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# The effect of wearable technology on badminton learning performance: a multiple feedback WISER model in physical education

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## Abstract

Traditional physical education mainly relies on the instructor's verbal explanations and physical demonstrations. However, learners might be confused about whether their movements and positions are correct. Moreover, a typical badminton class has approximately 50 students, creating a huge teaching load for an instructor. To reduce the instructor's workload and improve learners' badminton performance, a multiple feedback WISER model was designed for badminton classes. The model provides visual feedback, information feedback, and verbal guidance to learners. In this study, a quasi-experiment was designed and participants were divided into experimental and control groups. The experimental group adopted the multiple feedback WISER model while the control group applied the conventional method. The teaching experiment lasted for 8 weeks with 46 participants in the experimental group and 50 participants in the control group, respectively. To measure the learning performance, a movement detection system using wearable technology was utilized. The results indicate that the experimental group, which used the multiple feedback WISER model, outperformed the control group, which used traditional teaching methods, on badminton clear and smash skill learning (Clear:  $p < .001$ , EG = 71.03, CG = 54.76; Smash:  $p < .01$ , EG = 82.79, CG = 72.22). Further analysis reveals that the multiple feedback is more beneficial for learners with lower initial skill levels (Clear:  $p < .05$ , Lower = 63.21, Higher = 46.99; Smash:  $p < .001$ , Lower = 77.67, Higher = 39.39).

**Keywords:** Visual feedback, WISER model, Wearable technology, Badminton, Motor skill learning

## Introduction

Rooted in India, badminton was created by the British during the late 19th century (Lim & Aman, 2017). This sport shares many similarities with tennis, as it is played by hitting a shuttlecock across a net in singles or doubles. What sets badminton apart from tennis is that players are not allowed to hit the shuttlecock after it touches the ground. Badminton is a popular sport in Taiwan, and many college students show great interest in it. This is evidenced by the fact that every badminton course offered by the researcher reaches its maximum capacity. Therefore, effectively enhancing badminton skill learning has become a great challenge for instructors. In typical traditional badminton teaching,

learners first learn how to play badminton through the instructor's verbal and physical demonstrations. Then, learners are paired up to practice. Based on the instructor's observations, learners are guided and their erroneous movements and body positions are corrected group by group.

However, there are certain limitations to traditional badminton teaching. Firstly, learners may feel frustrated while learning. The entire learning process is conducted by the instructor's explanations and demonstrations, as well as learners' imitation, which may confuse learners as to whether their movements and positions are correct or not, because no concrete and reliable comparison can be shown to the learners. Secondly, instructors are willing but unable to teach effectively. Badminton is a popular sport in Taiwan, with a considerable number of college students enrolling in related courses each semester (Lin et al., 2020a, b, 2021; Liu et al., 2015). The courses include approximately 50 learners and lasts only about one hundred minutes per session. In addition to the overall time limitations, the time allocated to each group is also very limited. Therefore, it is quite unlikely to guide every learner effectively within such a short period of time. This challenge is very common in many physical education (PE) classes (Lan et al., 2010; Lin et al., 2014).

Recent studies have shown that the use of technology can benefit PE learning. From 2010 to 2012, online learning successfully helped learners improve their cognitive sport skills and rules through an e-learning platform (Huang et al., 2010). Additionally, basketball and table tennis skills can be effectively acquired through web-based multimedia courses (Hung & Chen, 2016; Papastergiou & Gerodimos, 2012). Moreover, the movements and techniques of table tennis and tactical actions of basketball can even be effectively learned through video recordings of world champion and expert players (Rekik et al., 2019; Zou et al., 2012).

Video is one of the most common elements in a learning system. Research shows that video technology is the primary content delivery channel and has great potential in both formal and informal learning environments (Giannakos et al., 2016). Since 2012, several studies have demonstrated that the use of video recording/playback using tablets can help learners improve their performance in table tennis, badminton, and swimming skill learning (Hung & Chen, 2016; Hung et al., 2018; Kretschmann, 2017). These studies indicate the importance of visual perception and the potential benefits of providing visual feedback for skill learning in PE. However, error movement detection was not explored in the aforementioned studies. Therefore, various advanced technologies, such as computer-aided systems, Inertial Measurement Unit (IMU), Kinect, and wearable technology, were employed and proved to be applicable for motion detection in sports (Chen et al., 2013; Chang et al., 2014; Huang et al., 2015; Kitagawa & Ogihara, 2016; Lee et al., 2015; Yang et al., 2017).

The rapid development of wearable technologies offers multiple possibilities for implementing smart learning environments. Therefore, proposing an implementation framework that leverages these emerging technologies is a critical issue (Hwang, 2014). Based on the advantages of visual feedback provided by videos taken with a tablet

and information feedback based on learners' movement detection using wearable technology, this study explores how these two teaching strategies could be integrated for PE learning. One strategy involves learners receiving visual feedback from video

recordings of their movements, and the other involves using a movement detection system to help learners further understand the details of their movements.

To fully utilize the benefits of the watching and imitating teaching strategies, researchers have adapted the WISER model developed by Hung et al. (2018). The WISER model is a teaching approach that demonstrates how tablets can be integrated into authentic teaching settings. This model consists of five steps: Watching, Imitating, Self-examining, Enhancing, and Repeating. By following this learning cycle, learners become familiar with badminton skills and can reduce the learning time compared to traditional methods (Hung et al., 2018). However, the original WISER model has a limitation in movement detection. To address this issue and better combine the WISER model with a movement detection system, this study proposes a new multi-feedback WISER model. In the “watching” step, learners watch an instructor’s demonstration directly instead of watching model demonstrations presented through handheld technology. In the “enhancing” step, the practice of “comparing through videos” is replaced by “multiple feedback.” This feedback includes three types: visual infographic, video comparison, and verbal guidance. The first two types are generated by the developed movement detection system, while the last one is provided by an instructor.

Therefore, the objective of this research is to evaluate the effectiveness of the modified multi-feedback WISER model in improving the learning performance of complex badminton smash and clear skills, in comparison to traditional teaching that relies on instructor demonstration and verbal guidance. To further investigate the advantages of adopting the multiple feedback WISER model, researchers will also collect learners’ reflections and perceptions of being taught with this model from their learning journals. Based on the research objective, the following two research questions have been formulated:

RQ1: Can the multiple feedback WISER model outperform traditional teaching for learning the badminton smash skill?

RQ2: Can the multiple feedback WISER model outperform traditional teaching for learning the badminton clear skill?

### **Motor skill learning theory**

The motor learning process can be explained by the closed-loop theory, which has been developed for a long time in the field of psychology (Adams, 1971). The closed-loop theory primarily emphasizes feedback, error detection, and error correction, which addresses the lack of exploration of errors in the previous open-loop theory. In general, during the learning process, knowledge of results (KR), which provides information on problem-solving and guides skill acquisition, is used to determine whether there is an error in the length of movement after a movement is performed. The process is then adjusted to improve skill learning and gradually reduce errors, with the ultimate goal of defining the movement with the fewest errors as correct. Learners can acquire movement with KR in the closed-loop cycle.

Bandura (1977) further developed the social learning theory based on motor skill learning. Feedback plays an essential role in the motor skill learning process, and the appropriate reference movement helps construct feedback in both spatial and temporal elements, as suggested by Lin et al. (2014). Appropriate feedback not only improves

learners' effectiveness in skill learning but also enhances instructional quality. Additionally, Newell (1991) proposed that information can facilitate motor performance. Information can be described as prescriptive feedback and a channel to search according to its application. Regardless of the type of information applied, feedback is necessary to improve performance. However, how information is processed is crucial to acquisition, as opposed to what information is processed.

Besides the abovementioned theories, Fitts and Posner (1967) proposed three stages of motor skill learning to illustrate how one skill can be acquired: the cognitive stage, the associative stage, and the autonomous stage. These three stages are useful in interpreting how motor skills can be learned, especially in motor skill learning. In the cognitive stage, each movement is being recalled and recognized, and learners explore what to do and how to do the movement correctly. Verbal instruction and movement demonstration play an important role in helping learners execute the movement coordinately and stably. The goal is to transfer the movement into long-term memory. In the associative stage, learners focus on doing the movement skillfully and detecting errors clearly in each execution. Learners primarily change declarative knowledge to procedural knowledge in this period, also known as the motor stage. In the autonomous stage, learners can execute the movement with less attention and make fewer mistakes. Learners can still improve, but the progress is limited (Adams, 1971; Gagné, 1984; Lin et al., 2020a, b).

The motor skill teaching approach often involves students passively following a teacher's instructions, which has been criticized by researchers for promoting passive learning (Zeller, 2017). To encourage greater participation and improve motor skill performance, self-learning activities and peer interaction have been suggested (Østerlie & Mehus, 2020; Hsia et al., 2022). Additionally, analyzing practice videos has been found to enhance physical skill performance (Kok et al., 2020; Nunes et al., 2020; Wang et al., 2022).

### **Visual feedback using mobile devices in PE**

Feedback is critical in the motor learning process as it provides information on successful and incorrect aspects of movements already performed (Möding et al., 2021; Wulf et al., 2010). Crawford and Fitzpatrick (2015) reviewed literature on technologies assisting PE before 2010 and suggested that studies using mobile devices, such as mobile phones or tablets with built-in cameras, can improve teaching approaches and contribute to PE knowledge by providing visual feedback. Zou et al. (2012) developed a Moodle course for schoolchildren's table tennis learning, in which the children could film their own movements with a digital camera and compare them with an expert's video. Coaches could then provide visual feedback using the pause and replay functions according to the video. Additionally, Potdevin et al. (2018) designed a gymnastics teaching strategy using a digital camera and self-assessment. Students received visual feedback and self-assessment after every five attempts, whereas those who learned with the traditional teaching method only received verbal feedback from the teacher. Results indicated that the learning performances of the teaching strategies using the digital camera to provide visual feedback were significantly better than those of the traditional teaching strategies.

On the other hand, the use of visual feedback and video instruction also has its limitations. Nunes et al. (2020) mentioned that students may not achieve optimal learning outcomes solely by reviewing their own practice videos. Instead, they require additional verbal guidance of support from teachers to enhance their learning. Therefore, relying solely on visual feedback may not be effective for all students. Differing from the abovementioned studies that used only a digital camera, in Kok et al.'s (2020) study, students were equipped with specific criteria to conduct self-analysis of their practice videos. This approach equipped students with tools for self-reflection and aimed to enhance their ability to improve on their own, even with limited teacher feedback on practice videos. Another study incorporated a digital camera and Dartfish video analysis software into hurdle clearance teaching. With the intervention of the teacher, who provided verbal instruction, and the functions of visual feedback, such as pause, slow motion, and playback, students could clearly observe their own movements, and the teacher could provide corrective and objective feedback according to the video. The results showed that by combining both the teacher's verbal instruction and visual feedback, the learning performance was significantly higher than when solely using traditional teaching methods (Amara et al., 2015; Palao et al., 2015).

In addition to digital cameras and Dartfish video analysis software, tablets have been used as motor skill learning strategies in physical education (PE) due to their real-time recording, reviewing, and high portability features. They are considered extremely beneficial for learners. Currently, tablets are being used in various sports teachings, including table tennis, swimming, and badminton. Compared to the conventional teaching method where students could only learn from their teacher and peers, using tablets in sports teaching allows students to record their own performances and watch the video in slow motion to reflect on their movements using visual feedback. The results of some studies showed that the learning performance of students who used tablets as a teaching method was significantly higher than that of those who used the conventional badminton teaching method. (Lin et al., 2014; Hung & Chen, 2016; Kretschmann, 2017). Therefore, feedback is considered an essential influencing factor for improving motor skills, in addition to observation exercises, self-directed practice, and conscious control of attention (Wulf et al., 2010). Giannousi et al. (2017) investigated the effects of different types of feedback on freestyle swimming and found that the combination of verbal and visual feedback was the most effective for improving swimming skills when compared to other types of feedback.

Moreover, Hung et al. (2018) developed the WISER model as a visual teaching method for badminton skills using tablets. The WISER model consists of five steps: Step (1) View model demonstrations; Step (2) Imitate the demonstrations and immediately record; Step (3) Self-examine the recorded videos for identification; Step (4) Enhance their motor skills via comparing the videos; Step (5) Repeat the movements and seek advice from the teacher. The results of the study showed that the learning performance of the real-time visual teaching method was significantly higher than that of the conventional badminton teaching method.

### Information feedback using wearable technologies in PE

Apart from using mobile devices, some studies have developed a teaching system utilizing Kinect technology, which features movement capture, voice recording, and face recognition in PE (Zhang, 2012). The Kinect-based teaching system provides information feedback in several sports fields, such as yoga, golf, badminton, and tai-chi, by analyzing learners' movements and converting the details of these movements into information feedback. The feedback includes weight transfer comparison, skeleton comparison, instantaneous motion comparison, and automatic grading. With this information, learners can identify what needs to be improved and avoid sports injuries. The results showed the learning effectiveness was enhanced and the teaching burden was significantly reduced. (Chen et al., 2013; Huang et al., 2015; Lin et al., 2018, 2020a, b).

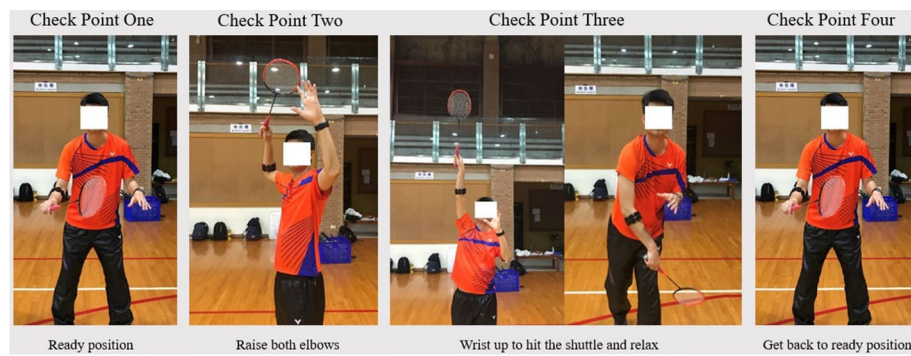
The applications of IMU and Electromyography (EMG) have been extensively discussed for their ability to measure movement trajectories and stiffness, respectively. By calculating the body rotation kinematics parameters, uniaxial acceleration, angular velocity, and curve variations, information concerning locomotion intensities and trajectories (e.g., running, jumping, and walking) can be obtained (Chang et al., 2014; Lee et al., 2015; Kitagawa & Ogihara, 2016). Additionally, the Myo armband, which features IMU and EMG and was released by Thalmic Labs in 2013, has been used to teach forearm-related skills, such as writing and hand hygiene training, using its functions of recognizing and classifying hand gestures (Abreu et al., 2016). The results have shown that the application of IMU and EMG provides instantaneous learning information that positively impacts learning performance. (Abreu et al., 2016; Yang et al., 2016; Kutafina et al., 2016).

Many studies have shown the high feasibility of using IMU and EMG to effectively teach skills. However, little research has incorporated motor skill learning theory and information feedback into PE thus far. Therefore, this study aimed to develop a movement detection system that could detect movements, provide visual infographics and video comparison feedback, and integrate the instructor's verbal feedback as multiple feedback. This system was applied to badminton teaching to improve the learning performance of badminton skills.

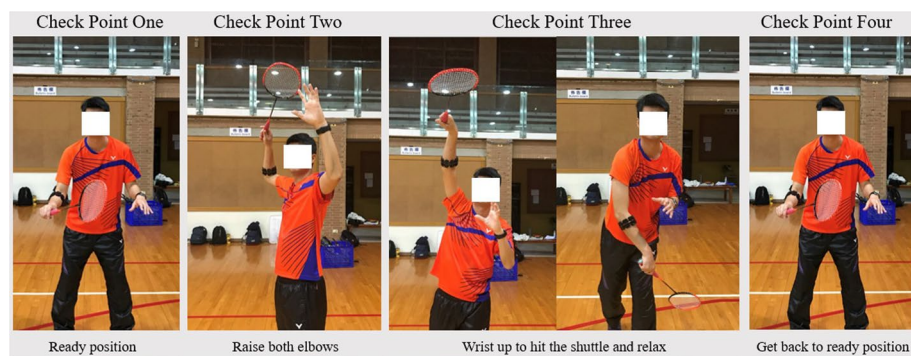
### The design of movement detection system using wearable technology

This study aims to design an accurate movement detection system that displays learners' radar charts, movement similarity scores, and practice videos to enhance their smash and clear learning performance. In the first step, four expert players were invited to wear the Myo armband, a wearable technology, and perform clear and smash movements 15 times each. Each badminton skill movement was divided into four checkpoints, and the checkpoint signals were collected using gyroscope signals from the IMU. The checkpoints for clear and smash movements are shown in Figs. 1 and 2, respectively. In the second step, the teaching system was programmed using the C# language and Waikato Environment for Knowledge Analysis (WEKA) to process players' forearm information in accordance with accurate data. In the third step, a backpropagation neural network was introduced to train and verify the professional model. Through the above three steps, a high Kappa accuracy was acquired for clear (0.90) and smash (0.89) movements.





**Fig. 1** Four check points in performing the movement of the badminton clear skill



**Fig. 2** Four check points in performing the movement of the badminton smash skill

After constructing the professional model, the gyroscope signals of the IMU were split. The Myo armband recorded the gyroscope signals, and by examining the twists and turns, each skill was divided into four sub-motions, each sub-motion scored from 0 to 100. Furthermore, as per the swinging principles of clear and smash, all sub-motions should be completed in sequential order from check point 1 to check point 4. To ensure learners perform the movements in the correct sequence, the movement detection system was designed to analyze the next sub-motion only if the learner had scored at least 50 points in the previous sub-motion.

After constructing the professional model and splitting signals, the movement detection system can provide multiple feedback, including radar charts, similarity scores, practice videos, and expert demonstration videos. The radar chart shows how well a learner has performed with respect to each of the four sub-motions, while the similarity scores indicate how similar a learner's movements are compared to the professional model. Figure 3 shows the radar chart and similarity scores. Once a learner identifies their movement issues after receiving the information feedback, they can review the visual feedback by comparing their practice video with the expert player's demonstration videos, as shown in Fig. 4. With the abovementioned information feedback, the instructor can provide more precise improvement suggestions to the learner based on the multiple feedback. The entire multiple feedback process is shown in Fig. 5.

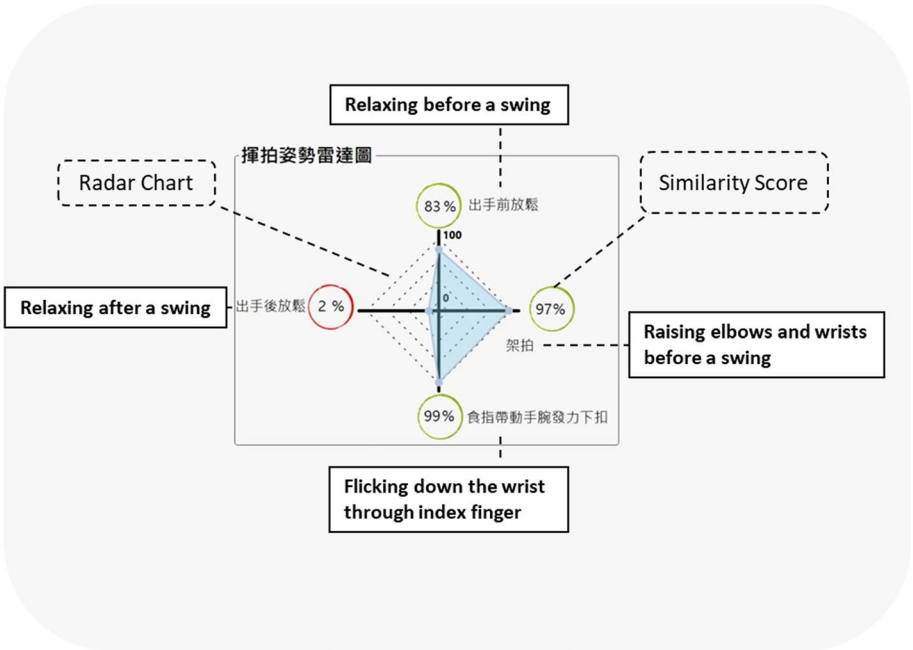


Fig. 3 The functions of radar chart and similarity scores



Fig. 4 The function of practice video and expert player's video replaying

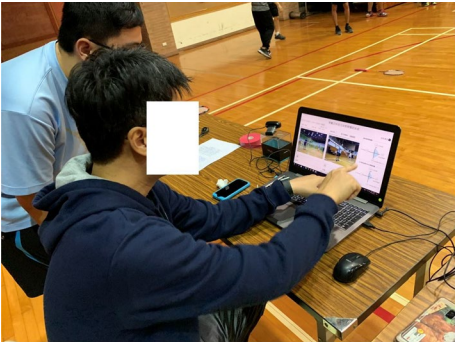


Fig. 5 The instructor provides precise improvement suggestions based on the radar chart, similarity score, and video comparison



## Method

### Participants

This study involved two classes of Sports & Health: Basic Badminton in college. One class was assigned to the experimental group (EG) with 46 participants, while the other class was assigned to the control group (CG) with 50 participants. The number of participants who had completed the whole process and their background information are shown in Table 1. To comply with research ethics, the researchers acquired approval from the Research Ethics Review Committee at National Tsing Hua University before the experiment started. In the first week of the course, consent letters were distributed to learners asking for permission. If any learners wanted to withdraw from the experiment, they had the absolute right to do so, and their withdrawal would not affect their learning or grading for the course.

### Experimental Procedure

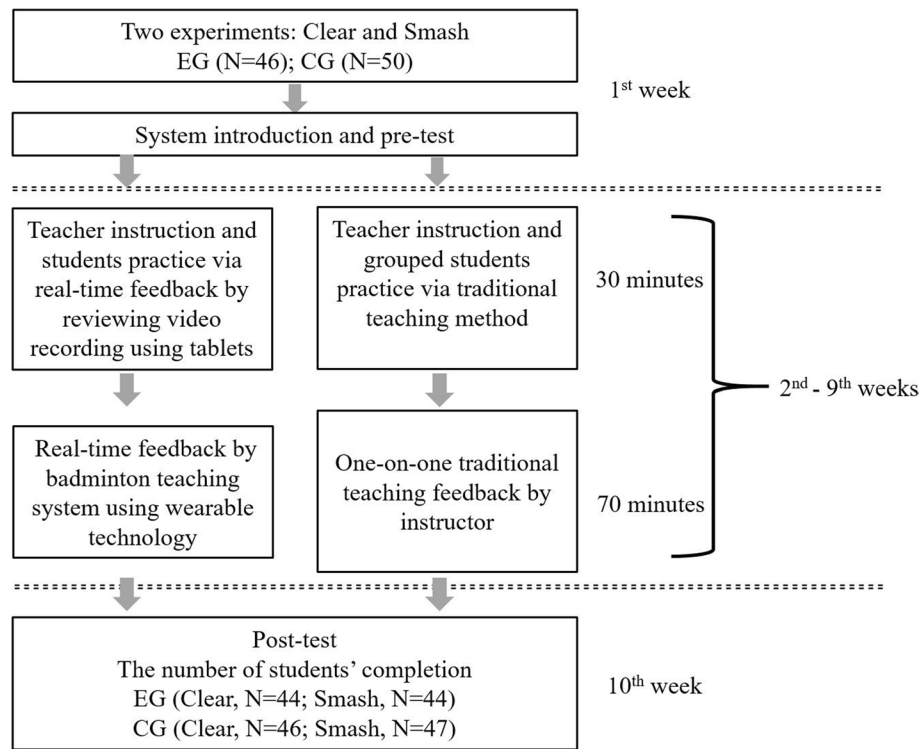
The entire experimental procedure is shown in Fig. 6. The experiment lasted ten weeks. In the first and the tenth weeks, learners took the pre-test and post-test using the movement detection system to evaluate and display learners' movement similarity scores. The scores were adopted as the pre-test and post-test motor skill performance indices of learners. In the first week, students took a pre-test without instruction. From the second week to the ninth week, both EG and CG learners learned smash and clear skills. Learners in the EG learned with the support of the multiple feedback WISER model (Fig. 7). The first step of the multiple feedback WISER model is "Watching the instructor's demonstration." The second step is "Imitating demonstrations and immediately recording via tablets." The third step is "Self-examining the recorded videos for identification." The fourth step is "Enhancing the motor skills via instructor's multiple feedback." The fifth step is "Repeating movements and seeking advice from the instructor." Learners in the CG were taught with traditional teaching method, i.e. instructor's demonstration and verbal guidance. Both groups took a post-test in the tenth week.

In the first 30 min of the session, the instructor instructed basic badminton principles of the smash and clear skills, and both EG and CG learners were grouped to practice with one another and were required to take weekly notes on their interactions with other learners from the second to the ninth week. EG learners practiced it and received visual feedback by recording and reviewing the video recording with tablets (as shown in Figs. 8 and 9), whereas CG learners did it and had group discussion without any help of technologies (as shown in Fig. 10).

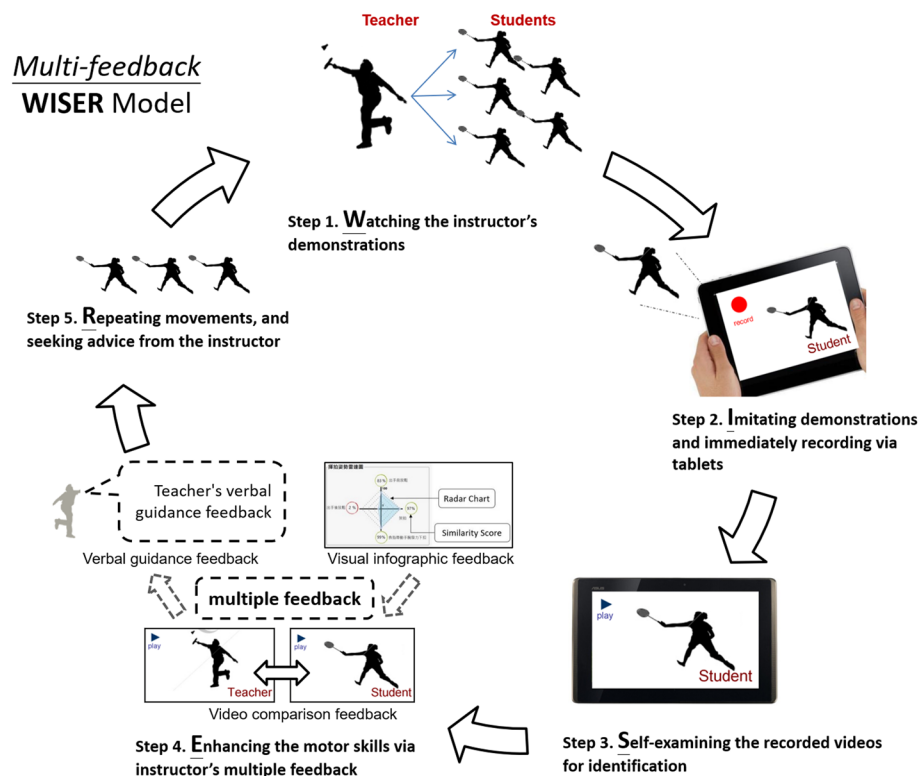
In the remaining seventy minutes, EG learners received multiple feedback from the movement detection system using wearable technology. Before going on the court,

**Table 1** Participants' background information

Skill	Group	N	Male	Female	18–20	21–22
Clear	Control	46	25	21	39	7
Clear	Experimental	44	26	18	38	6
Smash	Control	47	25	22	39	8
Smash	Experimental	44	26	18	38	6



**Fig. 6** The experimental procedure



**Fig. 7** The multiple feedback WISER model



**Fig. 8** Practice process of the EG-video recording



**Fig. 9** Practice process of the EG-reviewing recorded video



**Fig. 10** Practice process of the CG-group discussion without using any technologies

EG learners needed to wear the Myo on the forearms of their dominant hands and the research assistants checked the connection between the Myo and the laptop running the movement detection system was functioning. After the Myo has been readied on their forearm, the learners entered the badminton court to carry out the designated movements and their movements were videotaped and instantly graded by the movement detection system. Next, learners left the court to the laptop table, where they could see visual infographic feedback from the system. For learners who were still confused, they could get video comparison feedback by comparing their practice videos with expert



**Fig. 11** One-on-one feedback provided by the instructor for the CG

players' demonstration videos and recognizing the differences. Finally, the learners received the verbal guidance feedback to comprehend the instructor's suggestions.

In contrast, the CG learners received demonstration and verbal guidance feedback from the instructor. Different from EG, CG learners went on to the court directly and performed the designated movements without the support of the movement detection system. The instructor gave one-on-one verbal feedback according to the instructor's bare-eye observations. If learners were still confused, the instructor would demonstrate the correct movement again in person (as shown in Fig. 11), and learners improved the movement by imitation.

## Instruments

### *Movement detection system*

To effectively assess learners' performance, this study employed the function of the similarity scores of the movement detection system as the assessment instrument, scoring from 0 to 100. To estimate the reliability and validity of the instrument, the professional model of the movement detection system was constructed with four expert players, and the system was trained and verified. Thus, the instrument used in this study was proven to have high validity and accuracy (clear: 0.90; smash: 0.89).

### *Badminton class learning journal*

Badminton class learning journals were distributed to every learner after they were divided into groups, and both EG and CG learners were required to note down their interactions with other learners, including instructions and discussion. Each learner was coded according to their group in experiment design, subgroup number, and individual number. For example, if a person was number 2 in the first group of the experimental

**Table 2** The paired-samples *t* test of clear and smash learning between the pre-test and post-test

Groups	Skill	<i>n</i>	Pre-test		Post-test		<i>t</i>	<i>p</i>
			M	SD	M	SD		
CG	Clear	46	23.72	16.44	54.76	22.47	9.28	0.000***
	Smash	47	29.62	22.12	72.22	16.69	10.00	0.000***
EG	Clear	44	15.93	10.01	71.03	21.69	15.76	0.000***
	Smash	44	24.27	21.44	82.79	13.10	15.25	0.000***

\*\*\**p* < .001

group, his/her code will be EG0102. All learning records in the badminton class learning journal were examined with triangulation to ensure the objectivity of examination, thereby achieving higher validity.

### Data analysis

This study used the paired-sample *t*-test to test whether the two groups progressed significantly. If there was a significant difference, this study would continue to use ANCOVA to examine a significant difference between the EG and CG. Before conducting ANCOVA, a homogeneity test was conducted by taking the pre-test scores as the covariate (*X*) and those of learning performance (*Y*) as the dependent variable to examine if the slopes were equal. If the slopes of *X* and *Y* were equal, then ANCOVA could be continued for further analysis. Moreover, this study classified the EG into two groups. One is the low pre-test group (bottom 50%), and the other is the high pre-test group (top 50%). Finally, the independent sample *t*-test was conducted to examine the difference in the improvement (post-test scores minus pre-test scores).

## Results

### The analysis of badminton learning performance between the CG and the EG

This study aimed to examine whether different teaching methods led to better learning performance. The research results indicated that regardless of the teaching method adopted in the clear and smash learning processes, the post-test scores of both groups were significantly higher than the pre-test scores (as shown in Table 2). In particular, the post-test scores of the EG were better than those of the CG. To investigate the effects of the two teaching methods, this study employed ANCOVA to analyze the differences in learning gains between the two groups.

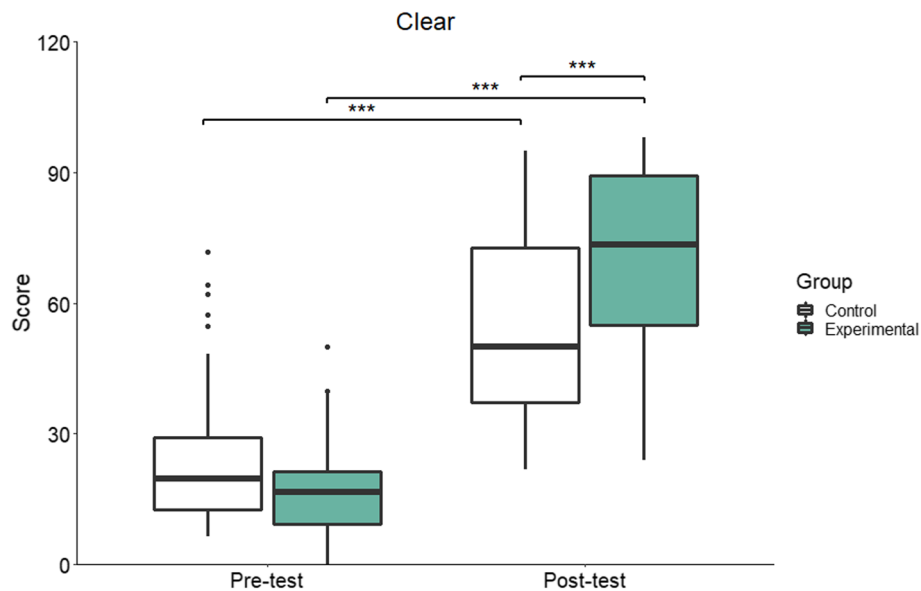
### Learning performance analysis for the badminton clear skill

After conducting the homogeneity test with ANCOVA, no significant difference was found between the interaction of the covariate and the dependent variable ( $p = .41$ ). Thus, ANCOVA was adopted for later analysis. The results of ANCOVA showed the score of the pre-test posed effects on the post-test. To account for this effect, the pre-test score was subtracted from the post-test, and a significant difference was found between the EG and CG ( $F = 16.82$ ,  $p = .000 < .001$ ), as shown in Table 3. After adjusting the marginal means of the two groups, the adjusted mean of the EG was 72.62, and that of the CG was 53.24. It can be concluded that compared to the traditional teaching, the



**Table 3** The analysis of covariance for the clear skill

Source	<i>n</i>	Mean	S.D.	Adjusted mean <sup>a</sup>	F value
Experimental Group	44	71.03	21.69	72.62	16.82***
Control Group	46	54.76	22.47	53.24	

\*\*\* $p < .001$ <sup>a</sup> Covariate in the model were evaluated at the pre-test = 19.91**Fig. 12** The learning outcomes comparison between the CG and the EG for the clear skill

visual feedback using video recording and movement detection system can significantly improve learners' badminton learning performance. The boxplot chart of the learners' pre-test and post-test is shown in Fig. 12.

#### Learning performance analysis for the badminton smash skill

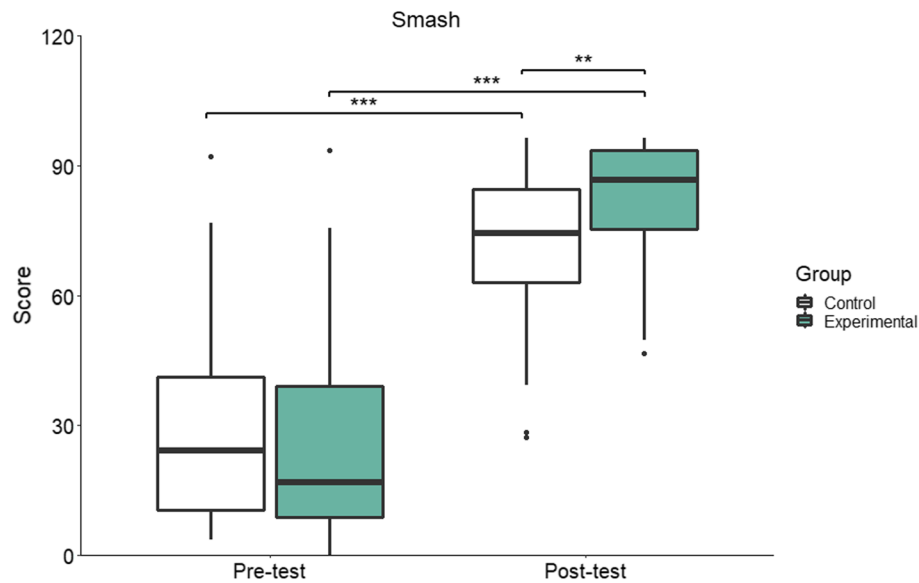
ANCOVA was also used to test the homogeneity, and there was also no significant difference between the interaction of the covariate and the dependent variable ( $p = .645$ ). As a result, ANCOVA was adopted for later analysis. The pre-test score was found to have no differential effect on the post-test score ( $p = .457$ ), leading to the adoption of an independent sample *t* test for further analysis. Assuming equal variance, the result showed a significant difference in the post-test between the EG and the CG ( $p = .001 < .01$ ), with the EG demonstrating significantly higher scores than that of the CG (as shown in Table 4). The boxplot chart of the learners' pre-test and post-test is shown in Fig. 13.

#### The comparison of learning gains between low pre-test group and high pre-test group for the badminton clear and smash skills in the EG

To further evaluate the effectiveness of the developed multiple feedback WISER model, the EG learners were divided into two groups based on their pre-test scores: the high pre-test group (top 50% performers) and the low pre-test group

**Table 4** The independent sample t test of the post-tests for the smash skill

Group	<i>n</i>	Mean	SD	<i>t</i>	<i>p</i>
Control	47	72.22	16.69	3.35	0.001**
Experimental	44	82.79	13.10		

*p* < .01\*\***Fig. 13** The learning outcomes comparison between the CG and the EG for the smash skill

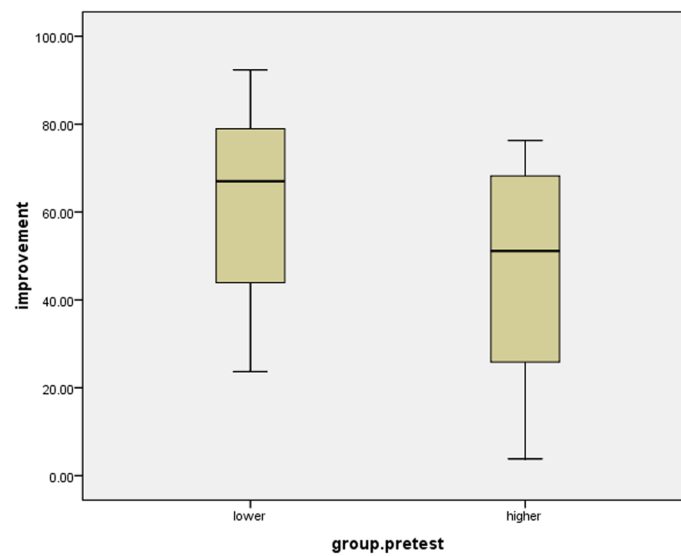
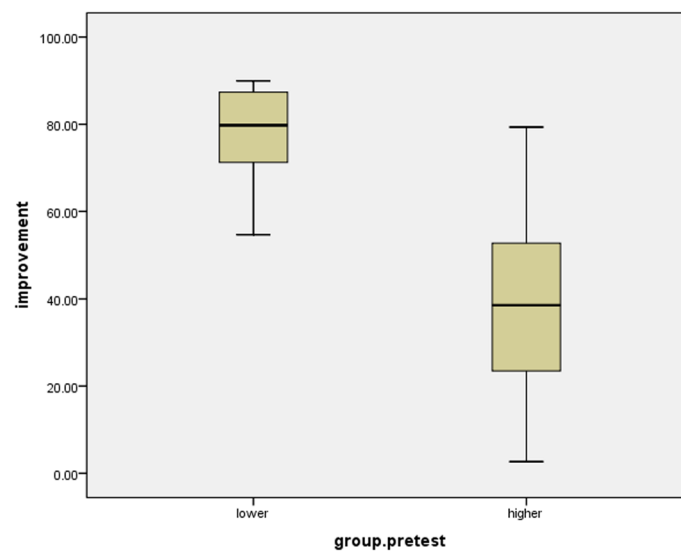
(remaining learners). The learners with pre-test scores lower than 16.5 in clear skill and pre-test scores lower than 16.85 in smash skill are classified as the low pre-test groups as opposed to the high pre-test group. The results show a significant difference in learning gains (post-test scores minus pre-test scores) between the low pre-test group and the high pre-test group for both clear ( $p = .018 < .05$ ) and smash ( $p = .000 < .001$ ), as shown in Table 5. The learning gains of the low pre-test group are larger than that of the high pre-test group, as shown in Figs. 14 and 15.

## Discussion

Based on the results presented above, the multiple feedback WISER model is effective in enhancing badminton-learning performance. The findings are consistent with previous research that has shown the benefits of using mobile devices to provide visual feedback for skill learning (Lin et al., 2014; Hung & Chen, 2016; Kretschmann, 2017; Hung et al., 2018). This study also supports the use of scientific information feedback from detecting movement errors to help learners identify weaknesses and improve their badminton skills (Chen et al., 2013; Huang et al., 2015; Lin et al., 2018, 2020a, b). Moreover, previous research has suggested that combining visual and verbal feedback in physical education (PE) learning may be the most effective way to improve motor skills performance, as opposed to using visual or verbal feedback only (Giannousi et al., 2017). However, few

**Table 5** The comparison of learning gains between low pre-test group and high pre-test group for the badminton clear and smash skills in the EG

Skill	Category	<i>n</i>	Pre-test Mean	Post-test Mean	Learning Gain	<i>t</i>	<i>p</i>
Clear	Low pre-test group	22	8.64	71.85	63.21	2.45	0.018*
	High pre-test group	22	23.22	70.21	46.99		
Smash	Low pre-test group	22	8.17	85.84	77.67	7.59	0.000***
	High pre-test group	22	40.36	79.75	39.39		

\* $p < .05$ ; \*\*\* $p < .001$ **Fig. 14** The learning gains of low pre-test group and high pre-test group for clear skill**Fig. 15** The learning gains of low pre-test group and high pre-test group for smash skill

studies have compared the effectiveness of multiple feedback that combines visual, verbal, and scientific information. Therefore, this study provides valuable evidence for the effects of multiple feedback on badminton learning performance and offers a helpful tool for coaches and PE teachers. In addition, this study improves upon the WISER model by incorporating multiple feedback, including error detection, visual infographic, and video comparison feedback. Furthermore, the study compared the performance of the EG and CG and found that the multiple feedback WISER model significantly improved the learning gains of learners in both the low and high pre-test groups for clear and smash skills.

For learners in the CG, this study showed that most of them were able to grasp the fundamentals through the instructor's verbal and physical demonstrations. Therefore, the traditional teaching approach was still effective to a certain extent. However, researchers further observed that some learners could not correctly perform the clear and smash movements during the learning process. For example, some learners in the CG struggled to coordinate their shoulder, elbow, and wrist during clear and smash movements due to the abstract nature and complexity of these movements. Additionally, traditional teaching methods may not effectively address repeated learning difficulties that learners encounter without providing a solution. Analysis of learners' study journals revealed that some in the CG faced similar challenges with their badminton skills, with the same issues being noted for over four consecutive weeks (CG0322, CG0517, CG0510). For example, the learner may understand the need to hit the shuttle directly with the wrist but struggle to properly lift their elbows due to poor coordination between their shoulders and elbows.

*I should lift my elbows wider and higher, and my wrist should be more powerful (Week 4, CG0517). "My elbows should be lifted higher, and my response is slow (Week 5, CG0517)." "My shot should be solid, with the elbows pulled high (Week 6, CG0517)." "My response and the speed of elbows are not fast enough (Week 7, CG0517).*

The above content indicates that learners in the CG reported recurring problems in their journals due to the lack of visual feedback. Hence, the traditional approach of verbal instructions and physical demonstrations still has some limitations.

For learners in the EG, their performance was significantly better than learners in the CG. The main reasons for this might be: (1) the effective use of visual feedback through a tablet; (2) the practical information feedback obtained through a movement detection system based on the multiple feedback WISER model.

First, our visual feedback approach using a tablet ensures learners initially observe their movements and have a better understanding of badminton skills. Learners also mentioned that in their journals:

*Through the video, I can see that my hitting point is not high enough, and my dominant arm is not entirely straight (EG0247)." Also, through the film, I found that my swing is oblique, and I found out what can be improved (EG0136)." "Through the video, I found that the movements still need to be adjusted. Therefore, I clearly know which of my movements are not standard (EG0403)." "Through the video, my movements are found to be incorrect (EG0506)." "Applying video taking in the*

*second week, I found my movements were incomplete (EG0546).” “Using a tablet to take videos of my movements, I found I had swung too far (EG0422).*

Second, the practical information feedback from the system indicates the wrong timing and position of the learners’ movement in a detailed manner, and learners would further discuss with the instructor so that they would know how to correct it. In addition, learners mentioned that it is helpful to quantify their movement performance. They said:

*Through the system, we can see the difference between automatic high-scoring and low-scoring movements (EG0417).” “Radar chart of the system let me know my 4th checkpoint is not well done, and my 3rd checkpoint is still not turning well. Therefore, I need to practice more (EG0516).” “Knowing the increased scores judged by the system, I know that I made improvement (EG0330).” “The system did not catch my fourth checkpoint because I did not complete the movement (EG0207).*

*Radar chart of the system let me know what needs to be improved. Through the actual measurement of the system, I know that I have made progress (EG0643).” “After systematic analysis, I found that there was no score for checkpoint 3 because the swing did not reach the thigh (EG0422).” “The system radar chart let me know what needed to be improved. My clear and smash performance was standard today. The instructor said I did well, and the data showed a great result (EG0340).” “I finally realized why I did not raise my elbow properly, thanks to the instructor’s feedback (EG0328).*

However, based on 10 learners’ journals, it appears that they struggled with predicting the timing of their shots. While the multiple feedback WISER model can enhance their overall skills, it may not be sufficient in helping them anticipate the optimal moment to hit the shuttle. To further develop learners’ experience and improve their timing during shots, instructors can incorporate feed-in practice. This practice along with the multiple feedback WISER model allows the learner to gradually improve their shot timing.

The learners’ journal results indicate that EG’s learning process extremely benefits learners based on the multiple feedback WISER model. While this model may not address the issue of shot timing for some learners completely, it enables them to focus on the coordination of the shoulder, elbow, and wrist to prevent sports injuries. Additionally, the model can be beneficial to learners in terms of learning effectiveness and to the instructor with regard to teaching efficiency. Both quantitative and qualitative results support that the multiple feedback mechanism improves learning performance and helps the instructor provide learners with precise and objective suggestions. Most importantly, the multiple feedback is proven to be more beneficial to learners in the low pre-test group than those in the high pre-test group.

Overall, this study aimed to overcome the difficulties of the traditional teaching method. Based on the motor skill learning theory, the most critical aspect of learning is whether learners receive accurate feedback (Adams, 1971; Bandura, 1967; Gagné, 1984; Newell, 1991). As a result, this study employed tablets and designed a movement detection system to transform abstract concepts into digitalized and concrete information.



## Conclusion

This study aimed to overcome the difficulties of traditional teaching methods by developing a multiple feedback WISER model to enhance learners' badminton skill learning, especially in large classes with many students. The main contribution of this study is to provide empirical evidence that adopting visual feedback through video recording and information feedback using a movement detection system can improve traditional teaching. However, the approach proposed in this study is more suitable for beginners, and future research could explore its applicability in more intensive training for coaches. Additionally, it is worth investigating the possibility of applying the designed multiple feedback WISER model to other sports, such as tennis and golf.

## Abbreviations

PE	Physical education
IMU	Inertial measurement unit
KR	Knowledge of results
EMG	Electromyography
WEKA	Waikato environment for knowledge analysis
EG	Experimental group
CG	Control group

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## Author contributions

All authors planned, wrote, read, edited, and approved the manuscript.

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## Availability of data and materials

Not applicable.

## Declarations

### Competing interests

The authors declare that they have no competing interests.

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