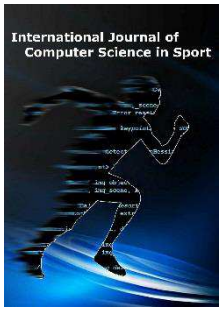
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The Impact of Blended Learning and Direct Video Feedback on Primary School Students' Three-Step Ball Throwing Technique

Kyriakidis, G., Panoutsakopoulos, V., Paraschos, I., Chatzopoulos, D., Yiannakos, A., Papaiakovou, G.

Department of Physical Education and Sports Sciences at Thessaloniki, Aristotle University of Thessaloniki, Thermi, Thessaloniki, 57001, Greece

Abstract

The purpose of this study was to evaluate three distinct methods of teaching the three-step ball throw simulating the javelin throw technique to primary school students. The sample consisted of 131 primary school students of 5th and 6th grade (Mage = 11.4, SD = 0.47 years) randomly divided into three groups. The control group (CON) received typical instruction, the first experimental group (EXP) followed a blended learning intervention which included an interactive learning activity software and the second experimental group (EXPVF) followed the same blended learning method with an additional direct video feedback system. A pre/post-test design was implemented to evaluate students' technique, using as criteria five selected technique elements of the three-step ball throw. Wilcoxon signed-rank test analysis showed that all three groups performed significantly better after the intervention in all five criteria. However, Kruskal-Wallis H test analysis with post-hoc test revealed that the results for EXPVF group were significantly better than the other two groups in all elements, while the EXP group showed significantly better results in three of the five elements compared with the CON group. In conclusion, students appeared to benefit more in their three-step ball throw technique through blended learning and direct video feedback.

KEYWORDS: BLENDED LEARNING, VIDEO FEEDBACK, ELEMENTARY EDUCATION, PHYSICAL EDUCATION, BALL THROW

Introduction

The overhand (or overarm) ball throw is a fundamental movement skill, comprising a common motor pattern used in several sports like baseball, softball and, in the case of athletics, the javelin throw (van Beurden et al., 2002). Performance in the latter was found to be related to release velocity, as well as with various spatiotemporal parameters, such as knee and elbow angles, torso inclination, etc., that comprise, among others, variables that interpret the javelin throw technique (Panoutsakopoulos & Kollias, 2013).

The acyclic translator movements of the javelin throwing technique in the final stage prior release increase the complexity of the movement and the requirement for adequate power production. This is due to the fact that a rapid deceleration along with the explosive throwing action are performed to transfer the energy gained at the run-up to the javelin at its release (Bartonietz, 2000; Campos, Brizuela, & Ramón, 2004; Frane, Borović, & Foretić, 2011; Silvester, 2003). The throwing action is optimized with the proper positioning of the limbs that enables constantly altering inter-segmental coordination patterns to establish the desired proximal-to-distal sequencing (Mero et al., 1994). These demanding tasks have led to the notion that the technique of the javelin throw is complex (Best, Bartlett, & Morriss, 1993). Due to the above, rather than the javelin throw, the ball throw using elements of the javelin technique is included in the Greek curriculum of Physical Education (PE) in primary education for the 5th and 6th grade (Avgerinos & Moundakis, 2014).

Students should learn to perform the throw with developed technical standards (Avgerinos & Mountakis, 2014). It is suggested that the throwing patterns observed in children are no different than those exhibited by skilled adult throwers and that they consist of a basic version of the skill (Young, 2009). Emphasis must be laid upon throwing at the pace of the last three steps, as the whole throwing technique is included (Tidow, 1996). Thus, teaching the three-step ball throw is an important step towards the full approach ball throw with javelin technique and Physical Education Teachers (PETs) are instructed to do so in Greek primary schools (Digelidis et al., 2006).

Research evidence regarding the technical characteristics of ball throw with javelin technique for young athletes, let alone Primary School students, is limited, if any. Blatsis et al. (2016) investigated the impact of the IAAF Kids' Athletics program on the overhead softball throw with javelin technique performance in 11-12 years old Primary School students. The achieved distance was recorded, without evaluating any technique elements of the throw. Nevertheless, qualitative analysis of the throw is not only essential for the effectiveness and economy of the movement but also for the prevention of injuries (Knudson & Morrison, 1996).

Typical instruction involves the initial information about the motor skill, its execution, the provision of feedback and its improved re-execution (Hebert, 2018; Schmidt & Wrisberg, 2008). Students must be provided with meaningful and quality information in order for the efficient motor skill learning to be achieved (Chatzopoulos, Foka, Doganis, Lykesas, & Nikodelis, 2020; Tzetzis, Votsis, & Kourtessis, 2008). The initial information can be given verbally with simple instructions or visually by demonstrating the skill. Observing this demonstration can lead to motor learning and is referred to as observation learning (Horn & Williams, 2004). Observation learning is accomplished through cognitive functions that form a mental representation of the motor skill which is used to reproduce it (Bandura, 1986). Thus, demonstration is a factor of major importance (Gallahue & Donnelly, 2007; Rink, 2006; Silverman, 1991).

In a typical approach, demonstration in PE lessons is provided by the PET and has better results when at the same time verbal instructions are given (De Maeght & Prinz, 2004; Ong & Hodges, 2012). A precise and detailed visual representation of the motor skill by the teacher, plays an

important role in its learning (Rink & Hall, 2008; Schmidt & Wrisberg, 2008). Yet, as evident in past research, PETs provide demonstration of mediocre quality (Vasiliadou Hristakis, Derri, & Emmanouilidou, 2006). Furthermore, the important points of the demonstrated skills appear to be overlooked (Coules & Tzetzis, 2005) despite their crucial importance in the development and elaboration of motor skills in sports (Thomas, French, & Humphries, 1986). Research shows that demonstration by an expert model enhances motor learning (Ste-Marie, Law, Rymal, Jenny, Hall, & McCullagh, 2012; Zetou, Tzetzis, Vernadakis, & Kioumourtzoglou, 2002), especially when the complexity of the motor pattern increases the difficulty for the student to discover the appropriate solution to achieve the goal (Hayes, Ashford & Bennett, 2008). Using video is an option for school environments, but extra care should be taken when adopting such a solution because a large amount of visual information may have little impact on learning. (Blischke, Marschall, Muller & Daugs, 1999).

The information a learner receives about the execution of a motor activity is called feedback (Hattie & Timperley, 2007; Kluger & DeNisi, 1996). This may occur within a detection - correction cycle, where feedback is important for learning a movement (Mulder & Hulstijn, 1985). Generally, there are two sources of feedback. The internal source which involves the perceptual information coming from the sensory system of the learner, it depends on the performed task and is referred to as task-intrinsic feedback. The second source is external and can be a coach, a video, a photo etc. This information enhances the task-intrinsic feedback or gives information that the sensory system of the learner cannot provide and is referred to as external or augmented feedback. The later comes in two forms: a) the Knowledge of Results (KR) which is information about the outcome of a movement execution like the distance in a throw and b) the Knowledge of Performance (KP) which informs about the quality of the execution such as specific technique elements (Magill & Anderson, 2014; Sigrist, Rauter, Riener & Wolf, 2013). Both forms seem to be effective in motor skill learning. However, when the skill requires specific movement characteristics and kinetic activity profile and/or concerns novices, KP is more effective (Magill & Anderson, 2014) as in throwing activities (Kernodle, & Carlton, 1992; Sharma, Chevidikunnan, Khan, & Gaowgzeh, 2016).

Although augmented feedback can be provided in various ways, visual feedback using video is at the center of research interest. Self-modeling and expert modeling are two augmented visual feedback methods that are mostly used. Self-modeling allows the learner to observe oneself after the execution of a movement, so that possible mistakes can be corrected. Expert modeling uses a model that properly performs the skill, for the learner to observe. Sometimes the combination of the two is used but it cannot be concluded which implementation is more effective as research that compares them directly is very limited (Mödinger, Woll & Wagner, 2021). Implementing such augmented visual feedback methods using video, offers many benefits to the learning process, including the capacity to shorten it, increase learning probability, and improve learning outcomes (Schmidt, Lee, Winstein, Wulf, & Zelaznik, 2018; Palao, Hastie, Cruz & Ortega, 2015). Most of the studies in the field have investigated the effect of video feedback and found improved performance (Kamnardsiri, Khuwuthyakorn, Boripuntakul, & Janchai, 2021; Mavragani, Zetou, Michalopoulou, & Aggelousis, 2021; Panteli, Tsolakis, Efthimiou, & Smirniotou, 2013; Puklavec, Antekolović, & Mikulić, 2021; Barzouka, Sotiropoulos & Kioumourtzoglou, 2015). However, as the time and equipment required to apply video feedback in a PE course appear to be a limiting issue, most of the relevant studies were conducted outside the frame of PE classes (Weir & Connor, 2009). Some forms of feedback such as self-controlled video feedback might seem promising, but their benefits require verification, since they can be difficult to be implemented in real PE lessons, particularly in primary education (Van der Kamp, Duivenvoorden, Kok, & van Hilvoorde, 2015). Regardless of the method, research shows that the most effective implementation is by combining video feedback and brief verbal instructions

regarding specific points of the performed motor activity (Potdevin, Vors, Huchez, Lamour, Davids & Schnitzler, 2018; Rucci & Tomporowski, 2010; Schmidt et al., 2018; Ste-Marie et al., 2013; Thow et al., 2012).

What the optimum amount of augmented feedback, mainly regarding frequency, would be, is a remaining question. Reduced augmented feedback frequency has been found to give better learning results, while 100% augmented feedback frequency leads to degraded performance. Moreover, high feedback frequency leads to dependence on feedback and to lower performance with its absence (guidance hypothesis) but this only occurs when acquisition is supported by a large number of trials (Marschall, Bund, & Wiemeyer, 2007). On the contrary, these effects only occur when simple learning tasks are involved, while learning with frequent feedback is more effective for complex tasks (Magill & Anderson, 2014; Wulf et al., 1998; Zhou et al., 2021). Increased frequency in providing augmented feedback is beneficial also for novices and students in early stages of learning (Edwards, 2010; Wulf & Shea, 2002). But while these results are mainly from laboratory-based research (Potdevin et al., 2018), very few studies have explored the effect of augmented feedback frequency on student skill learning in real PE classes and further research in this field is needed (Zhou et al., 2021), especially for video feedback in the form of KP.

In addition to feedback, technological advancements can considerably enhance learning in PE by increasing the effectiveness of teaching (Almerich, Orellana, Suárez-Rodríguez, & Díaz-García, 2016). The rapid development of computer technology, digital media and the internet, led to the investigation of utilizing them in PE instruction. Combining digital media such as video, sound, images etc. in an application for learning is called multimedia learning (Mayer, 2017). However, contradictory results were presented in early implementations in PE, mostly due to the poor quality of the digital material used, while in typical instruction learning results were depended on the effectiveness of the PET (Siskos, Antoniou, Papaioannou & Laparidis, 2005). Nevertheless, integrating technology in instruction seems to have positive outcomes in various domains of PE. Video technology in PE appears to improve students' engagement by increasing their attention and concentration, resulting in a better and more supported understanding of motor activity (Mohnsen, 1995). Combining video with interactivity enhances user-student engagement even further (Geri, Winer, & Zaks, 2017; Hammond, Cherrett, & Waterson, 2015). Using multimedia, Zou, Liu & Yang, (2012) reported enhanced knowledge and perceived competence in 7-12 years old students, though no difference in the motor domain was observed. Palao et al. (2015) found improved skill execution, technique and knowledge in athletics, with the implementation of digital video in all stages of a PE course. The integration of new technologies in PE classes, led to increased self-determined motivation, cognitive skills and motor performance in gymnastics in primary education students (Legrain, Gillet, Gernigon, & Lafreniere, 2015). Positive results in motor skill performance were found in swimming (Kretschmann, 2017), in badminton regarding motor skill performance and motivation (Hung, Shwu-Ching Young & Lin, 2018) and also in football for deaf students regarding various motor skills (Alhamdi, Salih, & Abd, 2019).

Technological enhanced instruction can favour the development and improvement of motor skills in PE (Harris, 2009) through enhancing the students' knowledge level by increasing their motivation and engagement (Papastergiou & Gerodimos, 2013; Wiemeyer, 2008). Also, simple learning-oriented video games, as well as interactive video games, can increase students' knowledge, skills, perceptual ability, and attitudes in PE (Boyle et al., 2016; Papastergiou, 2009). The link between children's knowledge and improved athletic performance has been observed in a variety of sports, including tennis for children aged 11-13 years (McPherson & Thomas, 1989) and basketball for children aged 8-12 years (French & Thomas, 1987). The knowledge development process can be considered as a precondition of motor skills development (Gallego,

González, Calvo, Del Barco, & Álvarez, 2010).

Rapidly developing technology has created a mismatch between the tools offered and the way they were applied for effective teaching. It is not surprising that initially there were controversial results on the effect of multimedia learning (Russell, 1999). Teaching was based on what technology could do and not how students learn with technology (Mayer, 1997). Importance should not be laid upon technology itself, but on the pedagogical environment in which the technology is implemented (Casey, Goodyear, & Armour, 2017). Technological means in PE should be used as pedagogical tools in order to be proved effective (Basadre, Nunez & Paton, 2015) while learning design should follow the latest multimedia principles for learning (Dania, Hatziharistos, Koutsouba & Tyrovola, 2011).

Blended learning

Recognizing the limits of typical instruction, researchers have experimented with teaching techniques that combine (blend) new technologies with conventional learning. Volleyball and basketball skills have been reported to be taught effectively using these methods (Vernadakis, Antoniou, Zetou, Kioumourtzoglou, 2004; Vernadakis, Zetou, Avgerinos, Giannousi, & Kioumourtzoglou, 2006) as has been teaching the long jump (Vernadakis, Avgerinos, Zetou, Giannousi and Kioumourtzoglou, 2006). Terms like "mixed model instruction", or "hybrid learning" emerged, to describe such methods (Graham, 2006). These efforts led to the blended learning method (Bersin, 2004). Blended learning is the combination of online learning and digital media, with established classroom forms that require the physical presence of a teacher and students (Friesen, 2012). A course following the Blended Learning method is carried out partly online and partly utilizing other modalities (Chism & Wilkins, 2018; Stockwell, Stockwell, Cennamo & Jiang, 2015).

Recognizing that blended learning is constantly evolving, Staker and Horn (2012) came up with a taxonomy of application models. Across K12 Education, the blended learning programs are categorized into four models known as: 1) the Rotation model in which students rotate between learning modalities, online learning included, 2) the Flex model in which the content is delivered mainly online and students follow an individually customized schedule while face to face support is provided by the corresponded teacher in small groups or individually, 3) the Self-Blend model, in which students take the courses entirely online using the campus facilities or off-site, to support the typical instruction, while the corresponded teacher is available online, and 4) the Enriched Virtual model, in which students have a full online school experience with seldom on campus sessions.

Moreover, the Rotation model is divided into 4 sub-models: a) the Station Rotation with the students moving among class-room based teaching methods in a fixed schedule by the teacher, b) the Lab Rotation sub-model (the one is used in this study), in which students rotate among different locations in school with one of them being in the computer lab for online learning in a fixed schedule by the teacher, c) the Flipped Classroom were students rotate between face to face teaching at school and online delivery of the course content after school, and d) Individual Rotation in which students have a personal customized schedule among learning modalities with one of them one of them being online learning.

The application of this method during PE classes has also been considered appropriate (Papastergiou & Gerodimos, 2013; Vernadakis, Giannousi, Derri, Michalopoulos, & Kioumourtzoglou, 2012). In the context of PE, the Lab-Rotation sub-model is proposed. In the computer lab, students are taught using online multimedia instruction. Then, they move to the field to apply concerned knowledge and to perform the motor activities. Thus, a rotation is completed. This is done on a fixed schedule or at the PET's discretion (Staker & Horn, 2012).

To the best of our knowledge, there is limited if any research in the field of PE that implements an intervention based on the blended learning method and its models.

Aim of the study

It can be concluded that there is a gap in the literature concerning the investigation of blended learning interventions in Primary School PE courses that employ interactive software and direct video feedback in general and on the technique elements of the three-step ball throw, specifically.

Moreover, there is a shortage in research regarding motor skill qualitative analysis, especially in primary education students. In the present study, a teaching intervention that takes advantage of the evolvements in new technologies, including software with interactive activities and a software based direct video feedback system was developed, within a blended learning teaching method. The Lab Rotation sub-model was used as a base for the development of the interventions. The hypotheses of the study were that a) the blended learning teaching approach will significantly improve the technique of students in the 5th and 6th grade of Primary School in the three-step ball throw compared to typical instruction, and b) an intervention which utilizes a blended learning teaching method that includes a direct video feedback system will result in advanced outcomes regarding students' technical execution in the three-step ball throw.

Methods

Participants

The sample of the research was a convenience sample that consisted of one hundred and forty-eight students from seven classes of two typical Greek public primary schools. Three classes were of the 6th grade and four classes were of the 5th grade. Prerequisites for the participation of the students were: a) the students had not completed the 12th year of their age, b) they had not participated in athletics sports clubs, c) each student had a valid Individual Student Health Card that allowed the participation in PE lessons without limitations, in accordance with current national legislation. In addition, to include each student's measurements in the research, they would have to participate in all its stages. Since 17 students did not meet any or some of the conditions or were absent at some stage of the research, the present study was completed by 131 students (63 boys and 68 girls) with an average age of 11.4 years (± 0.47). The CONSORT flow diagram for the present research is illustrated in Figure 1. The research was carried out during regular PE lessons. Parents of students who submitted written parental agreement to participate in the study were given detailed information, with the option to withdraw at any time throughout the study. The school Principals also gave their consent. The procedures for the study were based on the most recent edition of the Declaration of Helsinki for human research. The study was also carried out in accordance with the local university's Ethical Guidelines for Research and was approved by an Institutional Review Board (approval no: to be added following the reviewing process).

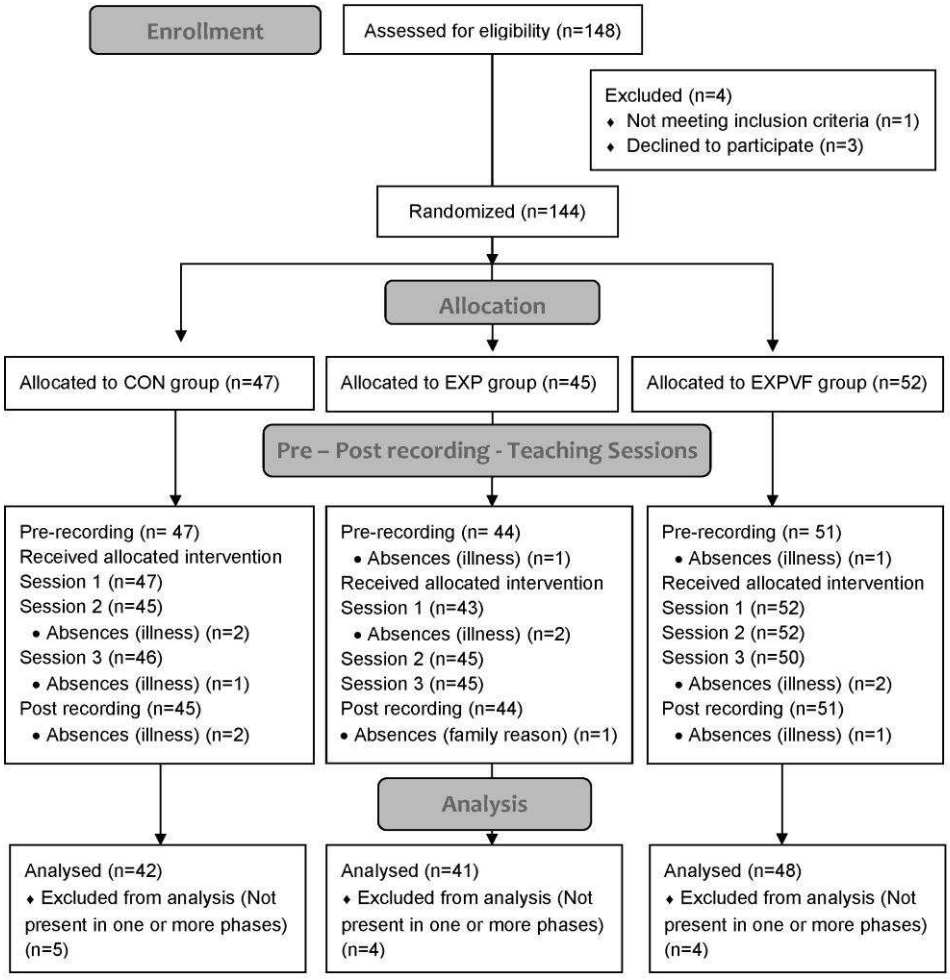


Figure 1: The CONSORT flow diagram of the research regarding the participants.

Measures

For evaluating the overhand throw technique on children, several researchers used elements from the Roberton and Halverson's (1984) components model of overarm throwing which is based on a qualitative assessment of the motions of the enabled body segments (feet, trunk, humerus and forearm) during the throwing action (Cohen, Goodway, & Lidor, 2012; Palmer et al., 2020). Elements from a broader model should be utilized for evaluating the three-step ball throw technique. In specific, a model that incorporates the common features of the components model of overarm throw and extends to the additional technical parts, based on important biomechanical factors that affect the movement goal (Chow & Knudson, 2011). Based on biomechanical principals, researchers developed deterministic models as a basis for qualitative analysis of sports skills (Bartlett, 2007; Chow & Knudson, 2011; Hay & Reid, 1988). Such models are proposed as the best approach to qualitative technique analysis (Hay & Reid, 1988; Knudson, 2007) and have been successfully used for studying the throws and jumps in athletics (Chow & Knudson, 2011). Based on such models, Tidow developed model technique analysis sheets for almost every athletics event, including the javelin throw (Tidow, 1996). These models have been proposed to be effective for both teaching and the qualitative evaluation of athletics technique (Panoutsakopoulos& Kollias, 2008). The use of such method for technique evaluation requiring visual observation is not considered as accurate, since the speed of movement exceeds the observer's ability. Thus, to address this disadvantage when assessing quick motor activities, the use of advanced functions of modern video technology, such as slow motion, still image etc.,

is required (Knudson 2000; Knudson & Kluka, 1997; Tidow, 1996).

Two academic experts chose five criteria from the Tidow's model technique analysis sheet for the javelin throw, regarding the final three steps of the throw (Tidow, 1996). Since the technique of the throw is generally acknowledged to be complexed (Best et al., 1993), the technique elements were chosen considering the objectives in primary education for track and field throws, the age of the students and the time available within the school curriculum. Specifically, PETs are instructed not to insist on a large number of technical characteristics during teaching sessions, instead they should focus on 3 – 4 key elements that lead to a basic technique (Digelidis et al., 2010). Therefore, it is clear that the chosen elements were used in teaching sessions also, for the students to establish a basic throwing technique. Each element could be evaluated as "not correct", "partially correct" or "correct", according to the suggestions of Tidow (1989). The evaluation of the five technique elements for each throw was carried out by the field-to-field examination of students' video recordings. Table 2 lists the technique elements investigated.

The first three technique elements examined (D10, E15, H26) are related to the constant extension of the throwing arm until the final double support that is required for the ball to gain maximum speed (Campos et al., 2004). Moreover, they contribute to the alignment of the shoulder axis to the direction of the throw. The five technique elements are as follows:

D10: The first step. The extended throwing arm contributes to a larger trajectory of acceleration of the throwing implement, that in turn is positively related with release velocity and throwing distance (Hay, 1985; Ogiolda, 1993; Schmolinski, 1983).

E15: Second step/intermediate stride. The throwing arm must be kept extended and in constant position as related to the shoulder line, contributing to the alignment of the longitudinal axis of the shoulder to the direction of the throw (Tidow, 1996).

H26: Third step. The throwing arm still extended, lifted parallel to the ground. In this final step, the delivery and the release of the ball are performed. The throwing arm must be still extended and at horizontal alignment, for the bow tension to be achieved and to allow the thrower to go under the ball (Tidow, 1996). An extended throwing arm's elbow at the initiation of the delivery phase result in placing the throwing implement in a proper position for its effective release (Leigh, Liu, & Yu, 2010; Morriss & Bartlett, 1996; Tazuke, 2009). In this phase the arm is lifted relatively to the shoulder axis, which is slightly at diagonal position. A lower arm position at this point would make the motion of the elbow harder in the next phase, the striking position. Thus, this arm positioning is more convenient for the proximal-to-distal segmental sequencing that is the efficient arm extension pattern for optimizing the release parameters (Liu, Leigh, & Yu, 2014).

K40: Striking position (element K40). In that latter phase, the elbow of the throwing arm leads the movement, pointing forward upwards and above the level of the shoulder. The elbow must lead the movement for an effective strike (Tidow, 1996).

L48: Release position – bracing leg. The last examined technique element (L48) is about the braking action of the front leg, which is the mechanism to transform the throwers' horizontal velocity to reach maximum release velocity (Campos et al., 2004). In addition, its blocking function and extension at the instant of the release facilitates the energy transfer to the throwing implement (Morriss, Bartlett, & Navarro, 2001). Furthermore, the absence of knee flexion of the front leg during the release phase contributes to a higher height of release and to a longer trajectory of acceleration (Dyson, 1977; Panoutsakopoulos & Kollias, 2013; Tidow, 1996).

Experimental procedure

Students from the seven classes were randomly assigned to three groups. The draw was made so

that each group included one 6th and one 5th grade class. Since two of the four 5th grade classes had a small number of students, they were grouped and regarded as a single class. The three groups were formed as follows: the control group (CON, n = 42, Mage = 11.5, SD = 0.44 years) the first intervention group (EXP, n = 41, Mage = 11.2, SD = 0.51 years) and the second intervention group (EXPVF, n = 48, Mage = 11.4, SD = 0.50 years). Two recording sessions were performed for each student: the first before the intervention and the second two days after the final teaching session. Following the first video recording, the three groups took part in a teaching intervention that included three 45-minute sessions with exercises that were the same for all three groups, all of which took place during the PE course. Since two lessons per week are applied in the PE course in Greece for the 5th and 6th grade, the intervention lasted 10 days. For the qualitative evaluation of the students' technique, the effectiveness of the technical execution of the throw was evaluated using five selected technique elements that served as criteria.

Teaching interventions

The warm-up procedure employed in this study followed conventional recommendations for pupils and was indicative to standardized warm-up utilized by PETs (Chatzopoulos, Yiannakos, Kotzamanidou, & Bassa, 2015). Furthermore, the exercises used for teaching the ball throw were based on the syllabus and were commonly applied to all three groups. The throwing drills sequence was as follows: standing ball throw, step and throw, walk and throw and three step throw. The feedback provided to students was in the form of KP in all cases.

Typical teaching intervention

Students in the CON group underwent a syllabus-based three-step ball throw instructional intervention. The initial demonstration of the full throw and for each exercise was provided by the PET, along with verbal instructions. After each performance and in case of incorrect execution, a combination of verbal and visual corrective feedback was given by the PET, highlighting points that needed to be improved. In case of a correct execution, general positive feedback was given verbally, like 'nice' or 'well done'. Depending on the teaching phase in each session, students were instructed to focus on one or more of the five technique's key elements, for a basic throwing technique to be established.

Blended learning intervention

EXP group students followed a three-step ball throw teaching intervention based on the Lab-Rotation sub model of the blended learning approach (Kyriakidis & Papadakis, 2015; Staker & Horn, 2012). Students rotated between the schools' computer lab where the online learning took place and the exercise area where they performed the physical activities. In total, three rotations took place, one for each teaching session.

Initially, the students went to the computer lab and performed the online part of the lesson that lasted 7 – 10 minutes. After that, they moved to the exercise area where they performed the drills, they were taught in the computer lab. The PET demonstrated each exercise once without explaining the main points of the technique, so that the students knew which exercise would be performed. It is evident that the demonstration part of the lesson was replaced by the online multimedia learning. The feedback was given as in the CON group, prompting the students to remember the motor pattern they were taught in the computer lab. The time available for the exercises in the field was 35 minutes. The time required for the online part was regained since the PET didn't provide detailed description of the exercises.

For the online part, 12 interactive activities were developed to be utilized in 3 lessons. The

activities should: 1) be implemented in the context of the PE course, using the schools' computer lab, 2) be available through the internet and function on tablets and mobile devices with any operating system, 3) be portable so that they could be available to the educational community through digital objects repositories, 4) be able to be altered by the PET according to the needs of the course, 5) be able to run only with a mouse using drag n' drop functionality or touch interface on modern tablets and mobile devices, 6) be able to run locally without the need for an internet connection, 7) be short and enjoyable for the students. H5P, a free GPL-licensed platform that provides tools for the creation of interactive multimedia content, met these requirements (H5P, 2017). H5P was installed as a plugin in the Moodle Learning Management System (Dougiamas & Taylor, 2003) which was running on an Ubuntu 16.04 LTS virtual private server (VPS) at the URL: https://fisikiagogi.gr. The aim for the activities was to teach the ball throw using high quality accurate and detailed visual representations through various types of interactive activities of the H5P platform such as interactive videos, short games, quizzes etc., highlighting the most crucial technique elements in order for students to comprehend and develop the correct motor pattern. The content of the digital part of each session was directly connected to each group's physical activities that were performed by the students in the exercise area immediately after the online learning part ended. For each teaching session, the online activities lasted 7 to 10 minutes. The interactive activities content is described in Appendix.

Blended learning with direct feedback intervention

Students of the EXPVF group followed the same blended learning intervention as the EXP group students, with an additional software based direct video feedback system. The later was consisted of a tripod mounted camera (Logitech C-920 HD) connected to a 15.4" laptop running Kinovea 0.8.26, a free and open-source software (Charmant and contributors, http://www.kinovea.org). Specifically, the camera was connected to the laptop and was placed so as to overlook the exercise area. A time delay was calculated based on the time that was needed for each student to reach the feedback system, so that they could observe their performance. This delay was found to be 10 – 12sec. After performing an exercise, each student moved to the video feedback system. During this transition, a brief oral instruction was given by the PET regarding the technical element that the student should observe in the video. Additionally, the PET was prompting the students at regular intervals to concentrate on the motor pattern that had been taught. The system was completely automated in a way that, after the initial setup, no one was needed for its operation, so students and the PET were able to concentrate in the exercises. In Table 1, information about the instructional method, time distribution and feedback, is shown.

Table 1: Summary of interventions

Group	Instruction	Demonstrations, rules etc.			Feedback		Motor activities
		Provider	Time	Place	Format Provider	Content Form	
CON	Typical	PET	during the lesson	field	V PET	C, P KP	Common
EXP	Blended learning	Online Multimedia Instruction	7-10' beginning of lesson	CL	V PET	C, P KP	
EXPVF	Blended learning	Online Multimedia Instruction	7-10' beginning of lesson	CL	V - visual PET-AVF	BI KP	

CON: control group (typical instruction); EXP: 1st experimental group (blended learning approach); EXPVF: 2nd experimental group (blended learning with direct video feedback); PET: Physical Education Teacher; CL: Computer Lab; V: Verbal; AVF: Automated Video Feedback; C: Corrective; P: Praise; BI: Brief Instruction; KP: Knowledge of Performance.

Three-step ball throw testing procedure

Students performed a test throw, following an appropriate standard warm-up consisting of dynamic stretching and throw exercises. After the test throw, each student performed a three-step ball throw which was recorded for its evaluation. Students were starting the run-up 5 - 6 m before the final throw line (foul-line). They were also instructed by the PET to throw the ball for maximum distance without passing the foul-line.

Data acquisition and analysis

A Casio EXILIM EX-FH20 camera (Casio Computer Co. Ltd, Shibuya, Japan) was used to record the students' throws. The camera was operating in 210 fps mode and was mounted on a fixed tripod at 14m from the throwing area to the extension of the foul-line. The camera's optical axis was perpendicular to the plane of the throw and its field of view was 6m wide, capturing the full examined motion of the students.

To determine the inter-rater agreement between the two experts' judgement of the quality level of each technique element, thirty randomly selected throws were used to run a weighted kappa (κ_w) with linear weights test (Cicchetti & Allison, 1971). There was a statistically significant agreement between the two experts for K40 element (κ_w = .847, 95% CI [.689, 1.006], $p < .001$). Since K40 had the lowest weighted kappa value of all elements, the strength of agreement was classified as excellent for all five technique elements (Fleiss, Levin, & Paik, 2003). After the inter-rater agreement analysis, the video files containing the throws were randomly divided into two groups and given to the experts for evaluation.

Table 2: Definition of the technique elements used in the present study (according to Tidow, 1996).

Technique Element Abbreviation	Phase of the throw	Explanation
D10	First step	Throwing arm to be extended, parallel to the ground
E15	Second step/Intermediate stride	Throwing arm in constant position as related to shoulder line.
H26	Third step/Drive split position	Throwing arm still extended, lifted parallel to the ground
K40	Striking position	Elbow joint is led over the shoulder
L48	Release position	Bracing leg completely extended

Statistical analysis

A two-factor design was used to analyse the data, with the within-subject factor being time (pre/post) and the between-subject factor being group (CON/EXP/EXPVF). The technique elements values "not correct", "partially correct" and "correct" were coded as 1, 2 and 3, respectively. The dependent variables concerning the technique elements were of ordinal scale

without specific interval size, nor normal distribution of their scores as assessed by Shapiro-Wilk's test ($p < .05$). Therefore, they could not be processed as continuous variables within the parametric framework (Lalla, 2017) and a rank-based non-parametric approach was required (Calver & Fletcher, 2020; McCrum-Gardner, 2008; McDonald, 2009). A Wilcoxon signed-rank test was used to compare pre- and post-measurements for each group. Effect size (r) was calculated and considered as small ($r < .3$), medium ($r = 0.30 - \leq .50$) and large ($r > .5$) according to Cohen's classification (Cohen, 1988). A Kruskal-Wallis H test was used to analyse differences in the distribution among groups in both pre- and post-measurements. The eta squared (η^2_H) estimate of effect size based on the H statistic was calculated (Cohen, 2008; Tomczak, & Tomczak, 2014) and considered as small ($\eta^2_H < .01$), medium ($\eta^2_H \geq 0.01 - < .14$) and large ($\eta^2_H \geq .14$ (Richardson, 2011). In case of a significant effect on group, pairwise comparisons after Bonferroni correction were performed using Dunn's (1964) procedure for multiple comparisons in order to determine significant differences between groups. Adjusted p values are presented. All statistical tests were conducted using the IBM SPSS Statistics v.26 software (International Business Machines Corp., Armonk, NY). The level of significance was set at $\alpha \leq 0.05$.

Results

Table 3 shows the differences and statistical results for each group's pre-post comparison. There was a statistically significant difference between all three groups ($p < .05$) after the intervention; however, the effect sizes (r) varied.

Table 3: Statistical results of the technique elements for time factor.

Element	CON (*n* = 42)			EXP (*n* = 41)			EXPVF (*n* = 48)		
	z	p	r	z	p	r	z	p	r
D10	5.43	<.001	.592	5.73	<.001	.633	6.03	<.001[a, b]	.615
E15	4.34	<.001	.474	5.20	<.001[a]	.574	6.11	<.001[a, b]	.624
H26	2.32	.020	.253	4.70	<.001[a]	.519	5.57	<.001[a, b]	.568
K40	2.18	.029	.238	3.11	.001[a]	.343	4.42	<.001[a, b]	.451
L48	2.11	.035	.230	3.96	<.001	.437	5.35	<.001[a, b]	.546

CON: control group (typical instruction); EXP: 1st experimental group (blended learning approach); EXPVF: 2nd experimental group (blended learning with direct video feedback); D10: 1st step, throwing arm to be extended, parallel to the ground; E15: 2nd step, throwing arm in constant position as related to shoulder line; H26: 3rd step throwing arm still extended, lifted parallel to the ground; K40 striking position, elbow joint is led over the shoulder; L48: release position, bracing leg complete extended; [a]: $p < .05$ vs CON; [b]: $p < .05$ vs EXP.

In detail, starting with the element D10, a large effect size was observed for all examined groups. In element E15, large effect sizes were revealed for EXP and EXPVF, while there was a medium effect size for CON. Large effect sizes for element H26 were evident in EXP and EXPVF. On the contrary, the effect size was small for CON in elements H26, K40 and L48. For the last two elements (K40, L48), a medium and a large effect size were revealed for the EXP and EXPVF groups, respectively. The effect size findings are in line with the students' positive differences between pre- and post-measurements, which are illustrated in Figure 2.

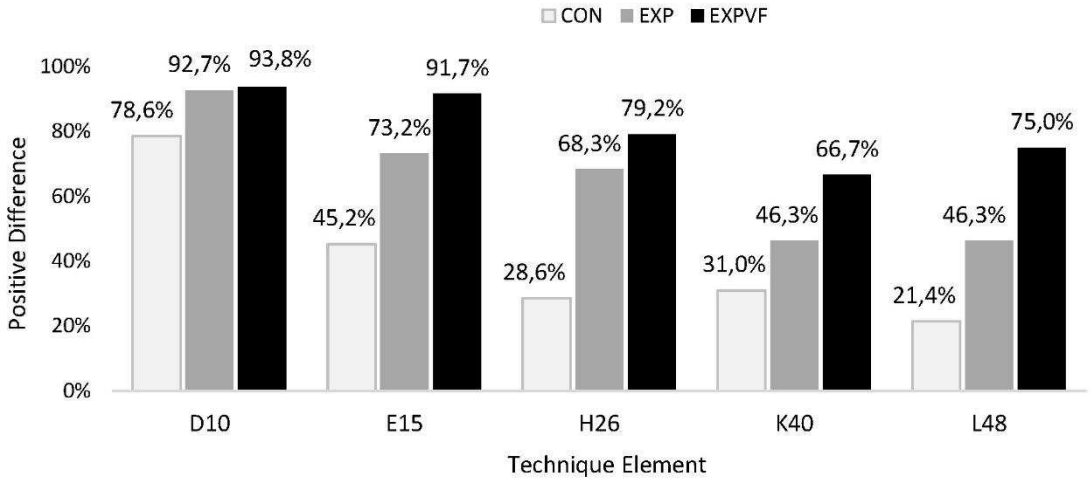


Figure 2: Positive differences for each group. CON: control group (typical instruction); EXP: 1st experimental group (blended learning approach); EXPVF: 2nd experimental group (blended learning with direct video feedback); D10: 1st step, throwing arm to be extended, parallel to the ground; E15: 2nd step, throwing arm in constant position as related to shoulder line; H26: 3rd step throwing arm still extended, lifted parallel to the ground; K40 striking position, elbow joint is led over the shoulder; L48: release position, bracing leg complete extended.

D10 (1st step, throwing arm to be extended and parallel to the ground)

There was no significant difference between groups in the pre-measurement (H_2 = .123, p = .940, η^2_H = .015). In the post measurement, a medium effect size was observed while the distributions of scores were statistically significantly different between groups (H_2 = 16.867, p < .001, η^2_H = .116). Pairwise comparisons using Dunn's test with a Bonferroni correction indicated significant differences between CON (mean rank = 52.24) and EXPVF (mean rank = 80.33, p < .001) groups and between EXP (mean rank = 63.32) and EXPVF (p = .044) groups, but not between CON and EXP (p = .371) groups.

E15 (2nd step, throwing arm in constant position as related to shoulder line)

Results of the Kruskal-Wallis H test showed that there was no significant difference between groups in the first measurement (H_2 = .583, p = .747, η^2_H = .011). In the final measurement, large effect size was observed. The distributions of scores were statistically significantly different between groups (H_2 = 27.580, p < .001, η^2_H = .200). Pairwise comparisons using Dunn's test with a Bonferroni correction indicated significant differences between CON (mean rank = 47.15) and EXP (mean rank = 65.45, p = .029) groups, between CON and EXPVF (mean rank = 82.96, p < .001) and between EXP and EXPVF (p = .032) groups.

H26 (3rd step, throwing arm still extended and lifted parallel to the ground)

There was no significant difference between groups in the pre-measurement (H_2 = 1.284, p = .526, η^2_H = .006). In the post measurement, a large effect size was observed while the distributions of scores were statistically significantly different between groups (H_2 = 29.729, p < .001, η^2_H = .217). Pairwise comparisons using Dunn's test with a Bonferroni correction indicated significant differences between CON (mean rank = 46.67) and EXP (mean rank = 64.68, p = .035) groups, between CON and EXPVF (mean rank = 84.04, p < .001) and between EXP and EXPVF (p = .015) groups.

K40 (Striking position, elbow joint is led over the shoulder)

Kruskal-Wallis H test showed that there was no significant difference among groups in the pre-measurement ($H_2 = 2.816$, $p = .245$, $\eta^2_H = .006$). A large effect size was observed in the post measurement, while the distributions of scores were statistically significantly different between groups ($H_2 = 28.593$, $p < .001$, $\eta^2_H = .208$). Pairwise comparisons using Dunn's test with a Bonferroni correction indicated significant differences between CON (mean rank = 47.14) and EXP (mean rank = 65.12, $p = .031$) groups, between CON and EXPVF (mean rank = 83.25, $p < .001$) and between EXP and EXPVF ($p = .023$) groups.

L48 (Release position, bracing leg completely extended)

No significant differences were revealed among groups in the pre-measurement ($H_2 = .398$, $p = .820$, $\eta^2_H = .013$). In the post measurement, the distributions of scores were statistically significantly different between groups, along with a large effect size ($H_2 = 23.256$, $p < .001$, $\eta^2_H = .166$). Pairwise comparisons using Dunn's test with a Bonferroni correction indicated significant differences between CON (mean rank = 49.73) and EXPVF (mean rank = 82.18, $p < .001$) and between EXP (mean rank = 63.73) and EXPVF ($p = .023$) groups but not between CON and EXP ($p = .140$) groups.

Discussion

After the three teaching sessions, the results showed a significant difference in all five technical elements for all three groups. However, this was recorded in a different magnitude for each group, as EXPVF showed a significantly better performance in all five technical elements compared to EXP and CON groups. The EXP group that followed, showed a significant difference in three of the five technical elements (E15, H26, K40) compared to the CON group. Based on the findings, both research hypotheses were confirmed.

Performance in all three groups was improved, although by different extent in each group. This supports research findings showing that children aged 11-12 years have a greater capacity to rapidly improve their motor control (Gallahue, Ozmun, & Goodway, 2006; Tzetzis & Lola, 2015). The present findings are consistent with previous findings that visual instructions can improve children's motor performance in ball throwing (Sorgente, Cohen, Bravi, & Minciacchi, 2022). In addition, past research that has indicated blended learning to be the best approach for teaching PE (Chism & Wilkins, 2018; Kyriakidis & Papadakis, 2015; Papastergiou & Gerodimos, 2013). Regarding video feedback, the positive results are also in agreement with past studies (O'Loughlin, Chróinín, & O'Grady, 2013; Palao et al., 2015; Potdevin et al., 2018; Schmidt et al., 2018; Sigrist et al., 2013; Mödinger et al., 2021).

The first three technique elements examined (D10, E15, H26) are related to the constant extension of the throwing arm until the final double support that is required in order for the ball to gain maximum speed (Campos et al., 2004). This is considered to be a difficult task to achieve (Tidow, 1996). For EXPVF and EXP groups, almost every student improved after the intervention (Figure 2), followed by the CON group (93.8%, 92.7% and 78.6%, respectively). However, EXPVF showed a significant difference compared with the other two groups, indicating the beneficial effect of the added direct video feedback.

Moving forward to the second step (element E15), the throwing arm must be kept extended and in constant position as related to shoulder line. At this point, EXP group showed a significant difference compared to the CON group. However, EXPVF students' performance was significantly better than the other two groups. This second selected element (E15) is the point

from which the effect of each intervention becomes evident, as distinct patterns of positive differences were observed for this and the following technique elements. This can be attributed to the increasing complexity of the movement during this intermediate step, which is corresponding to the impulse stride, namely the step were the optimal conditions for the release are created (Bartonietz, 2000; Silvester, 2003).

In the last step that follows, the delivery and the release of the ball are performed. The throwing arm must still be extended and at horizontal alignment (element H26), for the bow tension to be achieved and to allow the thrower to go under the ball (Tidow, 1996). The performance of EXP was better compared to CON. However, EXPVF students performed significantly better compared to EXP and CON groups. In the next phase (element K40), the elbow of the throwing arm leads the movement, pointing forward upwards and above the level of the shoulder. The results for that element were expected based on the interpretation of the group performance of previous technical elements, especially concerning elements E15 and H26 for the second and third step respectively. The students of EXP group performed better compared to CON but EXPVF students were rated even better, resulting in significantly enhanced performance compared to the other two groups.

The last examined technique element (L48) concerns the braking action of the front leg, which is the mechanism required to transform the throwers' horizontal velocity in order to reach maximum release velocity (Campos et al., 2004). EXPVF group performed significantly better compared with the two other groups regarding technique element L48. No significant difference between CON and EXP groups was observed. In general, a flexed front leg knee angle at release is a common technique error in young athletes due to their limited capacity to exploit their strength application capability (Maximov, 1979; Panoutsakopoulos, Vujkov, Kotzamanidou, & Vujkov, 2016).

The implementation of a blended learning course in the two experimental groups was the factor that distinguished teaching the three-step ball throw between the EXP/EXPVF students from the CON group students. The online part included software developed based on past research findings for enhancing learning using new technologies. Incorporating modern technologies into PE instruction aids students in developing a mental model of what they should perform (Legrain et al., 2015). High quality, accurate and detailed visual representations of the throw performed by world-class athletes that would be impossible for PET to demonstrate in a PE class with typical instructional methods were included. This precision in the presentation is necessary for students to learn a motor activity (Rink & Hall, 2008; Schmidt & Wrisberg, 2008). Likewise, contemporary interactive media were used such as interactive video, which further increases students' attention and participation than a normal video (Geri et al., 2017; Hammond et al., 2015). This lessens students' cognitive load, allowing for the gradual construction of new knowledge (Mayer et al., 2003). In addition, students were taught the rules, resources, and facilities needed to perform the sport, along with the usefulness of the three-step ball throw and the connection of its motor pattern to the javelin throw (O'Keeffe, Harrison, & Smyth, 2007) in a way that typical instruction cannot provide. Thus, it can be argued that the experimental groups' students developed, through multimedia learning, a sharper mental model or knowledge structure (Mayer, 1999, 2002) for the intended throwing motor pattern, which resulted to a more accurate performance of the throw.

Another important element that distinguished the EXPVF teaching intervention was the feedback provided. An automated software based direct video system was implemented so that the students could observe their own performance immediately after their execution. This was accompanied by a short verbal guidance by the PET to focus on the appropriate technique elements (Schmidt et al., 2018). The comparison of the students' own performance with the ideal

motor pattern that had been taught earlier within the online part increases motivation (O'Loughlin et al., 2013) and creates internal processes that help students to improve (Mohnsen, 1995). It also reinforces and shortens the learning process and leads to better learning results compared with typical verbal feedback by the PET only (Palao et al., 2015; Schmidt et al., 2018). In particular, the direct video feedback system appears to have played a key role in improving the technique of the EXPVF students, since they performed significantly better in all five technique elements after the blended learning intervention, compared to the students of the two other groups. This group had the advantage of being able to observe their execution, compare it to the reference model, and therefore self-regulate to execute optimally.

The study has some limitations that relate to the lack of measurement of the distance of the students' throws. According to the syllabus, PETs should, among other things: a) encourage the technical execution of the throw without comparing the students' performance (distance achieved), b) give feedback on quality elements of the technique and not on the distance achieved and c) focus on 2-4 basic elements of the technique and not on many technical characteristics. (Digelidis et al., 2010). For the grading of the students, the quality of the execution is evaluated, not the distance achieved. Comparing students' performance (distance achieved) is not in accordance with the school PE course goals and should be avoided (Digelidis et al., 2010; Avgerinos & Moundakis, 2014). Nevertheless, the study was successfully implemented showing the feasibility of the method proposed. The sample might impose yet another minor limitation. The students of a typical Greek public primary school come from the general population without any special criteria for enrolment, other than their residence distance. The two schools from which the sample was drawn, were in an urban region, not including students from rural regions. However, considering the fact that the urban population constitutes 79.1% of Greece (U.N., 2018) we can argue that the sample was quite representative of Greek students of 5th and 6th grade. In addition, a gender difference is suggested to exist in pubescents concerning the qualitative assessment of throwing to a target (Gromeier, Koester, & Schack, 2017) or for distance (Nelson, Thomas & Nelson, 1991). However, in all groups, boys and girls were almost equally distributed to address a possible gender difference.

Based on the findings of the current study, the recommendations for future research are:

1. To investigate additional technique elements in secondary education including measurements such as distance achieved angle of release etc. for a more accurate understanding of the method presented for teaching the three-step ball throw, following the current research.

2. To perform a biomechanical analysis of the three-step ball throw to gain further insight of the magnitude of the kinematical parameters such as joint angles, body segment inclinations and joint angular velocities that interpret the throwing action.

3. To develop a deterministic model and to quantify the inter-relationships among the parameters that determine the efficacy of the three-step ball throw in primary school students.

Conclusion

Most of recent research findings for teaching using a blended learning technique with interactive software and video feedback were combined in this study. The rotational sub-model of the blended learning method appeared to be more effective in teaching the three-step ball throw to Primary School students of 5th and 6th grade. Furthermore, the addition of a software based direct video feedback system further enhanced the performance of the students in the examined technique elements. These findings confirm prior research and expand current knowledge on the topic, by providing evidence that showcase this method's efficacy regarding the learning outcomes concerned with the qualitative elements of the three-step ball throw.

Technological novelties are beneficial for the development and improvement of motor skills in Primary School students. As the usage of innovations in technology comprises a significant motivator and increases students' engagement in PE through enhancing the students' knowledge level, PETs are encouraged to adopt the proposed combination of Blended Learning methods and direct video feedback to obtain an enhanced learning outcome in teaching motor skills of complex technical execution.

In conclusion, the use of interactive software in the teaching of the three-step ball throw with javelin technique within a blended learning environment results in better performance in the technical execution of the three-step ball throw than typical instruction. Furthermore, the addition of a direct video feedback system further improves the learning outcomes of students of 5th and 6th grade in terms of technique in the three-step ball throw.

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Appendix

The interactive activities related to three-step ball throw included in the digital part of the teaching sessions. Short quizzes, labels, icons, were integrated in all interactive videos, together with various playback functions such as slow motion etc.

1st Teaching Session

- A short video (~ 40 sec) presenting the three-step ball throw.
- An interactive video of an athlete performing the three-step ball throw, emphasizing the main points of the technique with various interactive elements.
- A still image with embedded short videos of sports with similar throwing pattern.
- A quiz assessing the technique of the throw at the release of the ball.
- A video game where students had to associate the correct ball with the respective sport with similar throwing pattern as the three-step ball throw.
- An interactive video showing the drills for the students to perform in the field, after the end of the online part.

2nd Teaching Session

- An interactive video regarding the drills from the 1st session and a quiz.
- An interactive video for teaching the steps of the approach for the throw
- An interactive video with throwing exercises for the students to perform.

3rd Teaching Session

- An activity with an interactive video and a quiz, repeating the entire three-step ball throw technique.
- An interactive video for the students to find the technical faults of a throw execution and a quiz.
- A memory card game and an interactive video reviewing the drills that students would perform in the field.