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# MFF: Performance Interference-Aware VM Placement Algorithm for Reducing Energy Consumption in Data Centers

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## *Abstract*

Virtualization is the main technology that powers cloud computing and has enabled the execution of multiple applications in same physical hardware using virtual machines (VM) for efficient utilization of resources and energy savings. Although virtualization successfully isolates co-resident VMs from a security perspective, it does not offer a guarantee from a performance interference perspective. This means that sharing of resources results in competition, which is the cause of performance interference. Performance interference is more pronounced in homogenous workloads, where applications workloads contend to the same shared resource. In this case, application workloads run for longer times due to reduced performance and thus consume more energy. To address this problem, a VM allocation policy should ensure that VM running homogeneous workloads is not co-located. In this paper, we propose a VM allocation algorithm called Minimum Interference First Fit (MFF), which co-locates dissimilar workloads. The algorithm clusters VMs using K-means based on resources usage. Before a VM is placed into a physical machine (PM), similarity index (SI) of all the active PMs is computed, the VM is then placed in a PM with least SI. MFF has been evaluated on a simulated data center using CloudSim Plus cloud simulator on application workloads logs obtained from a production data center. Results show that MFF outperforms well-known VM allocations algorithms such as first fit (FF), worst fit (WF) and best fit (BF) from an energy consumption perspective.

**Keywords:** cloud computing, virtual machine allocation, k-means, virtualization, data center energy consumption, performance interference.

## 1. Introduction

The growing appetite for workload processing power has resulted in cloud service providers (CSP) putting up many data centers. Unfortunately, data centers consume a lot of electrical energy resulting in high operating costs (Rallo, 2014). Besides, excessive energy consumption has a negative impact on the environment, which is the emission of carbon dioxide gas to the environment (Anton, 2013). Not all the energy that goes into a data center does useful work, some goes to waste. There are a number of known causes of energy wastage in data centers

such as low level of server utilization, wastage of server idle energy and consolidation of homogeneous workloads (Chaima, 2014; Derdus, Omwenga & Ogao, 2019). The problem of low server utilization and wastage of idle energy has been addressed in a number of research work such as in (Anton, 2013; Delimitrou, 2015).

Consolidation of workloads has an effect on performance and energy consumption issues. For instance, it has been shown that it is advantageous to co-located heterogeneous workload than homogenous workloads (Derdus, Omwenga & Ogao, 2019). Homogenous workloads have applications, which contend the same shared resource. Thus, if VMs run application workloads, which contend the same shared resource, the pressure put on that resource will make tasks to run longer because of reduced throughput. As a consequence, more energy is used (energy is a product of time and power). This is effect is known as performance interference. Although virtualization successfully isolates co-resident VMs from a security perspective, it does not offer a guarantee from a performance interference perspective (Tsfatsion, 2018). Performance interference can be very severe. For instance, network I/O bandwidth can vary by almost 50% due to inter-VM interference (Pu et al., 2010).

The methods used to address the problem of performance interference include hardware partition and VM placement and allocation policies (Tsfatsion, 2018; Amri, Hamdi & Brahmi, 2017). In former, the physical hardware resources are divided to enable hosted VMs to have exclusive access the resources. In the latter, VM placement policies are used, where the incoming VM's behavior is analyzed so as to co-locate VMs, which contend different resources. The commonly used bin packing based VM placement algorithms such as first fit (FF), worst fit (WF) and best fit (BF) are not suitable because they do not take into account VM characteristics before placement (Kumar, Sathasivam & Periyasamy, 2016; Dabbagh et al., 2015; Gohil et al., 2016). For instance, FF places an incoming VM in the first active PM or host, which has enough resources to accommodate the VM. If no suitable host is found, a new PM is activated. In BF, all PMs are checked for residual resources and the incoming VM is placed in a PM, which will suffer least resource wastage. In WF, the incoming VM is placed in a PM with most residual resources.

Various research works have been performed to address the problem of performance interference. Most of this research work is focused on either detecting, predicting or measuring performance interference in co-resident VMs with the goal of proposing a solution.

Xu, Liu and Jin (2016) discovered that apart from performance interference caused by executing application workloads, the existence of heterogeneous hardware similar VM instances can be a source of performance variations. Based on this claim, the authors have proposed a system called Heifer, which predicts the performance of hosted applications in a similar VM instance considering the performance interference in different hardware. Heifer provisions VM instances from the best performing hardware based on the predicted performance interference.

Chen et al. (2015) proposed a system called CloudScope, which is used in diagnosing performance interference among co-resident VMs. CloudScope measures performance interference using VM profiling information obtained from the hypervisor layer and then reassigns VMs to PMs in way that interference is minimized. CloudScope has been implemented on Xen and according to the authors, it achieves an average error of 9% in predicting interference and a 10% VM performance improvements as compared to Xen's default scheduler. The authors also argue that CloudScope is lightweight with less computation needs as compared to other approaches, which uses online training.

Amannejad, Krishnamurthy and Far (2015) proposed a machine learning based system for detecting if a web service running in hosted VMs is suffering from interference. The proposed system relies on VM customer accessible metric (such as transaction response time data collected by a web service) as a way of detecting performance degradation since hardware level metrics (such as CPU utilization) are only accessible by CSP. The actual performance values are

then compared to the expected performance. If performance interference is detected the system can mitigate it such as by using a different VM instance or using a different CSP.

In this paper, we extend our work (in Derdus, Omwenga & Ogao, (2019)), by proposing a VM allocation algorithm that maps a VM to a PM, which is hosting less similar VMs. In our approach, interference is estimated by computing a value called similarity index, which is a measure of how similar a host is to an incoming VM.

## 2. Materials and methods

### 2.1 Cloud model and system process

The target cloud deployment and service model for the proposed algorithm is a multi-tenant public Infrastructure as a Service (IaaS) cloud. Users request VM resources and the VM is placed in a PM in CSP's data centre. The user can then execute any type of applications in the VMs, and from a CSP's perspective, applications are a black box host in a VM. However, a CSP can access a VMs profile (such as VM resources consumption) from the hypervisor layer and in turn analyze the behaviour of user host application (Amannejad, Krishnamurthy, & Far, 2015). Further, the proposed system process is shown in Figure 1.

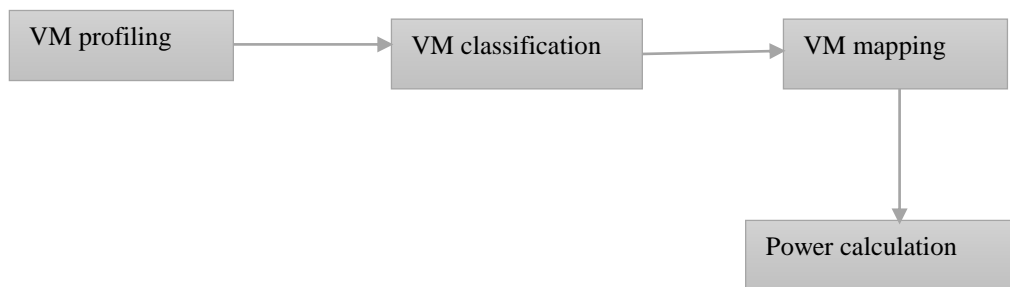


Figure 1: Proposed system process

**VM profiling:** in this part, the resource usage of the VM is monitored and recorded over a period. This is done by the CSP via the virtualization layer. The collected data forms the historical data, which is fed into a VM classifier. This is possible and has been demonstrated in (Wajid, et al., 2016)

**VM classification:** this component receives historical VM resource usage from a profiling database and then classifies VM based on resource usage. In this paper, we have used k-means to classify VMs based on the following features:

- Average CPU usage – the average CPU used by a VM for the entire period of profiling.
- Average memory usage – the average RAM used by a VM for the entire period of profiling.

The choice of the k-means clustering algorithm is because of its success in clustering workloads in previous research such as the work by Alam, Shakil and Sethi (2016), Yousif and Al-Dulaimy (2017) and Di, Kondo and Cappello (2014). In the following sections, we will explain how k-means was applied in a dataset of choice.

**VM mapping:** the VM mapping component receives a VM and the class to which it belongs and then maps it to the appropriate PM. This is the component, which runs our algorithm. The algorithm logic has been explained in a later section.

Power calculation: this component computes the total amount of power used to execute VM workloads for a given VM scheduling algorithm. It is important to calculate this power because the aim of our algorithm is to reduce power consumption. Power,  $P_T$ , is computed according to equation 1.

$$P_T = \sum_{i=1}^n ((P_i^p - P_i^b) * \left(\frac{N_i}{100}\right) + P_i^b), \quad (1)$$

where  $n$  is the number of hosts in a data center,  $P_p$  is the peak power consumption of the  $i$ th host,  $P_b$  is the host's idle power and  $N$  is the percentage CPU utilization of the host. Energy,  $E$ , computed as shown in equation 2.

$$E = P_T, \quad (2)$$

where  $P$  is equivalent to  $P_T$  (measured in watts) and  $T$  is a time (in seconds) interval.

## 2.2 Dataset used

The dataset used in this paper is called *c* and is obtained from the Grid Workload Archive (GWA) (Delf University of Technology, 2018). The dataset is used in the following three ways: (1) for clustering purposes i.e. to demonstrate the use of k-means in clustering application workloads as well as the existence of groups of VMs, (2) to aid in determining characteristics of a data center to be used in evaluating our proposed algorithms, and (3) to aid in determining resource demands of VMs used to execute workloads in the process of evaluation. Materna trace is obtained from a VMware ESX environment consisting of 49 Hosts, 69 CPU cores and 6780 GB memory. This trace data is packaged in CSV files and it shows resources (such as memory, processor and storage) assigned to VMs and the resources that were actually used by the VMs. Materna trace consists of three different traces obtained from the infrastructure during three different times. The first trace, which has been used in this paper, consists of 520 VMs. Thus, there are 520 CSV files, each showing resources allocated and resources actually used by the VMs. Different VMs were allocated different resources. For instance, storage capacity ranged from 54 GB – 138 GB, memory was either 2 or 4 or 8 or 16 GB whereas a number of CPU cores were either 1 or 2 or 4 or 8. CPU utilization also showed the percentage usage in MHz. Resources allocated to VMs did not change the entire period of profiling. On the other hand, resources actually used by VMs varied the entire period. We have used the average VM resource usage to represent VM resource usage for the entire profiling period. Thus, we have created one CSV file with 520 records showing VM resource usage averages from the 520 CSV files. Classes of VMs are created via k-means using average memory usage and average CPU usage as a feature set.

## 2.3 Algorithm design

This algorithm determines the PM to host a VM, based on the VM's class. The algorithm minimizes the number of VMs of a similar class running in the same PM. The algorithm can be summarized using the following steps and the flow chart shown in Figure 2.

- Step 1:** From all host machines (PMs), identify all PMs with enough resources to accommodate the incoming VM. This is the *candidate host list*.
- Step 2:** Compute the similarity,  $S$ , of the incoming VM with each of the *candidate hosts*.  $S$  is computed according to equation 3.
- Step 3:** Sort the *candidate host list* in ascending order using  $S$ .



**Step 4:** Place incoming VM in the first host of the sorted *candidate host list*.

$$S = \frac{i}{j} \quad (3)$$

where  $i$  is the number of VMs in a particular host, which belong to the same class as the incoming host and  $j$  is the total of VMs in that host.

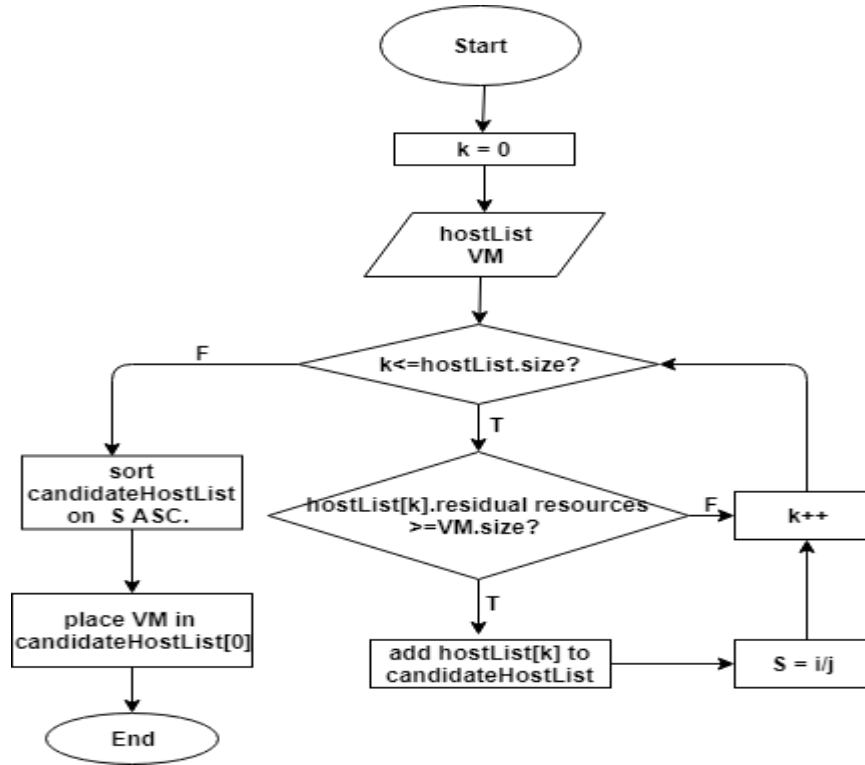


Figure 2: Flow chart for the proposed algorithm

#### 2.4 Algorithm evaluation

Our algorithm is evaluated using GWA-T-13 Materna (explained earlier) on CloudSim Plus simulator, CloudSim Plus is a java-based cloud simulator forked from CloudSim (Rodrigo et al., 2011; Manoel et al., 2017). CloudSim Plus is easier to use because it follows software engineering standards with code duplication entirely removed. CloudSim Plus perfectly emulates a cloud datacenter – it has the following components; a Cloudlet, VM, Broker, Host and Datacenter. A cloudlet is similar to user applications, which are executed inside VMs. VMs are held in hosts, which are typically servers in a datacenter. A datacenter is comprised of hardware with physical computing resources and all the software that is used to manage the hardware. CloudSim Plus framework allows the creation of the aforementioned components in Java code. It also provides interfaces and abstract classes, which can be implemented and extended respectively, to enable the creation of own algorithm to determine how VMs are mapped to PMs. Some of the commonly used VM allocation algorithms such as FF, WF and BF have been implemented in the default installation of CloudSim Plus simulator. In this work, we have simulated a datacenter with 49 hosts and 520 VMs. The datacenter has 69 CPUs (454 cores) and 6780 GB of memory. The memory and CPU allocation to each VM is in line with GWA-T-13 Materna dataset. The cloudlets are also simulated to consume the same amount of resources depicted in the workload. The idle

power for each host is set at 60% of the host's peak power. For algorithm implementation, we have created a class, which inherits from *VmAllocationPolicyAbstract* and implemented the algorithm in a method called *findHostForVm*. The workload depicted in the dataset is then executed in the datacenter using FF, WF, BF and MFF VM allocation algorithms in turn. At the end of each execution, energy consumption by the data center is recorded.

### 3. Results and discussion

The results presented and discussed in this section relates to the outcome of clustering of the used dataset for the purpose of determining VM allocation and the performance of the proposed algorithm as compared to other algorithms. Figure 3 shows the clustering results of GWA-T-13 Materna. Indeed, it shows that there existed groups of VMs based on VM resources consumption (CPU and memory). K-means revealed the existence of 4 groups, which can be described as extra small VMs, small VMs, medium VMs and large VMs. The population of each group and a description of the VM groups have been summarized in Table 1.

Table 1. Population and description of VM groups resulting from clustering GWA-T-13 Materna dataset

VM Cluster group	VM population (number and %)	VM group description
Large VMs	1 ( $\approx 0.2\%$ )	We have considered this group to contain an outlier because there is only one member. The VM in this groups shows a high memory consumption, with moderate CPU consumption.
Medium VMs	29 ( $\approx 5.6\%$ )	The VMs in this group shows a moderate memory consumption with varying CPU usage.
Small VMs	96 ( $\approx 18.4\%$ )	The VMs in this group shows a moderate memory consumption with varying CPU usage. However, the memory demand for this group is lower compared to medium VMs.
Extra small VM	394 ( $\approx 75.8\%$ )	The VMs in this group shows low consumption in both memory and CPU.

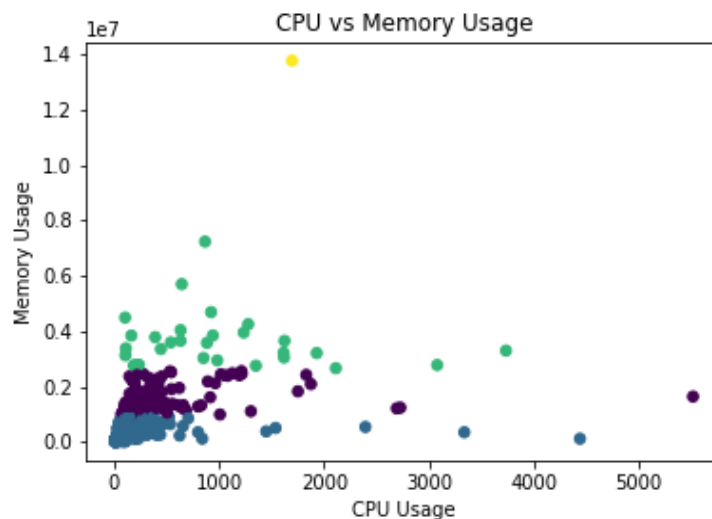


Figure 3: Scatter plot showing results of clustering of GWA-T-13 dataset

Further, Figure 4 shows the amount of energy consumed by the datacenter (consisting of 46 hosts) while executing the workload using a different VM allocation algorithm. We compared our proposed algorithm, MFF with FF, BF and WF. From the results, it is noticeable that MFF consumes the least amount of energy (18766 joules). On the other hand, BF consumes the highest amount of energy to execute the same workload to completion (22674 joules). The reason for MFF's better performance from an energy perspective is because it co-locates VMs, which content different computing resources (heterogeneous VM). This type of allocation reduces inter-VM interference caused by VM when they compete with hypervisor capacity. By ensuring that dissimilar VMs are co-located, all computing resources are used in a balanced manner, which also means that physical resources' idle power is put into useful processing.

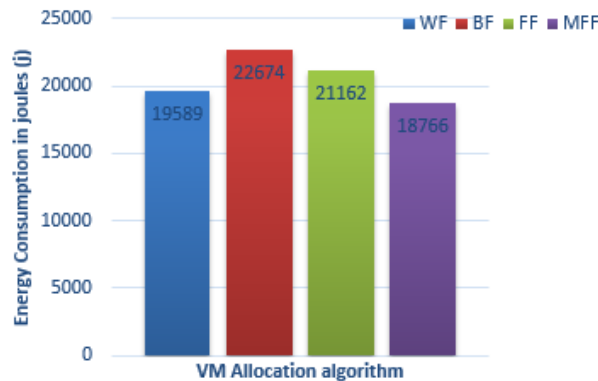


Figure 4: Energy consumed by datacenter hosts to execute same amount of workload across different VM allocation algorithms

#### 4. Conclusion

In this paper, we have proposed a VM allocation algorithm, MFF, for mapping VMs to PMs, based on historical resources consumption of VMs. MFF is motivated by the fact that inter-VM interference of co-resident VM is reduced when the VMs content different computing resources. We have used a k-means clustering algorithm to identify groups of VMs in a dataset used. Simulated results show that MFF beats FF, BF and WF VM algorithms and we consider this an achievement. As future work, we plan to apply MFF to a wide range of real cloud workloads. We also plan to combine MFF and BF to further enhance resource utilization efficiency.

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The authors declare no competing interests.

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## Social Inequalities and ICT Teacher's In-Service Training

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### *Abstract*

The purpose of this paper is to present the teachers' views about their in-service training in ICT. This research is part of a more general research aimed at exploring the educational needs of teachers and the application of ICT in the education system and their impact on the teaching, learning and cognitive process. The sample of this research consists of 162 teachers working in primary schools in Northern Greece. Of these, 70 (43.2%) were men and 92 (56.8%) were women. The results of the research show that teachers emphasize the functioning of the institution of education in ICT as a tool for implementing educational policy of the dominant social groups, but also their reflection on European education policy. They also express the need for continuing education, while differing in its role in removing educational inequalities.

*Keywords:* ICT, in-service training, social inequalities.

### 1. Introduction

ICT is the new cognitive tool in modern society that differentiates both the social structure and the life of social subjects (Robins & Webster, 2002: 3-9). ICT are approached as a system of values and actions that can penetrate any social reality, influencing both the way society is organized and the way of thinking (Rannerberg et al., 2009) and expanding social inequalities (Feather, 1994). According to the OECD, those who do not have access to ICT and have no skills in them, face a new inequality, that of the digital divide. There is, therefore, a need for the future school to develop social subjects with critical thinking, creativity, flexibility, responsibility and cooperation skills, self-regulated learning and making critical decisions under pressure, ambiguity, and uncertainty (Raptis & Raptis, 2002). At the same time, ICT is considered in the modern globalized educational environment as a complex process involving individuals, processes, ideas, means, and organizational functions aiming at the analysis and management of learning (Egea, 2013; Serwaes & Heinderyck, 2002; Solomonidou, 2006; Witte & Mannon, 2010)). The development and changes that are taking place make it necessary to continuously train individuals to avoid social exclusion from social, economic and political activity (OECD, 1996).

### 2. Sociological approaches of ICT and in-service training

Structural-functional analysis point out that the primary goal is the maintenance and perpetuation of the social system, highlighting the unifying role of common values and common ideas and perceptions in building social consensus (Stolley, 2005). It is argued that all sections of

society, even the poorest, contribute in some way to maintaining order and stability in society. Social stratification exists in all societies, while education uses meritocracy as a mechanism to motivate and secure the best position in the social division of labor for the most capable (Ferrante, 2011). The theory of functioning is at the core of modernity, where through capitalist ideology and market practice it seeks to lead to economic, social, cultural, political, and technological development (Weane, 1989). Structural - functional analysis recognize that if a part of the social system is transformed, then the other parts of it are adjusted to balance. ICT, in this context, by transforming the social system, is shaping the new conditions for occupying social positions. Accessibility, information management, social skills and skills in ICT are the meritocratic criteria for hierarchies, social stratification and the reproduction of social constants.

- Teachers emphasize the functioning of the institution of education in ICT as a tool for pursuing an educational policy of the dominant social groups, but also their reflection on European education policy;
- Teachers express the need for continuing education, while differing in its role in removing educational inequalities;
- While increased funding, teachers considered necessary as means of better quality upgrading of ICT training.

The postmodern social division of labor requires the ease and convenience of managing and producing information, applications, and materials from a social subject (broader process in terms of literacy), and the deeper acquisition of concepts and capabilities (Rapporteur, 2006), which revises the didactic-pedagogical reality of the school and the curriculum. Pedagogy and teaching science deal with the introduction of ICT in education, describing the problems (Law et al., 2008; Pelgrum, 2001; Slaouti & Barton, 2007) and the effects on learning (Kafai et al., 2002; Rumpagaporn & Darmawan, 2007) highlighting a technocratic-positivist approach. At the same time, state intervention to ensure more effective teaching is intense (Bromley & Apple, 1998). Paraphrasing what Castells (1998) said about work, we can say that the teacher has never been more vulnerable to the organization of the teaching practice, as he is isolated in a malleable network, which he himself does not know, which is exactly where he is placed, as it is constantly modified. The teacher is called upon to transform his knowledge and skills, to acquire information literacy (Bikos, 1989) in order to enhance the teaching practice, but also to be able to meet the increased and changing needs of young social subjects. The above transmits a lot of pressure to teachers and highlights the project of their training. In such an environment of liquidity and change, the teacher therefore needs education and training (Elliot, 1977) adapted to the new social conditions, to acquire a higher level of skills, for global education, and to establish “lifelong” education (Vergidis, 1993; Bagakis, 2000). ICT alone does not automatically modernize a school unit. This essentially means that training is mainly a function of the identified needs of the teachers themselves, which are determined by the pre-existing basic education, by their work and by the educational system in which they work. Contributing to this is the existence of a specific training policy, which in the context of a broader educational policy which promotes the academic, professional and personal development of the teacher (Athanasoula-Reppa et al., 1999).

Here we must point out that the old contract that was a relationship agreement was based on teacher-centered teaching and student “devotion”. The new contract in education tends to be more and more short-term, based mainly on the processing and transformation of new social data and the development of critical thinking and the individual's ability to constructively compose the multitude of stimuli and experiences, while “dedication” In the old sense has been eliminated (DiMaggio et al., 2001). Education as a mechanism for influencing and sensitizing teachers (Witte & Mannon, 2010), seeks to reshape the meanings that teachers give to the educational process and to establish new interpretations of the criteria of socialization and selection and the importance of ICT in them.



### 3. ICT in-service teacher training programs in Greece

Over the last few decades, there has been a growing teacher training activity in ICT, which is presented as a parameter of a more general reform effort for education. Of course, any reform is inevitably linked to the political ideology and programmatic planning of each government. In the mid-1990s, the first programs for the training of teachers in ICT (Jimoyiannis, & Komis, 2007) began, while in the following years, with the co-financing of EE, programs such as “ODYSSEY” (1996-2001) were implemented. “In-school training” (2000-2001), the program “Training of Primary and Secondary Education Teachers in Basic ICT Skills in Education” (Level 1) (2001-2005) (Fragouli & Hammond, 2007) and “Training of teachers for the use and application of ICT in teaching practice” (Level B) (2007-2013) (see “Information and Cooperation Portal of Level B Training”), which continues. From the programs in the training of ICT that were implemented, difficulties emerged related to the teaching techniques used by the trainers, but also the use of ICT in the school context (Giavrimis et al., 2012; Karamanis et al., 2000; Minaidi & Hlapanis, 2005) and positive points regarding the change in the level of knowledge and skills of teachers (Zagouras, 2005) and the use of ICT in teaching practice (Demetriadis et al., 2003; Tsitouridou & Vryzas, 2004).

The purpose of this paper is to present the views of teachers on their training in ICT and their correlation with inequalities in the education system.

### 4. Method

#### 4.1 *Sample*

The sample of this research consists of 162 teachers working in primary schools in Northern Greece. Of these, 70 (43.2%) were men and 92 (56.8%) were women. Regarding their age, 7 (4.3%) were under 30 years old, 69 (42.6%) belong to the age group 31-40 years, 81 (50%) belong to the age group 41-50 years and 5 (3.1%) in the age group 51-60 years. Of the additional demographic data collected, 17 people (10.5%) are single, 138 (85.1%) are married and 4 (2.5%) are divorced and 3 (1.9%) are cohabiting. The average years of service of the teachers of the sample is 14.14 (T.A. = 6.72), with an average of 13 years, a lower value of one year and a maximum value of 30 years. Regarding the years since the acquisition of the teacher's degree, it seems that the average is 20.35 years (T.A. = 6.28), the average is 21 years, the lowest value is two years and the maximum value is 33 years.

#### 4.2 *Researching tool*

An improvised questionnaire on teacher training in ICT was used to conduct the research. It includes a total of 80 questions. The questions are divided into five topics: (a) Reasons of attendance: Includes questions related to the reasons for attending an ICT program, (b) Satisfaction and teaching methods from the ICT program: Includes questions related to teacher satisfaction from the ICT program they attended and the methods and techniques used by the instructors, (c) Knowledge in ICT after the program: Includes questions related to the skills acquired by the teachers after the end of the program, (d) Attitudes about ICT after the program: Includes questions which refer to the attitude of teachers towards ICT and their inclusion in their daily and educational practice, and (e) Sociological approaches: It includes questions of sociological content, which concern the position of the school in the social becoming. This paper presents questions related to the third and fifth thematic sections.

### 5. Findings

Table 1 and Figure 1 show that the teachers of our research: (1) point out the importance of continuing education for the management of educational reality, (2) attach great importance to funding and the changes that entail in pedagogical-teaching practice, (3) emphasize (at least 50% of them) the contribution of education to the elimination of social inequalities, (4) have a negative view (at least 50%) on the fact that ICT alleviates educational inequalities, the common European policy on education and training replacing in-person training with distance learning, and (5) differentiate opinions with statistical significance [multivariate criterion of variance analysis with repetitive measurements: Hotelling’s Trace,  $F(2, 160) = 63.2, p < 0.001, \eta^2 = 0.70$ , primary function:  $F(1, 161) = 383.44, p < 0.001, \eta^2 = 0.70$ ] (Figure 1), where they consider continuing education as very important in relation to the others. Issues, on the second level of significance, are related to funding for the elimination of social inequalities, while they have the most negative view of the ICT assistance in the elimination of educational inequalities, European policy and distance education.

Table 1. Funding, training, ICT and inequalities

Questions	Median	Quadrants			
		10	25	50	75
The continuing education of teachers helps in the daily life of the school (Q. 1)	5.00	2.00	4.00	5.00	5.00
Adequate school funding affects the quality of ICT education provided (Q. 2)	4.00	3.00	4.00	4.00	4.00
The increase in funding for school ICT should be combined with pedagogical changes in the education system (Q. 3).	4.00	3.00	4.00	4.00	4.00
ICT education can bridge social inequalities (Q. 4)	4.00	2.00	2.00	4.00	5.00
Training in new technologies in education will alleviate educational inequalities (Q. 5)	3.00	1.00	2.00	3.00	4.00
I am in favor of a common European policy for teacher training (Q. 6)	3.00	1.00	1.00	3.00	4.00
Distance learning is just as effective as in-person teaching (Q. 7).	3.00	1.00	1.00	3.00	4.00

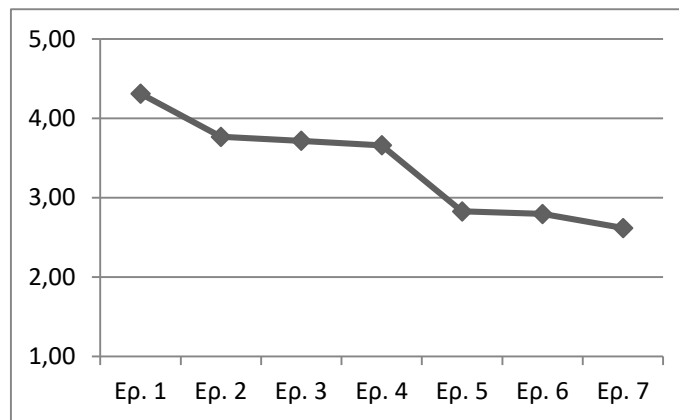


Figure 1. Hierarchical ranking

The influence of gender on the above questions does not seem to be significant and the view of men and women does not differ [Er. 1: Mann-Whitney  $U = 3062, Z = -0.609, p = 0.542$ , Fig. 2: Mann-Whitney  $U = 3065, Z = -0.724, p = 0.469$ ], Fig. 3: Mann-Whitney  $U = 3141, Z = -0.393, p = 0.694$ , Fig. 4: Mann-Whitney  $U = 2985, Z = -0.827, p = 0.408$ , Fig. 5: Mann-Whitney  $U = 2815, Z = -1.433, p = 0.152$ , Fig. 6: Mann-Whitney  $U = 2957, Z = -0.938, p = 0.348$ , Fig. 7: Mann-Whitney  $U = 2661, Z = -1.978, p = 0.480$ ], while the years of service are not correlated with

their views on education and inequalities [Er. 1:  $r = -0.004$ ,  $p = 0.958$ , Q. 2:  $r = -0.021$ ,  $p = 0.793$ , Q. 3:  $r = -0.066$ ,  $p = 0.404$ , Q. 4:  $r = 0.076$ ,  $p = 0.337$ , Q. . 5:  $r = -0.234$ ,  $p = 0.543$ , Q. 6:  $r = -0.074$ ,  $p = 0.346$ , Q. 7:  $r = -0.106$ ,  $p = 0.178$ ].

More than 75% of teachers appear to have a negative view of the help that ICT education can offer in terms of improving their basic education, scientific training and self-esteem, which does not appear to meet the new educational needs. The opinion of 25% of teachers is in the middle of the scale. In relation to ICT, they state that training helps a lot in acquiring skills, while about 25% are negative in this regard as well.

Table 2. Training in ICT and professional development

Training in ICT helps:	Median	Quadrants			
		10	25	50	75
Improving your basic education	2.00	2.00	2.00	2.00	3.00
In response to new educational needs	2.00	2.00	2.00	2.00	3.00
To increase your scientific training	2.00	1.00	2.00	2.00	3.00
In increasing your professional self-esteem	2.00	1.00	2.00	2.00	3.00
In the acquisition of skills in ICT.	3.00	1.00	2.00	3.00	3.00

Referring to the factors that influence the design of ICT training programs, our research teachers cite the requirements of capital and the economic system as the most important. The use of the variable criterion of analysis of variance with repeated measurements found statistically significant differences in the specific views [Hotelling's Trace,  $F(2, 160) = 31.12$ ,  $p < 0.001$ ,  $h^2 = 0.28$ ]. The comparison for the primary function was also statistically significant:  $F(1, 161) = 64.00$ ,  $p < 0.001$ ,  $\eta^2 = 0.28$ . The averages of the 3 questions are shown in Figure 1 in ascending order. From the above data, it can be seen that teachers significantly differentiate between the importance of influencing social institutions in the structure of training programs. In more detail, teachers believe that social demands do not significantly affect the decisions made in the preparation of training programs. The most important role is of the demands of capital and the economic system, while the political choices of the states are also a lever of influence.

Table 3. Sources of influence of training programs

Training programs are designed based on	Median	Quadrants		
		25	50	75
Capital requirements and the financial system (Q. 8)	4.00	3.00	4.00	5.00
Political choices of states (Q. 9)	4.00	3.00	4.00	4.00
Social requirements (Q. 10)	3.00	2.00	3.00	4.00

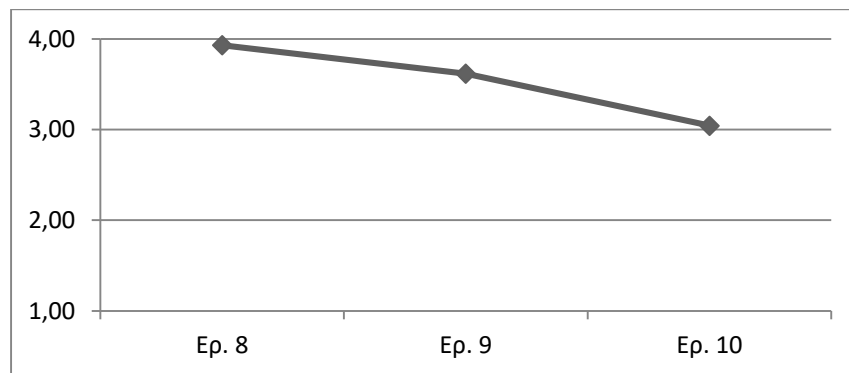


Figure 2. Hierarchical ranking of training impact sources

## 6. Discussion

The teacher and his insights into the growing inequalities in the educational context are a powerful influencing factor (Blackledge & Hunt, 2000). The research teachers give us meaning in their own role in the educational system, but also in the educational system itself in dealing with educational reality and in removing social and educational inequalities, indirectly emphasizing the functional role of education in providing equal opportunities through meritocratic processes that favor social mobility and alleviate social inequalities. The majority of our research teachers refer to the positive role that education can play in removing social exclusion, we would say in an ideal correlation, because at the micro level of ICT applications in education it seems that they have a more negative view. Social inequalities and their correlations with the outcomes of education have been studied in recent decades, highlighting several interpretive examples (Blackledge & Hunt, 2000; Lamnias, 2001; Fragoudaki, 1985), but also the role of intermediate variables, such as gender, social class, nationality and race (Romero & Margolis, 2005).

In the globalized and changing postmodern environment, the continuous training of teachers (Saitis, 2005) and especially in ICT is necessary. It is no coincidence, then, that strategies for implementing educational policy make teacher upgrading one of their top priorities (Bagakis, 2005). The teachers of our research interpret the institution of education as reproductive, where their contents and orientation are determined by the dominant social groups, which can impose their own ideological and political positions as another form of “symbolic violence”. European education policy is perceived, formally, negatively by teachers, indicating their opposition to mechanisms of pressure and homogenization of education, while broader social requirements do not play such an important role in the decisions taken to prepare training programs. Teachers give meaning to the institution of education as a mechanism for influencing the relative autonomy of the teacher, for the benefit of the dominant ideas and opinions (Mavrogiorgos, 1999).

The results of the research show that teachers point out the importance of continuing education, while rejecting distance education. Funding in education, but also in the introduction of ICT, plays a dominant role in upgrading the quality of education, but also in changing pedagogical-teaching practices, according to their views. Similar findings have been found in other research, highlighting the need to support teachers through training and changing culture and practices in education (Giavrimis & Giossi, 2011), but also to increase the financial resources available to upgrade the teacher’s project (Spyropoulou et al., 2004). The consequence of the above is the expression of a negative to ambivalent view by several teachers who believe that school cannot remove inequalities in education, not even with the use of new cognitive tools (ICT). This is supported by their views on the inadequate training of ICT teachers, which does not contribute to the improvement of basic education, scientific training, self-esteem and the full development of ICT skills, and does not appear to meet the new educational needs. Their. Similar results have been found in Greek and international space (Drent & Meelissen, 2008; Zagoura, 2005. Galanouli et al., 2004; Jimoyiannis, & Komis, 2006; 2007; Karagiorgi, & Charalambous, 2006). Education for all and alleviation of social inequalities are among the issues of the postmodern era, but both the functioning of education and the way ICT is introduced into education do not help eliminate educational inequalities. Education reproduces social inequalities by failing to provide a socially differentiated quality of learning, insisting on instrumental analyzes of technocratic elements and quantified cognitive data. As Althusser (1999) states, education functions as an ideological mechanism of repression, reproducing inequalities in the distribution of social roles and the labor market and normalizing students' performance in school and ICT (Blackledge & Hunt, 2000). These views do not seem to differ from either gender or years of service in our research.

In conclusion, teachers emphasize the functioning of the institution of education in ICT as a tool for pursuing an educational policy of the dominant social groups, but also their reflection on European education policy. They express the need for continuing education, while

differing in its role in removing educational inequalities. The insufficient fulfillment of the objectives of the training in ICT by state bodies advocates the above views of the teachers. There is, therefore, indirectly the educational project of building a functional training program that will keep up the pace with the new cognitive tools provided in the post-modern era, while increased funding is considered necessary as means of better quality upgrading of ICT training. Dominant elements, however, we think are the decentralization of educational decisions, the participation of teachers in decision-making for the implementation of ICT in education and for the implementation of their training, but mainly the change of culture and interpretive patterns used by teachers in relation to their operation within the educational system.

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## Using 360° Videos for Teaching Volleyball Skills to Primary School Students

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### *Abstract*

The study presents the results from a pilot project in which 360° videos were utilized for teaching students basic volleyball skills. The target group was thirty-six, eleven-to-twelve years-old primary school students, divided into two groups: the first was taught conventionally and the second using apps in which 360° videos were embedded. The project lasted for six two-teaching-hour sessions (three for each method), and data were collected using observation sheets and a questionnaire for recording students' views regarding their experience. The data analysis confirmed that, compared with conventional teaching, 360° videos allowed students to perform better the skills that were examined. The participating students also thought that by viewing 360° videos they were more motivated to learn and that their experience was an enjoyable one. On the other hand, students did not consider the 360° videos as being useful in their learning. Given the lack of research in this field, the findings provide an initial indication of 360° videos' potential in Physical Education. Then again, the results also point to the need of finding more innovative methods for integrating 360° videos in everyday teaching.

*Keywords:* 360° videos, primary school students, skills, volleyball.

### 1. Introduction

Physical Education (PE) is a learning subject that differs significantly from all others, as its main objective is the engagement of students in physical activities. In its current form, it focuses on team sports rather than in activities related to the outdated philosophy of Swedish/pedagogical gymnastics. That is because students' participation in team sports allows them to become physically fit and to develop their motor and social skills (Kelly & Melograno, 2014). What is more, the teaching of movement coordination and motor skills, contributes to the improvement of students' reflexes, helps to avoid injuries, and creates incentives for further involvement in sports (Šimonek, 2014). The role of PE teachers is quite complex, as they are called to carefully design and organize their courses in order to achieve the effective transmission of knowledge/skills and create a pleasant climate that motivates students to participate in the activities, even the ones of increased weight, integration problems, and low self-esteem (Greek Ministry of Education, 2016). The process of learning sports related motor skills and techniques has been the subject of numerous studies; many, often conflicting, opinions and theories were tested and eventually adopted or disapproved according to their results. What is widely accepted, however, is that it is not enough for a PE teacher to simply give some instructions for performing

an activity and students to reproduce it. Evidently, a modern teaching model of PE consists of theory, classroom management, design of student activities, and evaluation (Metzler, 2017).

- Physical Education has become quite important because of the modern way of life.
- The learning of skills related to team sports is an important part of Physical Education.
- 360° videos are an effective tool for teaching a wide range of learning subjects.
- 360° videos proved to be more effective than conventional teaching in the teaching of volleyball skills.
- Fun and motivation contribute to the effectiveness of 360° videos.

In the past decades, ICTs were introduced in all levels of education and across almost all learning subjects, including PE. However, the introduction of ICT tools in PE is not an easy task. The most common problem is the lack of infrastructure, which hinders or even prohibits the use of ICTs in this subject (Yaman, 2008). Then again, videos are quite commonly used in the context of PE with positive results (Weir & Connor, 2009). Their contribution to the educational process is found both during the teaching and evaluation phases. During teaching they are mainly used for demonstrating, for example, a movement, in order to enable students to understand its mechanics. During the evaluation, they provide an opportunity for PE teachers to document the improvement of students' skills (Mohnsen & Thompson, 1997). In recent years, videos have evolved; surpassing the limitation of the single point and limited field of view. The technology of 360° videos (also known as spherical videos), by using special cameras, allows the recording of images from a whole sphere. Users are then able to view these videos on their PCs, smartphones, or using head-mounted displays (HMDs). What is of interest, in the last two cases, is that when users move their smartphones or heads, a different area of the current scene is displayed. Thus, 360° videos offer an unparalleled viewing experience, immersing users in the environment they present (Higuera-Trujillo et al., 2019; Slater et al., 2016).

Research has demonstrated that 360° videos had a positive impact on learning, motivation, and enjoyment while learning (Lee et al., 2017). On the other hand, their educational potential is still largely unexplored, as relevant studies in the field of PE are sparse. Given this lack of research, a pilot study was carried out having as its main objective to examine whether 360° videos can produce better results, in terms of improving sport-related skills, compared to conventional teaching. It was also considered important to examine students' views on the use of 360° videos in relation to their motivation, enjoyment, and whether they thought that 360° videos can facilitate their learning. Details for the project and its outcomes are presented in the coming sections.

## 2. Physical education

The modern way of living has led to obesity problems, reduced physical activity, and bad eating habits. As a result, the need for quality training and exercise from an early age is imperative (Basoglu, 2018). PE can be part of the solution (SHAPE America, 2013). Its main objective, at all levels of education, is the development of students' motor skills and, through them, the cultivation of their physical abilities and the strengthening of their health (National Association of Sport and Physical Education, 1992). The above is achieved when students are able to perform a variety of motor skills, regularly participate in physical activities while being aware of their importance, and have a good overall physical condition (Metzler, 2017). PE is not only a set of motor exercises or physical games but, in a broader sense, it also involves the study of health issues and techniques that improve one's life. Through the teaching of PE and its various aspects, students are given the opportunity to promote and develop their critical thinking. Not only that, but students who are actively involved in physical activities perform better in school tests, in subjects such as mathematics, language, and the study of the environment (Azevedo, 2019;

Brusseau & Hannon, 2015; Conyers & Wilson, 2015). This led to the introduction of the term “kinetic literacy”, which describes the motivation, self-confidence, motor dexterity, knowledge, and the embracing of values related to lifelong physical exercise (International Physical Literacy Association, 2017). Therefore, students need to realize the benefits of PE (Singh, 2020).

Quite logically, one might ask what can be considered as effective teaching models in PE. Should the emphasis be on physical exercises or on the fun/enjoyment caused by physical activities? Although there is no easy answer to this question, as there are conflicting opinions, it appears that two major approaches exist. PE in the form of “fun activities” offers stronger incentives for participation (Prochaska et al., 2003; Werle et al., 2015), as they create a more attractive environment for learning (Garn & Cothran, 2006). On the other hand, PE in the form of “training/exercises”, because it is a more demanding and intense procedure, can result not only in the development of physical/motor skills but also in the improvement of self-confidence, which, eventually, allows students to adopt a healthier lifestyle and become physically active individuals throughout their lives (Ferkel et al., 2017).

Nevertheless, the most important priority of both approaches is students to acquire motor skills that are considered important. Systematic training provides the necessary knowledge and confidence, so as students to actively participate in various physical activities and sports (Rink & Hall, 2008). Previous studies have demonstrated that confidence is positively linked to student's inherent motivation. When they come to believe that their skills can be successfully performed at any time and, if necessary, new skills can be acquired, students build their self-esteem and confidence (Rink & Hall, 2008). In turn, as long as students feel that they are capable of performing an activity, they are encouraged and enjoy their participation in PE (Goudas et al., 2000; Whitehead & Corbin, 1991).

Mosston and Ashworth (2002) described a total of eleven PE teaching methods (i.e., commands, practice, reciprocal, self-check, inclusion, guided discovery, convergent discovery, divergent production, individually designed program, learner initiated, and self-teaching). Out of them, it seems that the dominant method and the most popular among PE teachers is that of commands (Kulinna & Cothran, 2003). In short, it is the PE teachers who make all the decisions about how to conduct the course. As far as a skill or an exercise is concerned, they divide it into smaller parts and demonstrate it. Following that, students are asked to perform the skill and PE teachers provide feedback on whether the skill/exercise was accurately performed or not. Also, a quite popular method is that of practice. As its name implies, students are divided into small groups and practice the given skill.

Coming to team sports, football and basketball are the ones most commonly taught in Greek schools; volleyball and handball are less frequently taught. Active participation in these sports is of paramount importance for learning the skills related to them. That is because the degree of participation determines the extent a skill is practiced but also has an effect on the desire of students to continue participating. As in all physical activities, modeling and visualization of a move/skill related to a sport, through kinetic representations, is vital. That is because it allows learners to decode the pattern of the move, facilitating the learning of the given motor skill (Zetou et al., 2002). In addition, feedback (in the form of oral comments from the PE teachers) when learning sports-related skills is also important. It is no surprise that from very early on, PE teachers are trained on how to provide this feedback (Cloes & Premuzak, 1995), with the emphasis being on the quality, but also in the form this feedback has to have. Positive feedback is often associated with the strengthening of students' inherent motivation, which ultimately leads to the strengthening of their resolution to perform better (Mouratidis et al., 2008).

The teaching of PE is not without problems, with the most important one being students' participation. Research has highlighted the inextricably linked relationship between a positive teaching climate, motivation, metacognition, and students' participation in sports

(Papaioannou et al., 2006). Regrettably, this problem becomes even more prominent as students grow up and pass from one educational level to another, resulting in a lower desire and motivation to participate (Van Wersch et al., 1992). Moreover, in the early stages of learning a skill, additional obstacles are encountered, that render difficult the process of mastering it. Such obstacles are the need to monitor a moving object (e.g., a ball), the need to (quickly) select the corresponding motor skill to be applied, and the correct synchronization of more than one moves (Zetou et al., 2002). Quite often, students' attention is directed to these factors, disproportionally increasing the effort they have to put in performing and/or learning the skill, or resulting in the incomplete/incorrect learning of it. Videos are probably the most important tool PE teachers use in their task of modeling/visualizing a skill or move. As already stated in the Introduction, videos are used in both the teaching and assessment stages. Studies have reported not only positive learning outcomes but also a positive impact on students' motivation (e.g., Palao et al., 2015; Robinson, 2011; Weir & Connor, 2009). In addition, together with oral feedback, videos helped to reduce the amount of practice needed for learning a skill/move (Palao et al., 2015).

### 3. 360° videos

As mentioned in a preceding section, 360° videos are recorded using cameras able to capture images from a 360° field of view (from a whole sphere to be exact), instead of the conventional limited angle of coverage of regular videos; thus, 360° videos offer a view that is perceptually similar to what individuals can see, in real life, by turning their heads in every direction (Pham et al., 2018). Video editing does not differ from the procedures followed with regular videos. While 360° videos can be viewed at any device and by using any software capable of playing regular videos, it is preferable to use a smartphone or, even better, an HMD. That is because the gyroscopes in these devices allow users to simply move their smartphones or their heads in order to display a different part of the scene. As a consequence, users are immersed in an environment that is not that different from reality, resulting in a high degree of engagement with what they see (Hebbel-Seeger, 2017). Interactive hotspots can be added that allow the transition to other (360°) videos or the display/playback of multimedia elements (e.g., web pages, images, sounds, music, and text) (Argyriou et al., 2016; Kallioniemi et al., 2018). 360° videos have found their way in diverse scientific/professional fields. For example, they are used for virtual guided tours (Garzotto et al., 2018; Hakulinen et al., 2017), for demonstrating medical procedures (e.g., a surgery) (Guervós et al., 2019), and, as expected, in education (Lee et al., 2017; Queiroz et al., 2018). As far as the latter is concerned, 360° videos are applied in a rather impressive range of subjects and disciplines such as history (Rasheed et al., 2015), astronomy (Rupp et al., 2016), foreign language learning (Huang et al., 2019), medical training (Yoganathan et al., 2018), chemistry and lab training (Clemons et al., 2019), and physics (Wu et al., 2019). Besides the positive impact on knowledge (e.g., Berns et al., 2018; Chang et al., 2019) and skills (e.g., Parmaxi et al., 2018), researchers have reported increased knowledge retention (Dolgunsöz et al., 2018), motivation and enjoyment while learning (Chang et al., 2019; Huang et al., 2019; Rasheed et al., 2015), and raised awareness of important issues (e.g., social, political, and environmental) (Elmezeny et al., 2018).

The keys for understanding the educational potential of 360° videos are immersion and the realistic experiences they provide; after viewing them students, as well as any other user, are left with the impression that they were “in” the environment presented in the video (Narciso et al., 2019). Moreover, because students have the opportunity to observe details that can be passed unseen in regular videos and to choose the perspective from which to observe and interact with the content, they are able to experiment without being afraid to fail (Hussein & Nätterdal, 2015). As a result, teaching, in the eyes of students, becomes a meaningful process, while, at the same time, they are provided with the incentives to participate in the course (Lee et al., 2017).

Teachers' attitude regarding the introduction of 360° videos in their courses is also positive (Geng et al., 2019; Stojšić et al., 2019).

On the negative side, a common problem is what is called "simulator sickness." Users often feel discomfort, vertigo, nausea, and dizziness, because their bodies (which are static) and their eyes (which view moving images) provide conflicting information to their brains (Lawson, 2014). This situation, although a temporary one, severely impairs their cognitive abilities and negatively affects the learning outcomes (Rupp et al., 2019). An additional problem is the weight of some HMDs, which can cause discomfort and/or fatigue (Broeck et al., 2017). Other issues mentioned in the literature are the instability of the video and lagging (it takes a few milliseconds between the turning of the head and the display of the corresponding part of the scene) (Martín-Gutiérrez et al., 2017). Students are sometimes distracted by the novelty of the experience (Rupp et al., 2016) and do not pay attention to what they are supposed to learn (Karageorgakis & Nisiforou, 2018).

Research regarding the use of 360° videos in PE and in sports is rather limited; therefore, the results of the relevant studies have to be viewed with some caution. They were used for PE teachers' training (Roche & Gal-Petitfaux, 2017), with the authors concluding that the participants considered them effective tools for monitoring students' performance. In another study regarding the usefulness of this tool in sports journalism (Delmazo, 2018), they proved to effectively convey to viewers the intensity of the effort of para-Olympics basketball players. In a number of studies in which 360° videos were used for improving athletes' decision-making skills in team sports, such as basketball (e.g., Pagé et al., 2019; Panchuk et al., 2018) and football (e.g., Kittel et al., 2020), the results were mixed. On one hand, participants enjoyed the experience and had a positive attitude towards their use. On the other hand, the results in terms of acquisition of skills were not that different from the ones that were achieved from the use of a virtual reality application (Pagé et al., 2019) or conventional training (Panchuk et al., 2018). The results were similar in the study of Kittel et al. (2020) but the authors noted that the retention of skills over time was better with the use of 360° videos.

#### 4. Method

As we presented in the preceding sections, although research on the educational uses of 360° videos is still at its early stages, the literature suggested that they constitute an interesting alternative teaching tool, applicable in a wide range of settings and disciplines. Having the above in mind, we decided to implement a pilot project in order to examine their impact on the teaching of skills related to PE. Out of the various sports, we selected volleyball, as it is among the ones that are not systematically taught (at least in Greece). As we were interested in comparing the results from the use of 360° videos with conventional teaching, we followed a two conditions/treatments between-subjects design, meaning that we had two groups of students who were taught the same subjects using two teaching tools/methods (conventional teaching-control group and 360° videos-experimental group). We set the following research hypotheses:

*H1. Compared with conventional teaching, 360° videos are more effective in teaching primary school students skills related to volleyball.*

*H2a-e. Compared with conventional teaching, primary school students consider 360° videos as being more (a) useful, (b) motivating, and (c) a more enjoyable experience.*

#### 4.1 Sample and duration

Given that in Greece's primary schools volleyball is usually taught at the last grades, we decided the participants to be eleven-to-twelve years-old students. We communicated with several public primary schools located in Komotini, Greece and we asked their PE teachers to provide some data for their students, which would help us to form an ordinary and typical sample (Creswell & Creswell, 2017). As a result, we selected two classes, each having twenty students (twenty-one boys and nineteen girls), who: (i) had never before been formally taught skills related to volleyball, (ii) had no prior experience in using HMDs, and (iii) the boys to girls ratio was close to the national ratio. To ensure compliance with the ethical standards and research guidelines, we applied for and we were granted a research approval from the University's ethical committee. Also, we asked for students' parents written consent, following a briefing regarding the study's objectives and methods. The duration of the project was six two-teaching-hour sessions (three for each tool).

#### 4.2 Materials

The development of the project's materials was a multi-stage process that lasted several weeks. The first step was to select which volleyball skills to teach. We decided to avoid teaching rules and tactics or to try to improve students' general physical skills; we deemed that it would be better to focus on basic moves that are relatively easy to quantify how well they are executed. By doing so, it would be easier for us to measure the interventions' outcomes. Consequently, we selected the setting, passing, and underhand serving as the project's subject matter. The next step was to search for suitable, ready-made, and freely available multimedia material. While we were able to find some regular videos, photos, and figures, we did not find any 360° videos relevant to the project. Therefore, for each of the three moves, we recorded several video-clips, using fairly cheap 360° cameras. We have to note that we recruited professional volleyball players to demonstrate the moves, so as to ensure that each was perfectly executed and also because literature suggested that this contributed to the better understanding of sport-related skills (Magill & Schoenfelder-Zohdi, 1996; McCullagh & Caird, 1990; Zetou et al., 2002). Not only that, but we recorded each move from three different angles (Figure 1). By doing so, together with the fact that, by default, in 360° videos, it is possible to zoom in and out, the viewer would be able to observe each move in in much greater detail than in a regular video.

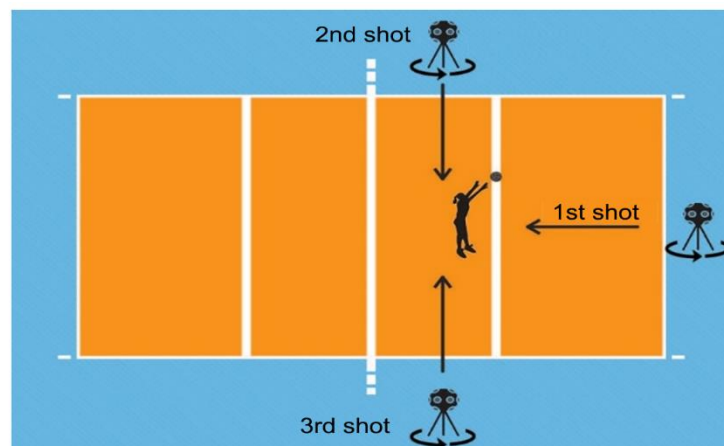


Figure 1. Recording of 360° videos from multiple angles

The next step was to edit the recorded video clips, add voiceovers and subtitles. Following that, the videos were imported to 3D Vista Virtual Tour (<https://www.3dvista.com/>),

for adding multimedia, as well as interactive features, and for the development of apps that could run on smartphones. This relatively easy-to-use software allows the development of apps which are, essentially, virtual guided tours. Hotspots were added allowing the transition between different scenes and the display of images, texts, and regular videos, which provided additional information for the move that was demonstrated (Figure 2). Out of the available methods to trigger these hotspots, we selected the “gaze” technique. In essence, for triggering an event, this technique requires users to focus on a certain area/hotspot and hold their position for about two seconds. Three apps were developed using this software, one for each move. Five sixth-grade students (who did not participate in the study) used the apps. On the basis of their comments, we re-edited some parts of the apps.

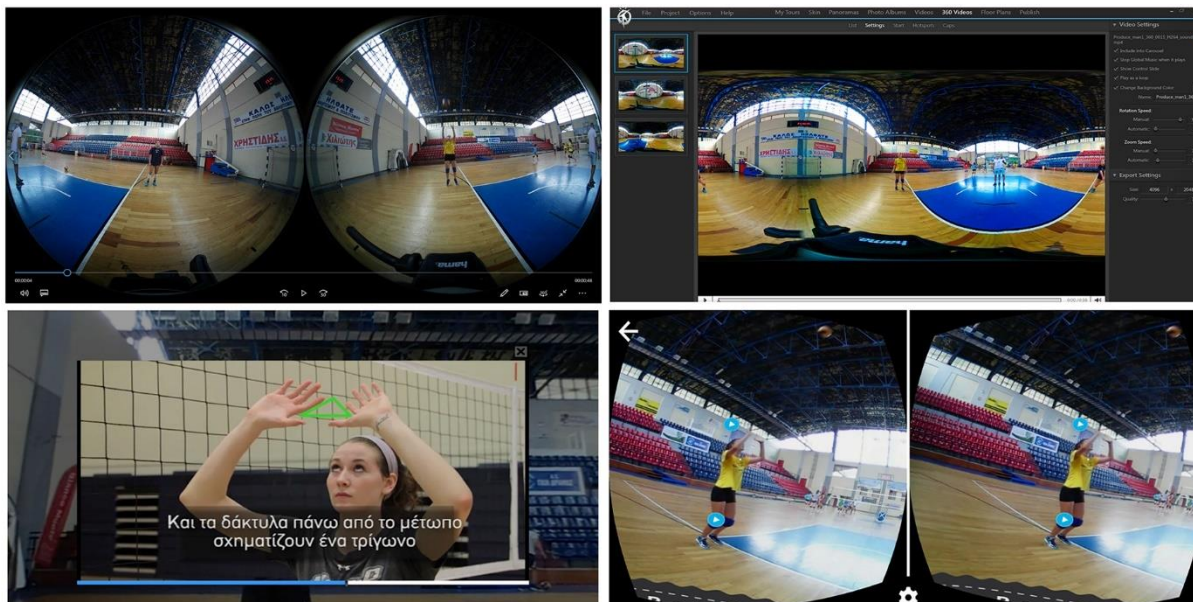


Figure 2. Screenshots from the development of the apps

For viewing the 360° videos/running the apps, the participants used their smartphones together with HMDs similar to Google Cardboard (which we provided to them). Google Cardboard is a low-cost system made out of cardboard or plastic with just two lenses and a compartment in which a smartphone is inserted. While they are not actual HMDs, as they do not have any electronics, Google Cardboard and its clones provided access to 360° videos and virtual reality applications to millions of users (Martín-Gutiérrez et al., 2017).

### 4.3 Instruments

For collecting data, we used an observation protocol. For that matter, each of the three volleyball moves/skills included in our study was broken into smaller easy to observe segments (Table 1). Two individuals acted as raters (a teacher and a researcher), simultaneously collecting observational data (i.e., whether each segment of the volleyball move/skill under examination was executed correctly). We trained them both in two sessions prior to the beginning of the project, by asking them to observe ten students (who did not participate in the study), who repeated each move for five times. We assessed the consistency among the raters using Cohen's kappa coefficient and we found it to be very good [ $\kappa = .89, p < .001, 95\% \text{ CI } (.87, .91)$ ] (Landis & Koch, 1977). During the implementation of the project, the participants were observed twice for each move/skill, once prior to the intervention and once right after it. In both cases, they were asked to repeat each move

five times. The raters added a point when all the segments of a move were executed correctly; otherwise, no points were added to the participant's scores.

Table 1. Observation protocol

<b>Setting</b>	<b>Passing</b>	<b>Underhand serving</b>
Are the legs open as much as the opening of the shoulders and one leg precedes the other? Are the knees bent?	Are the legs open as much as the opening of the shoulders and one leg precedes the other? Are the knees bent?	Is the left foot in front of the right and are the knees slightly bent? Is the trunk/body tilting slightly forward?
Do the indexes and thumbs form a triangle?	Are the hands "tied" properly? Is one palm inside the other?	Does the participant hold the ball with the left hand and is it in front of his right thigh?
Do the hands touch the ball at the forehead level?	Are the elbows stretched during the strike?	Does the participant's right hand moves from back to front to hit the ball?
Are the elbows bent?	Does the ball hit the bottom of the forearms?	Does the participant's hand touch the ball from behind and under it? Does the participant carry his/her weight from the back to the front foot when hitting the ball?

For examining H2a-c, we used a questionnaire that was based on a validated modular scale designed for examining digital educational applications (Fokides et al., 2019). We selected three of its factors, which corresponded to H2a-c, namely, fun/enjoyment (six items), subjective usefulness (six items), and motivation (three items). In this scale, all items are presented on a five-point Likert-type scale (ranging from 1 = strongly disagree to 5 = strongly agree). We administered this questionnaire to both groups at the end of all interventions.

#### 4.4 Procedure

Prior to the beginning of the project, in order to avoid technical problems and/or usability issues, we took a series of measures. First, we demonstrated to students participating in the experimental group how to use their smartphones together with the Google cardboard compatible HMDs. Following that, we installed an app on their smartphones. Although it was not relevant to the project, its structure and interactive features were similar to the ones developed for the project. Next, students were allowed to practice for about an hour and a half, for familiarizing themselves on how to handle the equipment, as well as on how to navigate and use the app. At the end of the familiarization period, we checked whether they were competent enough in using both the HMDs and the app. Each of the project's apps was installed on students' smartphones right before the corresponding intervention. For example, the app demonstrating the underhand serving was the last one to be installed, given that this move/skill was demonstrated during the third and final session.

At the beginning of each session, the participants (regardless of the group they belonged to), were individually asked to perform five times the move/skill that was the session's subject. For example, they were asked to perform a pass, the way they thought it should be done. While doing so, the raters observed them, following the protocol we presented in the preceding section. The reason for this was to collect data regarding the initial students' skills for the given move. Next, depending on the group, the students either used the app or the PE teacher explained and demonstrated the move. In any case, students were allowed to use the apps for three times, which were considered enough for grasping the basics of the move. The same applied for the



control group; the PE teacher explained/demonstrated the move three times. Following that, students were asked to perform, once again, for five times the move that was presented to them. At the same time, the raters observed whether the move was correctly performed, as they did at the beginning of the session.

### 5. Results

Although forty students were enrolled in the project, we had to exclude four of them because they were absent in one or more sessions. We averaged the score of each student in each move and we imputed the resulting data into SPSS 26 for further analysis. Table 2 presents descriptive statistics for each move/skill.

Table 2. Means and standard deviations per group and per move/skill

Observation sheet	Group			
	Control ( <i>n</i> = 18)		360° videos ( <i>n</i> = 18)	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Pre-intervention observation setting (max = 5)	1.58	0.65	2.03	0.93
Post-intervention observation setting (max = 5)	2.69	0.97	3.75	0.88
Pre-intervention observation passing (max = 5)	1.06	0.91	1.39	1.48
Post-intervention observation passing (max = 5)	2.17	0.84	3.39	0.83
Pre-intervention observation underhand serving (max = 5)	1.36	0.74	1.87	1.07
Post-intervention observation underhand serving (max = 5)	2.81	1.10	3.78	0.96

After checking that the data were suitable for one-way ANOVA testing (we found no violations of the assumptions), we conducted a series of these tests for determining whether there were differences between the experimental and the control group. The results demonstrated that there were no differences in the pre-intervention observation sheets ( $p = .106$ ,  $.421$ , and  $.106$  respectively) (Table 3). This means that any differences we were to find in the post-intervention observation sheets could be attributed to the different method/tool we used. Indeed, we found statistically significant differences in all the post-intervention observation sheets ( $p = .002$ ,  $<.001$ , and  $.008$  respectively), indicating that the students in 360° videos group had better results in the three moves/skills we examined. Thus, we can confirm H1.

Table 3. One-way ANOVA results for the observation sheets

Observation sheet	Result
Pre-intervention observation setting	$F(1, 34) = 2.77, p = .106$
Post-intervention observation setting	$F(1, 34) = 11.68, p = .002$
Pre-intervention observation passing	$F(1, 34) = 0.664, p = .421$
Post-intervention observation passing	$F(1, 34) = 19.22, p < .001$
Pre-intervention observation underhand serving	$F(1, 34) = 2.77, p = .106$
Post-intervention observation underhand serving	$F(1, 34) = 7.99, p = .008$

We checked the questionnaire’s overall internal consistency, as well as the reliability of the three factors, using Cronbach’s alpha. In all cases, we found  $\alpha$  to be very good, as it was well above the recommended value of  $.70$  (DeVellis, 2003) (ranging from  $\alpha = .785$  to  $.811$  for the factors and  $\alpha_{overall} = .804$ ). We present descriptive statistics for the factors included in the questionnaire in Table 4. For analyzing the data, we followed the same procedure as in the observation sheets. We found no statistically significant differences subjective usefulness ( $p = .800$ ) (Table 5). On the other hand, we found a statistically significant differences in fun/enjoyment ( $p = .002$ ) and motivation ( $p = .003$ ), indicating that students in the 360° videos group had more fun and were

more motivated to learn than in the control group. Given the above, we have to reject H2a, while we can confirm H2b and H2c.

Table 4. Means and standard deviations per group and per questionnaire’s factors

Factor	Control group		360° videos group	
	(n = 18)		(n = 18)	
	M	SD	M	SD
Fun/enjoyment	3.31	0.67	3.97	0.97
Subjective usefulness	3.38	0.79	3.44	0.85
Motivation	3.17	0.62	3.96	0.85

Table 5. One-way ANOVA results for the questionnaire's factors

Factor	Result
Fun/enjoyment	$F(1, 34) = 5.64, p = .002$
Subjective usefulness	$F(1, 34) = 0.65, p = .800$
Motivation	$F(1, 34) = 5.46, p = .003$

## 6. Discussion

The data analysis we presented in the preceding section confirmed our main research hypothesis, namely, that 360° videos are more effective in teaching primary school students volleyball skills compared to conventional teaching. We can draw some interesting conclusions from our results, as we elaborate in the following paragraphs.

An interesting observation comes from students’ scores in all the pre-intervention observation sheets. Depending on the skill that was tested and on average, they were able to correctly perform 1 up to 1.9 moves (out of five attempts per move) (see Table 2). Taking the results in the pre-intervention observation sheets as reference points, the results in the post-intervention observation sheets indicated a significant positive change, ranging from 70 up to 106% for conventional teaching and from 85 up to 144% for 360° videos. Whether these outcomes, in relation to the effectiveness of 360° videos, can be characterized as satisfactory, is a matter of debate. In fact, two opposing views can be supported. On one hand, some might argue that the positive effects of conventional teaching cannot pass unseen. Moreover, a skeptic might add that these results were achieved without using a “fancy” technology (such as 360° videos), without investing valuable time for the development of the relevant apps, and without additional costs (for purchasing HMDs). Moreover, the improvement of motor skills depends heavily on the repetition of exercises and recurring training (Zahradník & Korvas, 2012). In this respect, conventional teaching is an effective method that hardly needs to be reformed. On the other hand, some might argue that even the slightest positive change in the outcomes of training of motor skills is important (which is even more important when athletes are involved). In a way, the above arguments reflect the ongoing -and still unresolved- debate on the educational value of almost all ICTs, which is beyond the scope of our study. Nevertheless, the fact that we noted statistically significant differences between conventional teaching and the use of 360° videos, in favor of the latter and in all the three skills/moves we tested, allows us to support their integration into teaching.

Therefore, what we have to discuss is why the results of our study were in favor of 360° videos. Generally speaking, the results confirm the findings of several other studies regarding the effectiveness of this technology in several learning domains (e.g., Berns et al., 2018; Chang et al., 2019; Parmaxi et al., 2018). Our findings are also in line with past research that stressed the importance of videos in PE, as they allowed the better visualization of skills/moves (e.g., Palao et

al., 2015; Robinson, 2011; Weir & Connor, 2009; Zetou et al., 2002). Thus, we can argue that 360° videos are also effective in visualizing PE related skills/moves.

Quite interestingly, our findings contradict the ones of past research in which 360° videos were used in the context of PE or sports (e.g., Kittel et al., 2020; Pagé et al., 2019; Panchuk et al., 2018). That is because these studies reported that 360° videos produced similar outcomes with that of virtual reality applications or conventional training. Then again, we have to stress that it is rather hard to compare the results of our study with the above-mentioned studies, given that they focused on the improvement of decision-making capacities while we focused on the acquisition of skills. Although decision-making is an important perceptual process that determines the effective utilization of motor skills, however, it follows, methodologically, the learning of motor skills. Moreover, these studies had athletes as their target groups and not primary school students.

Yet, in line with previous studies (e.g., Chang et al., 2019; Huang et al., 2019; Lee et al., 2017), we found that students were more motivated to learn than in conventional teaching and had a more enjoyable learning experience. Consequently, motivation offers a plausible explanation for our results, as it directly (and positively) affects the learning outcomes in almost all teaching subjects (Fokides, 2017; Fokides & Atsikpasi, 2018). The same applies for enjoyment; it is as a rather common finding in most research regarding the educational uses of 360° videos, positively correlated (together with motivation) with the learning outcomes (e.g., Chang et al., 2019; Huang et al., 2019; Rasheed et al., 2015).

Unfortunately, our research hypothesis that students will find 360° videos as being useful tools in their learning of volleyball related skills was rejected. We set this hypothesis on the basis of past research which indicated that participants have a positive attitude towards the use of 360° videos (e.g., Kittel et al., 2020; Panchuk et al., 2018). A plausible explanation for this outcome is that students' pre-existing learning stereotypes inhibited their acceptance of 360° videos. Students are not trained using similar innovative educational means; therefore, the use of 360° videos was viewed as a deviation from what they are familiar with, making them a bit reserved. Moreover, we think that this result has to be considered together with the teaching framework we selected. We deliberately applied the commonly used method of commands as a teaching style to both groups, in order to avoid a possible impact of the teaching method on the results. Then again, literature suggested that constructivist, student-centered teaching frameworks are better suited when 360° videos are used (Fokides & Kefallinou, 2020). In this respect, the results related to the subjective usefulness of 360° videos, might have been better, if we had allowed students to be more actively involved in the learning process by using a different method, for example, self-check or guided discovery (Mosston & Ashworth, 2002).

### *6.1 Implications for research and practice*

The contribution of our study lies to the fact that it extends the -rather limited- literature regarding the educational uses of 360° videos given that we (i) examined the learning of sports-related skills with the help of this technology and (ii) contrasted the outcomes with that of conventional teaching and quantified their differences. The study's findings might have implications that could be of interest to researchers, software development experts, and educators. For example, we found that students did not consider 360° videos as being useful tools for learning the skills we tried to teach them. While this finding was rather surprising, as we elaborated in a preceding section, one should probably consider how to avoid this issue. One way to attract the interest of students is by adding game-like features to the apps, a solution that is applicable to most ICT tools (Fokides et al., 2019). On the other hand, caution is advised. That is because there is always the chance the novelty of the experience 360° videos offer, to overwhelm students, distracting them from the learning content (Rupp et al., 2016). The addition of game-like features

might amplify this problem. Improving usability, in terms of user navigation and interaction with the apps, might also help. In our study, the hotspots were triggered by focusing on them. Hand tracking would have allowed a more natural interaction method (Miller & Bugnariu, 2016), although this would have required additional hardware (and costs).

There are also several issues that need to be tackled if we are to successfully introduce 360° videos to PE. The first, and by far, the most important issue is the lack of relevant apps. Finding freely available 360° videos or even recording your own is one thing, but there is a considerable distance between that and developing pedagogically and technically sound apps. Even though on the basis of the experience we gained in this study, we can support that it is not that hard to develop apps in which 360° videos are embedded, it is questionable whether PE teachers have the expertise, the will, and the available time to do so. Therefore, we recommend education policymakers and administrators to take action with the objective of making available a large pool of ready-made apps to PE teachers. Certain ICT tools (including HMDs and 360° videos), in order to be successfully integrated and properly used in everyday teaching, require time. It is rather unrealistic to use such tools in just one teaching-hour, considering that technical problems might arise, students have to become familiar with the tools, and the teaching framework has to be adjusted. Therefore, primary school's timetable and program of study have to be reformed and become more ICT friendly.

### *6.2 Limitations and future research*

Although the results quite clearly demonstrated that 360° videos have a positive impact on the acquisition of volleyball related skills, the study has certain limitations that bear mentioning. The sample size, although adequate for the statistical procedures we followed, could have been larger; a more diverse age range could have been included as well. Moreover, we focused on a handful of volleyball skills, covering just a fraction of PE related subjects. Quite logically, one might have reservations for the generalizability of our results. PE is not just about knowledge and skills; attitudes and behaviors are also important. Alas, we did not examine the impact of 360° videos on the above. Then again, we have to stress that the study was highly exploratory in nature; 360° videos are an emerging technology and research on their educational uses is still at its early stages. Nevertheless, the limitations we mentioned above can act as guidelines for future research endeavors. The opinions, experiences, and attitudes of PE teachers towards the use of 360° videos during their teaching, are also interesting research subjects. The examination of a teaching method that will frame the use of 360° videos in PE would be extremely useful. Finally, it would be interesting to contrast the impact of 360° videos with that of other promising technologies (e.g., fully immersive virtual reality).

## 7. Conclusion

Nowadays, the importance of PE is emphasized, given that active participation in physical activities has become a necessity. This highlights the need of finding innovative methods that can effectively facilitate the acquisition of the relevant knowledge and skills, including the ones related to team sports. Videos are quite commonly used in training and PE. Given that (i) 360° videos are the next step in the evolution of regular videos, (ii) they constitute an interesting alternative teaching tool, applicable in diverse teaching frameworks and domains, and (iii) research on their use in the context of PE is rather limited, we implemented a pilot project in order to examine whether they can be effective in the teaching of basic volleyball skills to primary school students, by comparing their impact with conventional teaching. Indeed, the results revealed that students who viewed 360° videos performed better. Thus, it can be concluded that 360° videos are, under certain circumstances, an effective tool in the context of PE. Their effectiveness can be

attributed to the fact that they immerse users in a pleasant and motivating environment. While the study might prove useful to both PE teachers and researchers, there are unresolved issues in relation to the usability of 360° videos, the features that have to be included in the apps utilizing them, and to the changes that have to be made in schools' program of study and timetable. In conclusion, the educational potential of 360° videos and the added value they can offer to PE is still unexplored. Thus, there is room for many future studies in this field.

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