, gesture recognition algorithm, motion comparison and feedback.

Finally, another subcategory of the first group is differentiated from the rest in the following way: There is no demonstration by a virtual teacher and the students are asked to perform a movement of their own choice. Then their captured motion is being processed with a motion recognition algorithm and compared with the corresponding movements, from a movement database. Therefore, the workflow of these interactive systems consists of motion capture of the student, motion capture of the teacher, motion recognition algorithm, retrieval from the motion database, motion comparison algorithm and feedback. An example of this approach is the SuperMirror interactive dance training system by Marquardt et al. [58]. In cases such as the one developed in the WhoLoDancE project by [78] the DILS can be seen as a helpful tool for movement improvisation and exploration of different movement patterns, qualities and combinations inspired by the visual feedback [38].

5.2 Varieties of DILS based on Workflow Design Decisions

In the following section we present existing DILS based on the different ways they address the design questions on each phase of the workflow.

5. 2. 1. Initialization-What does the system expect from the user?

The teaching approaches. In relation to the adoption of a teaching /learning method, as the ones described in Section 2 (Mimetic, Traditional, Reflective, Generative), in the current bibliography for systems that focus in education, the predominant method is the Mimetic. That implies that the students after watching a demonstration of the proper move, they should try to mimic what they see and take into consideration the feedback from the system that will eventually improve their performance.

Some of the few Interactive Systems that are not implying mimesis but rather a reflective teaching approach or movement experimentation are Choreomorphy [38] [78], Delay Mirror [60], and Whatever Dance Toolbox by BAD co. [7]. Whatever Dance Toolbox offers a toolset for dancers and choreographers. The included tools help them create, develop and rehearse dance. They can also be used in an educational context or even by dance researchers to explore movement.[35] The tools and functions that Whatever dance Toolbox provides, set tasks to the dancer instead of indicating a correct way of executing the movement.

Choreomorphy[38][78]provides real-time feedback through visualization of movement effects and inspires the dancers by seeing themselves in different avatars in gender, shape, size, etc. It also provides an interface which makes it easy for the non-technical experts to change visualizations and avatars. In WhoLoDancE project[81], visual imagery is one of the main teaching and choreographic directions which guides the design of the learning experiences, as it has been widely applied in a variety of movement or somatic practices [80] and applications [9].

Selecting the move to learn: Usually the users are browsing through a list of movement segments or dance sequences until they find the one that they are interested in. A similar approach is investigated in the WhoLoDancE project, where the students would be able search by movement, based on similarity, a large library of pre- recorded movements of ballet, contemporary, Greek folk dances and flamenco [16]. In other systems, such as the one proposed by Aristidou et al. [6] "the student selects the desired dance to learn and a 3D avatar (teacher) selects arbitrary dance motion primitives from the template motions and demonstrates it to the user (student)", providing partly the decision

to the student. YouMove by Anderson et al. [4] is another example of such a system. The option of selecting the desired move to learn is an option given in YouMove as well. In "You Move" [4], there is the option of "query by example" where the student holds a representative posture attempting to reproduce the desired movement as a still pose which is matched with a set of similar ones from the system movement library. These are presented to the user in a grid form to select the best match. In the same system, there is another feature that gives the student the opportunity to customize their training and therefore can be considered as a special adjustment. Finally, YouMove [4] provides another feature that could be considered as a personal user setting. It gives the opportunity to record a new move, which will be added to the motion library of the system. The recording system is designed to be easy to use, so anyone can capture movement sequences and annotate them for learning, without the need for complicated motion capture hardware or software [4]. We notice, that this point of deciding what to show next within a DILS, or what options should be provided to the student according to teaching approach, dance genre, learning objectives or other preferences is not extensively addressed. In addition, providing tools for teachers or systems to easily create new movement content is still an open issue.

Technologies for capturing the teacher's movement. As it has already been mentioned, most of the interactive systems for dance education capture the movement of an expert dancer (teacher) in order to use it as demonstration only or as a golden standard for movement comparison. Most of the systems use Microsoft Kinect Sensors for capturing the teacher's movement because of its low cost and its portability. Such systems are: "Super Mirror"[58] and "You Move", while Alexiadis [3] and Kyan et al.[54] in their attempt to design interactive systems for ballet education, also propose MS Kinect for capturing the teacher's motion. Although Kinect is highly popular among the interactive systems for dance education, several systems capture the teacher's motion through optical motion capture technology which can provide very high accuracy. WhoLoDancE project [81], WebDANCE [8][52], OpenDance [57] project and the Multi-modal dance corpus by Essid et al. [39]are such systems. WhoLoDancE [81] in particular, has used state-of the-art motion capture systems (Vicon cameras) also combined with other devices such as gyroscopes, accelerometers, video cameras and microphones for recording the respiration of dancers. Hula dance training [79], as well, is designed using optical motion capture, along with the Virtual reality dance training system of Chan et al.[22] Finally, a very accurate apparatus is proposed in the Folk-dance training system of Aristidou et al.[6].

Visualization of the teacher. As it has already been noted, in many of the reviewed systems there is an initial demonstration of a dance move or a sequence of moves that the student should try to reproduce. In the case of the initial demonstration, the most common way to present the teacher is with a realistically rendered avatar. In other cases, a real representation of the teacher, through a video, is used, like in "You Move" by Anderson [4]. A skeletal avatar is introduced by Usui et al. [79] in the Hawaiian Hula Dance training project. In this work, the authors suggest that the student should observe a skeletal representation of their own previous performance, to correct their mistakes. Several other systems such as the aforementioned Laban Dancer, Life forms and others have focused on creating 3D visualizations for representing choreographies[63].

5.2.2 Student Moving-How to capture movement?

Equipment - Type of Experience. The presentation devices that each system employs are usually selected taking into account the objectives of the approach along with possible cost considerations. Most of the systems make use of a 2D display to present the result, although some employ more complex or advanced solutions. For example, "YouMove" uses an augmented reality mirror that offers the possibility for both physical representation and projections onto the user's avatar. The ballet dance learning environment by Kyan et al. [54] provides instructions through 3D visualizations using CAVE virtual reality technologies. Moreover, for the creation of a fully immersive environment, a head-mounted display is proposed by Chan et al.[22]. A rich collection of hardware devices is proposed in the Multi-modal dance corpus[39]. This system uses a variety of media modalities to capture concurrently teacher and student choreographies at two different sites. The Choreomorphy [38][78] prototype system developed in the context of the research project WhoLoDancE [81] follows a similar approach.

The aforementioned systems try to increase the level of interactivity with 3D display approaches. However, the majority of the interactive systems that are presented in this work use a simple 2D display. Despite the two-dimensionality of the display, these systems offer 3D interaction since the users can change their point of view to observe the teacher from different angles. We can see examples of this approach in the WebDANCE [8][52], as well as in other projects (WhoLoDancE [81], Aristidou et al. [5][6], Alexiadis et al. .[3], Usui et al[79]). Usui et al., in particular in the Hawaiian Hula training system, claim that students can improve their performance by using only a tablet device. The lack of 3D interaction is seen in SuperMirror [58] since both teacher and students are visualized in a screen without the possibility of changing viewpoints, zooming, rotating, etc.

5.2.3 Data Processing: What are the movement aspects that the system evaluates and how?
Movement aspects to evaluate.
Since dance evaluation is a complex aspect which involves a variety of parameters (accuracy, timing, shape, speed, etc.) which is hard to combine all at once, most of the systems that have been designed for assisting dance teaching focus on specific aspects providing a score-value. In that case, an initial demonstration of a movement is provided, and the student is asked to mimic, then motion accuracy is the main aspect to be examined. Moreover, the timing (rhythmicality) is also taken under consideration in the estimation of the final result because the movement of the student must be similar in timing with the one of the teachers. Systems trying to evaluate the performance in terms of motion accuracy and musical timing (rhythmicality) are You Move, the Multi-modal dance corpus[39], the virtual reality dance training system of Chan et al, as well as the works of Alexiadis et al. [3] and Kyan et al.[54]. Motion accuracy in comparison to a movement from an existing database is also used in cases where there is not an initial demonstration, e.g., Super Mirror [58]. In this particular example, the movement is processed through a motion recognition algorithm, the system extracts the corresponding move and it compares its motion accuracy with the one that has been executed by the student.
The multi-modal dance corpus proposed by Essid et al.[39] , apart from musical timing and motion accuracy aims to give further corrections in "Upper-body fluidity", the fluidity of the dancer's upper-body movements and "Lower-body fluidity", the fluidity of the dancer's lower-body movements, "body balance" and choreography. "Although technically the captured data can be of very high quality, dancing allows stylistic variations and improvisations that cannot be easily identified. Most motion analysis algorithms are based on ad-hoc quantitative metrics, thus do not usually provide insights on movement qualities of a performance", as Aristidou et.al. indicate [6]. Various efforts such as the ones by Camurri[15][17], Fdili et al. [40], Piana et.al. [66] and others highlight the importance of the movement qualities in dance performance and learning rather than the shape and form of the movement. Camurri et. al [15], propose dynamic symmetry, as one of the possible movement qualities used to evaluate students dance movement. Aristidou et al. [6] present a "framework based on the principles of Laban Movement Analysis (LMA) that aims to identify style qualities in dance motions".
The most common aspects that are evaluated in the presented interactive systems are the following:
- Motion accuracy refers to the extent that the posture of the student matches the posture of the teacher at each time frame. When there is a high number of matches between the two postures during a complete move, the motion accuracy is considered to be high.
- Rhythmicality: Timing and rhythm of the movement, as demonstrated by the expert
- Particular movement qualities, as the ones proposed by Camurri [17] e.g., balance, equilibrium, dynamic symmetry.
- Sequence Accuracy: it refers to the motion accuracy over time.

Method of comparison. The most common way of making the comparison between the teacher and the student's moves is by measuring the Euclidean distance between the joints or body parts of the two features. If there is also a time accuracy evaluation, then the comparison of the distance refers to a specific time point. This method is used by Kyan et al. [54] in the ballet training system that they propose and also by Alexiadis et al [3], by Chan et al [22] and Anderson et al. [4]. SuperMirror provides users only with motion accuracy feedback and uses the Euclidean distance between the body parts to compare the movements. A different approach is used in "Folk Dance Evaluation Using

Laban Movement Analysis" [6], where the comparison is based on "Laban Movement Analysis" and Effort in particular.

5.2.4 Feedback
Feedback - Continuous vs discrete
A very important point that we need to take under consideration when designing the interaction between the system and the user is whether the feedback is continuous or discrete. For example, visualizing one's movement in real time is a way to provide feedback continuously, without interrupting the sequential or continuous performance of the dancer. In the discrete mode of interaction, the user performs a movement, or a short sequence and then the system responds with feedback [33]. Some of the systems provide their users with continuous feedback, some of them only with discrete. It is also a common practice for many systems to give both kinds of feedback.
Super Mirror[58] and Choreomorphy[38] are some of the systems that provide only continuous feedback, while Delayed Mirror provides a discrete feedback. The same is done by Alexiadis et al.[3] in an evaluation of "a dancer's performance using Kinect skeleton tracking". The creators of the "multi-modal dance corpus"[39] and the "Folk-dance evaluation"[6], on the other hand chose to provide the students only with discrete feedback.
Depending on the specific needs and context both approaches might be helpful, since while the continuous feedback is immediate, real-time and does not interrupt the dancing of the student, it might be disruptive as the student will have to focus on another image, screen or modality while dancing.
Feedback - Correction vs. reflection.
We can identify two main groups of interactive systems for dance education from this perspective. The first includes systems that capture the student's motion with real time skeleton tracking with the purpose of giving back a corrective feedback. The second, on the other hand includes those that do not necessarily provide evaluation results in terms of performance in the form of scores or judgment, but they rather focus on providing different presentation and feedback on the student's movement through different modalities and leave the user/student to reflect on her/his own movement and performance. "The correction feedback that the training system provides does not need to be an exclusively quantitative score, but it may also involve a visual comparison between the teacher and student avatars", as proposed by Kyan[54].
A visualization for correction feedback can be the student's and teacher's avatars shown side by side or overlaid so that the mistakes and divergence from the golden standard can be easily detected. "Coloring or circling the body parts the movement of which is not the ideal one, is also a common practice that interactive systems for dance education use, for highlighting the student's mistakes.", as Chan suggests [22].
    A more traditional and qualitative method of providing corrective feedback, is by generating performance scores in the form of numbers, charts, curves, pass-fail indications, golden stars, "hits" or "misses", etc. Almost every system that we examine in this work provides feedback for correction and not reflection. Few systems provide reflective feedback, such as in the Whatever Dance Toolbox [7] through its Delay& reverse mode, Capture & replay and appear & disappear modes, Choreomorphy [38] through the various trails and traces and other visualizations, and the system proposed by Piana et al. through sonification of the dynamic symmetry[66] .
A system that facilitates a reflective approach can provide functionalities for one to observe or reflect on their own movement, rather than compare the movement to a "golden standard". That type of system seems to be more appropriate to more advanced, or even professional dancers, who need something more than learning specific steps, or mimicking a pre-recorded sequence. Loke et al. [55] provide a detailed categorization and examples on the design tools which can be applied according to the different purposes of interacting through movement. Tsampounaris et. al [78] propose a whole-body interaction experience which evokes the practitioners to observe their movement through different avatars and visualizations, changing them according to the aspects of focus. This category of tools (Reflective) invite the student or dance practitioner to dance or even improvise while they provide visual feedback rather than a judgment on the correctness on the movement. Depending on the context of use and dance genre this absence of specific correction or score can be an advantage as the experience becomes more open to the creativity of

the users and thus it can become a useful tool for dance improvisation and reflection on one's own movement, in a freer and less stressful manner. Usui et al.[79] have developed a training system for Hula-Dance, using tablets where the students can correct themselves after seeing their movement on a skeletal avatar. Although in this case the system does not play the role of correcting or judging the movement, it provides a tool for objective self-observation. Unlike video recording, the student can see only their movement isolated from the shape of face, body, clothing, anything that may distract from the movement itself and its details. Also, the added value of such tools comparing to video recording is the option of seeing the movement in 3D, rather from one perspective. In addition, 3D motion captured sequences can be studied in detail and the teaching tool can be used as a supporting tool for learning traditional and folk dances, a case applied in the projects WhoLoDancE[81] and WebDANCE [8][52].

Feedback- Corrective feedback – explicit on body parts.
A very common way of providing the users with real time feedback is by letting them review mistakes during their performance or after they completed it. One technique to do that is by circling the part of the body with inadequate performance. We can see that method in the system "You Move", where errors "in joint position are indicated by red circles"[4].Color coding is a very popular method of visualizing the student's mistakes. In systems "Super Mirror"[58], "You Move"[4] and "Virtual reality dance training system"[22], different color is applied in the body parts the movement of which should be improved. More specifically in Chan et al.'s work [22], the student's skeleton parts are turning from yellow to red when they diverge from the teacher avatar's way of moving. As the authors describe, "the color shows the correctness of the limb movement from deep red to white in ascending order according to the correctness. When the student finds a body part in red, he/she then checks the correct position from the virtual teacher, which is also rendered in the replay. Sometimes, the error may occur because of wrong timing of launching individual moves, which can also be found by comparing the motion of the virtual representative and the virtual teacher".
Another very common technique for communicating the user's performance and mistakes is showing the user's and teacher's avatars side by side, so that the user's moves can be seen and compared against a golden standard. This technique is common among the ballet training systems (Super Mirror[58], ballet dance training in a CAVE environment[54]) and applied in most of the recent works on DILS (Alexiadis et al. [3], Chan et al.[22], Aristidou et al. [5,6]).
   Overlaid figures of teacher and student are also used in many of the examined systems of teaching dance, so that the student is encouraged to perform well in order to stay aligned with the teacher. "You Move" is visualizing student and teacher's skeletons as overlaid figures in order to give feedback after the student's performance and a similar approach is followed in Kyan et al.'s ballet training system [54].

Corrective feedback – Student's overall performance results
Most of the systems use scores as a way of evaluating the student's performance. The scores are numeric representations of the achieved result (usually a percentage or a number).
In "You Move" system, according to the authors, "the learning experience consists of a series of stages, and each stage scores the user's performance based on the similarity between their movement and the target movement" [4]. Alexiadis et al.[3], provide "visualization of the temporally aligned dance movement of both teacher and students, , along with the associated evaluation scores, in a virtual 3D gaming environment". "Three scores are calculated as well, in the work of which are subsequently combined to produce an overall score" [3]. Another example of the importance of scoring in designing dance training is seen in the work of Chan et al[22], where "students are shown a general report about their performance. From the report, students can get an idea about which joint is better and which joint may need improvement" [22]. Finally, a score from 1 to 5 is provided by the system proposed by Essid et al. [39]. Corrective feedback is also provided in the system E-Ballet[77] in the form of emojis. Emojis are one of four different modes used. The rest include: "value verbal, visual corrective, and verbal corrective" types of feedback.

Feedback -Visualization of the correct position in the feedback phase

Some interactive systems for dance education combine the initial demonstration of the "correct" way of executing a move with the presentation of the "correct" way also in the feedback phase. However, it is not always expected that the modality of visualizing the teacher will be the same in the two stages of the learning procedure. In YouMove[4] as well as SuperMirror [58] a skeletal avatar is used as a way of representing the correct moves and position in the feedback phase. Another popular visualization is to use a photorealistic avatar. Alexiadis [3], Aristidou [6] and Kyan et al. [54], seem to adopt this method. WebDANCE [8][52], OpenDance[57] and the system for training in Hawaiian Hula dance [79] do not provide this kind of feedback since there is no capture of the student's moves. Finally, the multi modal dance corpus, gives feedback on the student's performance, without visualizing the "correct" way in the feedback phase.

Feedback- Evaluation presentation
Both a numeric and graph is provided as a score in the ballet training system of Kyan et al.[54][53]. Aristidou et al. [6] describe the "pass – fail" system as a more quantitative method as no specific number that indicates success, only a pass or fail mark, depending on how close the student is in comparison to the teacher's performance in terms of LMA efforts. The authors state that the overall "fail-pass" indication might be more effective for beginners than indicating body parts. On one hand providing feedback which goes beyond the precision of Body and Shape and evaluates the qualitative aspects of movement is critical, on the other hand "pass-fail" indication is closer to an overall judgment or score in a game experience rather to feedback which explains what it is wrong and how can be improved, which seems to be a challenging aspect in DILS. As a way of encouraging the student, in Super Mirror [58] a "hit" icon flashes in the screen when the student's move matches with the teacher's, whereas in You Move the users get a golden star if their performance quality is high enough. More specifically, in Super Mirror, student's moves are characterized by "hits" or "misses" when there is correspondence, or lack of correspondence, with a prerecorded pose [58]. Therefore, the system does not provide an overall result for the student's performance, but rather it characterizes every specific move as correct or incorrect. The usability of Super Mirror has been reported by Trajkova & Ferati [76]. Whatever Dance Toolbox [7] provides corrective feedback as well, since there are specific tasks that the student should complete in order to move to the next one. So, it follows a pass-fail mentality, in specific features. Other tools of the same system that provide a pass-fail evaluation feedback are "Matching positions", "Cage" and "Inertia".

Feedback- Tools for self-correction and Reflection
Some interactive systems are designed with extra features for stimulating and helping the students with their performance. In SuperMirror [58] for example, the student is prepared for the next position with the following technique: During her performance he/she sees as continuous feedback two skeleton models, in gray and blue. The gray figure demonstrates the correct final position and the blue one, the movement that leads to this position.
A similar feature is observed in YouMove [4]. In the movement guide, "the system provides 'cue ribbons' – 3D trajectories that help the user with timing by visualizing the upcoming movements" [4].
Another type of helpful feedback is "the slow-motion replay" suggested by Chan et al. [22]. According to the authors "Through the slow-motion replay, students can realize the errors in each posture by observing the color on their virtual representatives". Playback options seem to be a desired characteristic in the ballet training system of Kyan et al.[54] as well. Based on their description "one key element in ballet training is the synchronization of movements to music. The beginning and endings of dance phrases have particular importance"... "To help reinforce the importance of these key moments, (they) have developed three playback modes, which are normal mode, key posture mode, and tempo mode."Whatever Dance Toolbox [7] is not designed to help master a move in terms of its form movement and shape of the body but rather focuses on the meaning and quality of the movement itself. It employs visual analysis, tasks and temporally manipulated reproduction of captured images to allow dancers and choreographers to study and move towards more complex movement and composition. The machine factor generates an organization of choreographic elements different to what other choreographic methodologies can produce. We could say that it offers a way of exploring and improvising with one's way of moving, and it is more productive when used collaboratively.
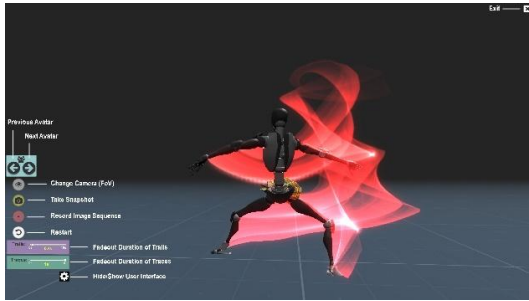
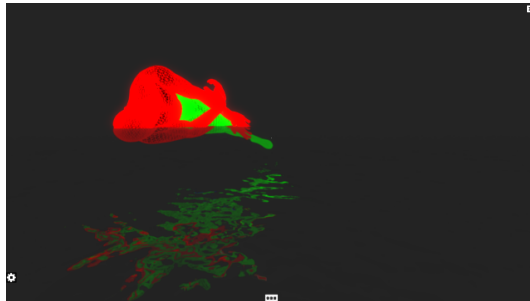Fig. 8. Choreomorphy Basic Interface
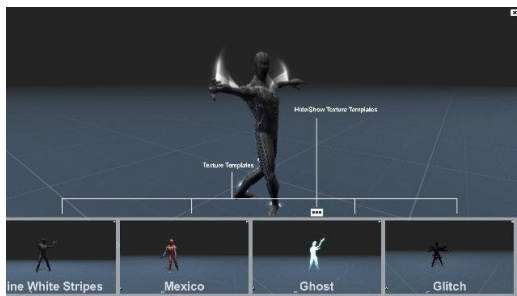

Fig. 9. Choreomorphy Water Scene
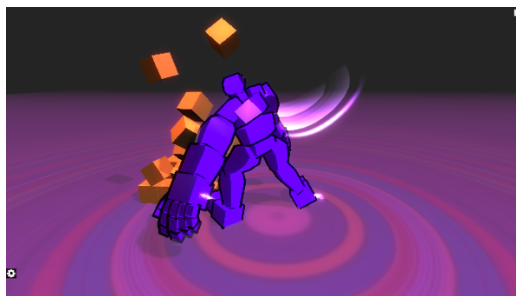

Fig. 10 Choreomorphy Texture template Menu

Fig. 11 Choreomorphy Interaction with virtual objects

Feedback -Visualization of the student. As already mentioned, systems with higher interactivity capture the student's movements and present them as part of the feedback procedure. Most of them, like in the initial demonstration phase, are visualizing the student in the form of a physically rendered avatar. However, there are a few cases of systems that choose to visualize the student as a skeletal avatar. SuperMirror is such an example. A skeletal avatar is also used in a virtual reality dance training system proposed by Chan et al.[22] The feedback that YouMove[4] provides is a combination of a natural mirror reflection and a skeletal avatar. What it does, is to project the user's skeleton, tracked by an MS Kinect, onto the student's reflection in an augmented reality mirror. In that way, the student is having an augmented, thorough understanding of her body posture and movements. Other systems represent the student's moves with physically rendered avatars. (Alexiadis et al.[3], Aristidou et al. [5][6], Kyan et al.[54], Essid et al.[39]). In Whatever Dance Toolbox [7], the way of visualizing the students in the feedback phase depends on the tool that they are using at the time and her personal preferences. In the text above, we discuss the importance of seeing one's own movement in different avatars in real-time and the way this might affect the focus on particular aspect of movement (shape vs. qualities), the way of moving (qualities) but also mood, emotion and creativity [38]. Fig.8, Fig.9, Fig.10 and Fig. 11, show some of these visualizations.

5.3 Other Characteristics of DILS

Distant and online learning

The majority of DILS, as Aristidou notes "do not intend to replace traditional dance tuition, but to provide an additional tool for training and education in dance, both at home and at school"[6]. Some systems such as WebDANCE[8][52], WhoLoDancE [81], and E-Ballet[77] are proposing a learning environment which can be accessed online. In their multi-modal corpus, Essid et al.[39] propose the scenario of an online class where the teacher will perform certain choreographies, and the students will repeat and present them through their virtual avatar in the online studio. Although the data corpus is tailored specifically for an online dance class application scenario, the data is free to download and use for any research and development purposes [39].

Portability

Systems which require heavy or complex equipment are considered less portable than others. For example, a Kinect based system can be considered as highly portable, but when the system includes complex augmented reality devices, optical motion capture for the student, etc. is not as portable. Super Mirror [58], WebDANCE [8][52] and the system for learning Hawaiian Hula [79] are therefore portable systems since they require only screens and the Kinect sensor, so is the system proposed by Alexiadis et al.[3] in his work for a dancer's performance evaluation.

The rest are considered to be non-portable. YouMove [4] needs an augmented reality mirror for its function which is too large to transport easily. The ballet dance training approach proposed by Kyan et al. [54] requires a CAVE virtual reality environment and the multi dance corpus includes too many devices (synchronized audio rigs, multiple cameras, wearable inertial measurement devices, depth sensors) that make its portability quite difficult.

Finally, the virtual reality dance training system proposed by Chan et. al [22] as well as the folk-dance evaluation of Aristidou et al.[6] require optical motion tracking of the user, therefore they cannot be considered as portable systems.

Whatever dance Toolbox can be considered as equally portable and non- portable, since it is more effective using a projector, however, it can also work with a simple screen. Table 1 presents an overview of the technologies related to dance education and summarizes part of the interaction characteristics, mostly related with feedback. These include: visualization of correct position in the initial demonstration, teaching approach, aspects of evaluating student's performance, visualization of the student in feedback, visualization of correct position in feedback, correction vs reflection, continuous vs discreet feedback, etc. We foresee that the percentage of portable vs. non-portable devices will rapidly change in the near future in favour of the former, following the rapid advance in the domain of motion capture and related hardware.

More technical information about the systems like the technologies used for capturing the student's and teacher's moves, the devices, whether the system is academic or commercial, portable or not, the kind of dance it supports, can be found in Table II.

Table 3 DILS characteristics in relation to the interaction workflow phases

| | DILS | Initialization | Capturing student's moves | Movement Parameters to evaluate | Visualization | | Correction, Judgment, Reflection | Continuous vs. Discrete |
					of student avatar	correct position in feedback		
1	Chan [22]	Demonstration of a movement by expert (3D avatar)	Optical motion capture	-Motion accuracy, Musical Timing	Skeleton	Avatar	**Correction and Judgment:** Side by side, Color coding, Score as number for each body part, slow motion	Continuous and discrete
2	Kyan [54]	Demonstration of a movement by expert (3D avatar)	Kinect	-Motion accuracy, Musical Timing	Avatar	Avatar	**Correction and Judgment:** side by side, overlay, slow motion playback, score as number, score as graph, use of a metronome	Continuous and discrete
3	Camurri [15]	Student performs on their own or along with the teacher	Kinect	Movement Qualities: Dynamic Symmetry, synchronization?	n/a	n/a	-**Reflection** -**Value feedback** auditory feedback –musical rewarding	Discrete
4	Choreomorphy [38] [78]	Depends on the mode	Optical-Inertial Motion Capture, Kinect	n/a	3D avatar	n/a	**Reflection:** different avatar visualizations	Continuous
5	Delay Mirror, Molina [60]	Student performs	Video camera	n/a	Video image	n/a	**Reflection:** delay of student's image-	Continuous
6	e-Ballet Trajkova [77]	User performs specific movements	Remote real teacher	All aspects	Video image (augmented mirror)	n/a Overlaid Dots on students' body parts.	**Judgment** (emojis & verbal value) **Correction** (dots & verbal correction	Discrete
7	Alexiadis [3]	Demonstration of a movement by expert (3D avatar)	Kinect	Motion accuracy Timing	3D Avatar	3D Avatar	**Correction and Judgment:** Avatars side by side, Scores	Continuous

| | DILS | Initialization | Capturing student's moves | Movement Parameters to evaluate | Visualization | | Correction, Judgment, Reflection | Continuous vs. Discrete |
					of student avatar	correct position in feedback		
8	Usui [79]	Student performs a move (no teacher visualization)	Motion Capture	n/a	Stick figure	n/a	Reflection	Discrete
9	Aristidou [5][6]	Demonstration of a movement by expert (3D avatar)	Optical motion capture system	LMA component: Body, Shape, Effort, Space	3D avatar	3D avatar	**Correction and Judgment** Qualitative ribbons, Side by side, pass-fail evaluation	
10	Fujimoto [45]	Demonstration of a movement by expert (video image)	Kinect	n/a	Video image	Video image	**Reflection:** student watch himself performing like the teacher	Continuous
11	Kitsikidis [53]	User performs specific movements	Gyroscopes in limps	Motion accuracy Rythmicality	3D avatar	n/a	**Correction** It tests the algorithm not the performer?	Discrete
12	Essid[39]	Demonstration of a movement by expert (3D avatar)	Depth sensors, multiple, cameras, inertial motion capture	Motion accuracy	3D avatar	n/a	**Judgment** -score 1-5	Discrete
13	OpenDance Magnetat-Thalman et.al. [57]	Demonstration of a movement by expert (3D avatar)	n/a	n/a	n/a	n/a	Mimesis	n/a
14	Super Mirror [58]	Student performs a movement of their choice (no teacher visualization)	Kinect	Motion accuracy	Stick figure	Stick figure	**Correction and Judgment:** Side by side skeletons, Color coding, "hits" or "misses"	Continuous
15	WebDANCE[8][52]	Demonstration of a movement by expert (3D avatar)	n/a	n/a	n/a	n/a	Mimesis	n/a
16	Whatever Dance Toolbox [7]	System presents a task that the user has to go through	Video camera	-performing a task using their body	white silhouette, video image	n/a	**Correction:** pass/ fail to the next task **Reflection:** Delay & reverse	Continuous/ and discrete

| 17 | YouMove, [4] | Student watches teacher perform as a video | Kinect | Motion accuracy, Timing | Video image Stick figure | Stick figure 3D avatar | mode, Capture& replay and appear & disappear modes

Correction and Judgment: Overlaid figures, Color coding, Vocal instructions Scores | Continuous & discrete |

Table 4. Other non-functional characteristics of existing DILS

	DILS	Capturing Teacher's Moves	Other devices	Learning Approach	Dance genre	Portability	Target group
1	Chan [22]	Optical motion capture	Screen, VR Head-mounted display, Fully immersive environment	Mimesis	Not specified	no	Amateurs
2	Kyan [54]	Kinect	-CAVE Virtual Environment -Stereoscopic glasses, -eye trackers	Mimesis	Ballet	no	All levels
3	Camurri [15]	Gyroscopes on limps	2D screen	Generative	Contemporary	yes	Adult amateurs and professional dance practitioners
4	Choreomorphy [38] [78]	Optical & Inertial Motion Capture, Kinect	2D screen, HoloLens	Generative - Reflective	Contemporary, Improvisation	yes	Adult amateurs and professional dance practitioners
5	Delay Mirror, Molina [60]	n/a	Short range projector and projection screen.	Generative - Reflective	Ballet	yes	all levels
6	e-Ballet Trajkova [77]	n/a	Projector, pc	Mimesis	Ballet	yes	ballet students all levels
7	Alexiadis [3]	Kinect	2D screen	Mimesis	Salsa dance	yes	Salsa dancers beginners and intermediate level

	DILS	Capturing Teacher's Moves	Other devices	Learning Approach	Dance genre	Portability	Target group
8	Usui [79]	Optical motion capture	2D Screen	Mimesis	Cypriotic Folk dance	no	All levels
9	Aristidou[5][6]	Optical motion capture	2D screen	Reflective	Any	yes	Mostly amateurs(
10	Fujimoto [45]	Optical motion capture	tablet	Reflective	Hula dance	yes	Hula dancers all levels
11	Kitsikidis [53]	Multiple Kinect sensors	2D screen	Mimesis	Greek Folk (Tsamiko)	Not very much	Dance researchers
12	Essid[39]	Optical motion capture	Synchronized audio rigs, multiple cameras, wearable inertial measurement devices, depth sensors	Mimesis	Salsa dance	no	Experienced dancers
13	OpenDance Magnetat-Thalman et.al. [57]	Optical Motion capture	2D screen	Mimesis	Traditional dances of various countries	yes	Adult all levels
14	Super Mirror [58]	Kinect	2D screen	Mimesis	Ballet	yes	Pre-professional ballet dancers
15	WebDANCE[8][52]	Optical motion capture, videos	2D Screen computer	Mimesis	Folk dances (Greek, British)	yes	All levels
16	Whatever Dance Toolbox [7]	Depth camera	Video camera projector computer	Generative - Reflective	Contemporary, Improvisation, Any	yes	Amateurs, experienced dancers, choreographers
17	YouMove, [4]	Kinect	Augmented reality mirror, projectors, controlled lightning	Mimesis	Not specified	no	Any level of students, beginners

6.   DILS as virtual environments for collaboration and tele-presence

Dance, depending on the genre and context, can extend from a performing art, to cultural heritage and tradition and from a demanding somatic activity, to a way to express emotions. Saxena highlights that "dancing is a social activity thus requires two or more persons to interact through non-verbal communication"[69]. In current bibliography, there are several digital interactive applications that are not specifically designed for dance education but can provide us with interesting insight on interactive tools and technologies that can be incorporated in a dance teaching scenario and enhance the ability for collaboration. Web technologies and virtual environments provide this possibility.

Such characteristics are suggested by Cie Gilles Jobin in "Ballet from the inside"[26], a system that aims to create a virtual performance of a contemporary dance where users can connect to the platform and watch from every point of view as the dancers evolve. The performance is taking place in a virtual space that can only be seen with VR Google glasses. The dancers that the visitors are seeing in the VR environment are animations driven by Motion Capture data. The visitors are being tracked by the motion capture camera system in real time. So, the visitors move in space as if they are in the VR space rendered in real time with the dance happening in the center. This method could be used for implementing a virtual class, where the student's real time rendered avatars will perform and the teacher will observe and provide them with real time feedback, in the context of a very meaningful distance learning experience.

The same philosophy is met in Ballet Pixelle as reported by Inarra Saarinen [49]. Ballet Pixelle uses technology to take the art form into a digital environment and provide a new experience to the audience. In this system, a ballet company performs in and takes advantage of a 3D virtual world on the Web, called Second Life. As they describe in their webpage "the company creatively utilizes unique aspects of VR, e.g., transforming from human into animal or dragon or growing old on stage. The ballet uses a new breed of dancers and a new classical ballet vocabulary created to take advantage of the innovative medium. Performing in a web-based virtual space can break geographical boundaries and time zones, and it allows new spectators to enjoy a ballet performance that they may not have possibility to access otherwise". The novelty of this system is the usage of the virtual reality platform Second Life. If a virtual dance could be held into this platform, apart from real time collaboration and feedback from the teacher, the users could use the extra features that the platform provides, like the communication tools, the ability to set the background and to create projections and events relative to the class. Overall it can enhance the virtual dance scenario with other virtual elements like meetings with the students and the parents, seminars and presentations, etc., which are supported by the Second Life platform.

Another attempt for a tele-immersive collaborative environment is the one by Yang et al. [85] (extensively described in [86], which they present "a study of collaborative dancing between remote dancers in a tele-immersive environment which features 3D full and real body capturing, wide field of view, multi-display 3D rendering, and attachment free participant". According to this work, "the tele-immersive environments have strong potential impact on the concept of choreography and communication of live dance performance. Moreover, the presence of multi-view display, real body 3D rendering, audio channel, and less intrusiveness greatly enhances immersion and, thus, the dancing experience". This work affirms that virtual worlds can contribute in dance education since they enhance the experience and provide the option for collaboration.

Shchaffer et al. [70] present "an infrastructure to handle full-body articulated avatars as driven by motion capture equipment, including calibration and avatar creation". In particular, the authors describe "an open source software system that uses motion capture tools as input devices for real-time collaborative virtual environments".

Saxena et al. [69] attempt "to visualize a future tool to complement current applications in dance education". The prototype which the authors call "disDans" (distance and dance) is "a concept sketch for one such future telepresence system for teaching dance remotely that uses the modalities of vision, touch and hearing to increase immersion for its users." As the authors describe this would be an augmented reality experience using "glasses (which) are used to project virtual dancers in the environment around a user. It is with these avatars and holograms that the users would interact and dance. These visual projections are further augmented by 'surround sound' audio instructions. The last layer of the immersive experience adds the element of touch using smart fabric costumes."

Ho et al. present "a new framework for synthesizing motion of a virtual character in response to the actions performed by a user-controlled character in real time" According to the authors "the proposed method can handle scenes in which the characters are closely interacting with each other such as those in partner dancing and fighting" [46]. This novel approach to dance interaction might be able to contribute to dance learning and education in cases of ballroom dances for example. In these dances, the student needs a partner in order to rehearse the steps of choreography. Ho et al. [46] method could be a solution for a virtual partner that plays the role of the leader or the follower.

From all the systems that have been considered, the only one that is an educational system and can provide a form of collaboration is Whatever Dance toolbox. The tool "*Matching positions"* that we have already described in a

previous section, supports a possibility for collaboration since if there is more than one body in front of the camera the computer will interpret their silhouettes as composing a "many-in-one" shape. For sure, the examples taken from the Virtual reality world of collaboration are very interesting and show that this technology can be applied for taking the dance learning experience one step further.

Finally, an interaction method for "learning to execute exact motions, which are often required in sports and the arts", is proposed by Yang et al. in a system called Just Follow me (JFM) [84]. According to the authors, "this method uses an intuitive "ghost" metaphor and a first-person viewpoint for effective motion training. Using the ghost metaphor (GM), JFM visualizes the motion of the trainer in real time as a ghost (initially superimposed on the trainee) that emerges from one's own body. The trainee who observes the motion from the first-person viewpoint "follows" the ghostly master as closely as possible to learn the motion"[84]. As the authors observe, "the ghost metaphor might be used as a performance evaluation tool" …"with the first-person viewpoint to put oneself in the trainer's shoes". The authors suggest that such an approach can be applied in virtual reality DILS. While most of the system, visualize either the teacher or the student in a third person view, the first-person perspective in augmented and virtual reality as although in first person view the student cannot see the whole body at once, it opens a new perspective for focusing on peripheral vision, working with the hands, and movements within a limited field of view.

7.   DISCUSSION

Dance Interactive Learning Systems (DILS) and experiences can definitely enhance and improve dance learning and teaching as well as dance performance. Moreover, interactive dance training systems can contribute a great deal in researching bodily knowledge, innovating the teaching of dance, preserving cultural heritage, revolutionizing choreography, widening the access and practice of dance and augmenting the experience of performing. All of these fields are very promising and merit further research. Therefore, we have collected the interactive dance training systems that could be found in bibliography, and we have categorized the characteristics that describe them.

After examining each system in terms of the aforementioned aspects, the findings suggest particular trends in this field. Each dance training system offers a different degree of interactivity, with the ones that provide feedback to be considered as highly interactive and the ones that do not as less interactive. The majority of the systems were found to be highly interactive, as they provide feedback to the users by evaluating their performance or indicating their mistakes. Feedback is a very crucial characteristic for the student's progress and with the current state of the art in motion capture technologies, we expect that motion capture will soon be much more accessible also in low cost solutions than it was in the past. Moreover, all the systems examined, provide real time feedback allowing the student to have an immediate understanding of their performance and their mistakes.

In terms of the system workflow, the majority of the interactive systems choose the following model: First there is an initial demonstration of the correct movement, the student's move is captured, this move is directly compared with the correct move (teacher's move) and feedback is provided. Some systems use variations of this system's workflow, but this is the most common scenario. The most popular and yet obvious way of comparing the two motions is by measuring the Euclidian distance between the joints.

Concerning the technological means of capturing the motion we have come to the conclusions that optical motion capture is usually used for capturing the expert's (teacher's) movement whereas, MS Kinect is used mostly for capturing the student's movement. This is only natural, since optical motion capture is much more accurate but also much more expensive, so it is normally used once (for capturing the exemplar, ideal movement) and in that way, the quality and accuracy of the demonstrative movements are high. Ideally, the student's movements should also be captured by optical motion capture. Some of the interactive systems do so, however it is understood that this is not yet a cost-effective solution for a product to be made available to this consumer target group. New motion capture systems are expected to offer more accuracy in low cost.

The devices (hardware) that are mostly chosen as equipment apart from the motion capture devices, in most cases are simple 2D screens, as shown in Fig.12. Although quite a few systems try to increase the level of immersion and interactivity with augmented reality devices (head mounted displays, augmented reality mirror, etc.), most interactive

systems that are presented in this work, use a simple screen as an interface of interaction. Despite of the two dimensions, these systems offer a 3D interaction since the users can change their point of view, so that they can observe the teacher and themselves from different angles.

Visualization of student and teacher is met in all interactive dance training systems. The modality chosen more often for visualizing the teacher in the initial demonstration as well as the correct position (teacher) in feedback is a realistically rendered avatar. The same applies for the visualization of the student in feedback. There are also a few cases that a skeletal avatar is chosen instead of a humanoid avatar. However, the ghost metaphor used in the interactive system Just Follow me [84], is a quite different scenario. The results from Yang et al.'s work [84], suggest that the ghost metaphor would be very useful in slow motion training of a movement. This is quite interesting, since practicing of a movement in very slow motion is often a pre-condition for being able to execute this movement faster. Generally, designers have not been experimenting much with the modality of visualizations, probably because the majority of the systems are designed for dance genres that require precision in movement, like ballet. For other kinds of dances which are more abstract, like contemporary dance, experimenting with other types of visualizations, abstract or not, is an interesting direction, at the moment investigated in the Choreomorphy tool. Experimenting with visualizations is a common technique used in whole body interaction augmented performances and maybe with the proper research it can contribute a great deal in dance learning and training as well.
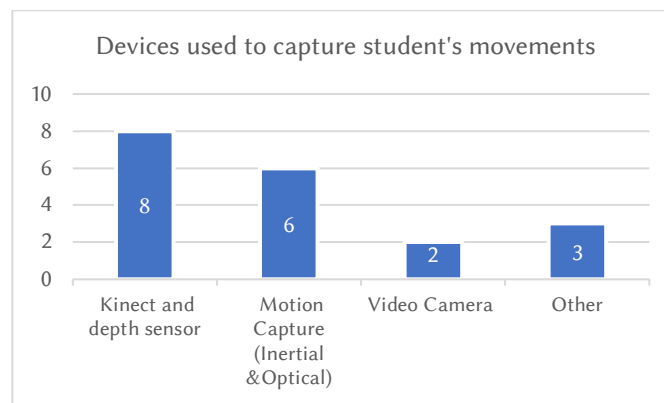As a teaching approach, mimesis is the one applied in most of the systems.

Fig. 12. Number of examined DILS using per devices used to capture students' movements

The aspects of evaluation are mostly motion accuracy and rhythmicality, when there is an initial demonstration to compare timing. There have been some attempts of evaluating more qualitative aspects of dance like expression, including a variety of movement qualities as they are considered essential for dance performance and training.
In terms of feedback, correction, but also overall judgement in the form of a score or a value, is mostly applied. Corrective feedback is provided through color coding, showing the teacher's and student's avatar side by side and by overlaying them. Providing scores is also another very popular way of feedback used by almost every system. The score can be given in the form of a number, percentage or chart for overall performance, or for each body part separately. According to the study, the way the system provides clear and valuable feedback is still an open issue which needs further investigation, considering also different modalities (visual, audio, verbal, tactile, etc).
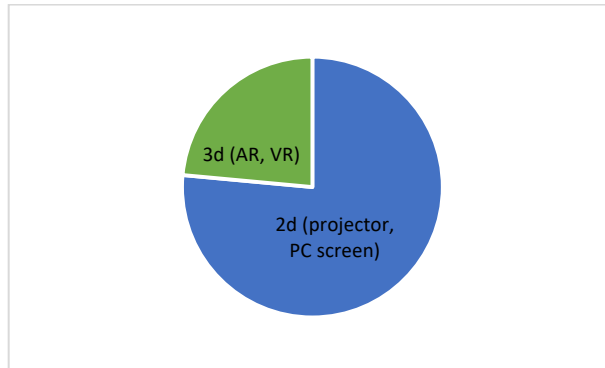
Fig. 13 Number of existing DILS using 2D and 3D perspectives to visualize students and teachers' movement

Many of the systems examined above follow the metaphor of an augmented mirror. Although this analogy is valuable since it follows a real -life example, it brings the risk of perceiving movement mainly through a visual, two-dimensional perspective, whereas technologies such as, sonification of movement, Cave, AR, MR and VR can offer new opportunities in widening this perspective and only a few examples have explored the potential of three dimensionality as shown in Fig. 13.

Another outcome from reviewing the interactive systems for dance training is that approximately, 50% of them are considered highly portable whereas the other half cannot be considered as such, since they demand complex or heavy equipment for their use.All systems suggest that they can be used either for home training or for classroom training and few imply that they can substitute the role of the teacher.

8.   CONCLUSION

Future designers of interactive dance learning systems can use the various examples of other existing interactive systems as a source of inspiration. Collaboration in virtual environments has a lot to offer in dance training. The main conclusions regarding the open issues in the domain can be summarized as follows:

Research for an effective DILS is an interdisciplinary process. Comprehensive representation of movement needs further investigation, exploring a variety of modalities (visualization, sound, verbal descriptions, metaphors, etc.), looking also into what is been explored by choreographers and researchers in the field of dance and technology in general. Dance Interactive Learning Systems should most of all aim to be tools for transmitting bodily knowledge thus the way of representing the body and movement should be aligned with the philosophy and aesthetics of the practice nowadays. Designing an effective DILS requires both deep understanding of the dance practice, and requires interdisciplinary perspective including technologists of various expertise, educators, and artists.

Bringing a DILS into the dance practice requires close collaboration with the dance community. Understanding the dance community requirements and apply not only user-centered design but also co-design where dance practitioners will bring their perspectives and needs early in the project are critical. Especially in creating tools for real-life and use in the studio where dancers learn, practice, rehearse, it is important to document early what a digital tool can add to a practice, or teaching/learning experience, always in relation to the context of use.

To this point, it is necessary to stress that designing tools which introduce functionalities but also use of hardware to a bright new community of users it is a huge challenge. Since needs and specifications are defined from scratch it is very important to work with the dance practitioners rather than for them. In addition, evaluation is a huge challenge not only because of the complexity of technology but also due to the novelty effect which occurs when users react positive to the new experience not due to the experience itself but due to their enthusiasm of using cut-edge, novel technologies for the first time. Involving dance practitioners and experts in the early stage of design is key.

There is no one solution to fit all. What works for ballet or Greek folk, does not necessarily work for flamenco or contemporary. Practices vary in the way the learning approaches are applied, in what are the learning objectives

and on how they deal with specific movement vocabularies and forms vs. improvisation and qualities of movement. This is the first questions to answer for designing the tool: What is the most important factor in this particular dance genre or style: Precision? Form and shape of the body? Foot work? Relation to Rhythm? Movement qualities? How are they defined and could be measured? To what extent does this dance practice involve and rely on Improvisation and creativity? Collaboration? Communication and interaction? Tradition and other aspects of cultural heritage?

Going beyond a score as feedback is critical. In relation to this, how and when the system provides feedback beyond a score value, giving comprehensive and clear feedback for both correction and reflection needs further thorough investigation. The student does not only need to know "how well they did" but to understand exactly how they moved their body parts and what they can do to improve in terms of trajectories, movement qualities, rhythm, and other aspects which seem important to this particular dance genre or practice. The existing DILS, according to literature show impressive achievements in terms of examining accuracy in time and motion and indicating the exact mistakes of the student. However, there is much more to conquer in order to make these systems efficient and meaningful for use in the day to day practice of dance education. Currently the majority of DILS adopt the Mimetic learning approach and the paradigm of mimicking a pre-recorded movement to learn, which is only one part of dance education. (Fig.14)
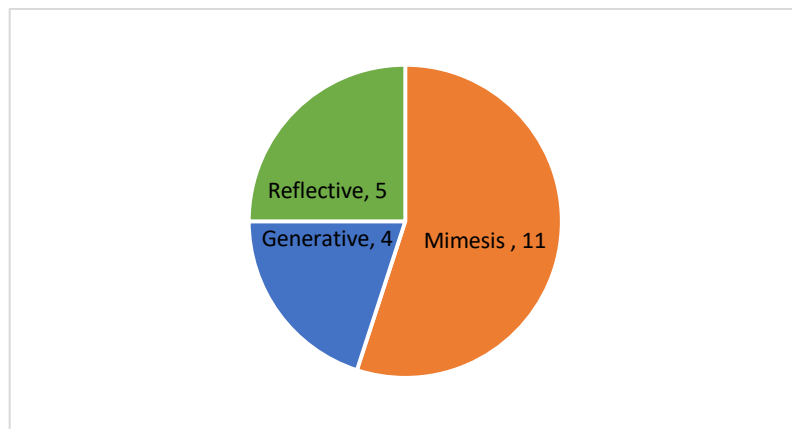

Fig. 14. Most common Learning Approaches used in existing DILS

Building simple prototypes to test how they work in real environments is important. While there are several interesting DILS in the recent literature, exploring state of the art technologies such as Motion Capture, VR/AR, Cave, digital tools for learning have not yet reached the studios apart from a limited experimental context. It is unknown if the reasons for not reaching wider audiences are only practical such as complexity, non-portability and cost of such installations, or the unwillingness of dance practitioners. Further research on actual needs and experimentation with simple devices and settings can help to understand the needs and narrow this gap between experimental research and practice.

Although the aforementioned efforts show a great potential for effective dance learning, evaluating the long-term learning effectiveness of DILS is still an open issue. Most of the existing systems in literature, especially those using motion capture, AR and VR have been evaluated in terms of usability and user-experience in laboratory environments or during workshops. Nevertheless, these conditions are far different from actually using the tools in real-life environments (home, studio, dance class) and scenarios. Ideally, the users (students, practitioners, teachers) should be able to use the tools in real-life conditions for longer periods of time, which at the moment seems like a challenging issue due to the low portability, complexity and high-cost of the majority of DILS.

By taking advantage of the possibilities offered by virtual reality platforms like Second life, more interactive concepts can be applied. In combination with the already presented technologies and methodologies, collaboration in virtual worlds can offer the possibility of an online real time class with students from all over the world while meaningful feedback can be obtained from the system for each one of them.

Dance educators and practitioners, as experts in bodily knowledge can play a great role in human computer interaction design and revolutionize the concepts of co-design, embodied interaction and research through practice.

We believe that designing and evaluating tools for artistic and cultural domains, can largely contribute to the computing domain, not only for the technological challenges they emerge. This intersection of disciplines poses the question of how we chose objective functions for evaluating expressive human behaviors; a critical question especially if we impose the "right/wrong" paradigm for integrating technologies such as AI, machine learning, etc. Inspired by M. McLuhan [87] we would question ourselves: what are the values and the behaviors that we are amplifying through expecting a technological tool to evaluate a complex, expressive and creative human activity?

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