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Applying augmented reality in physical education on motor skills learning

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ABSTRACT

Physical education is a course that integrates knowledge of sports with skill drilling. Augmented Reality (AR)-assisted instruction has infrequently been applied in sport skill drilling. Video-assisted instruction has frequently applied to physical sports; however, it neither involves interactive practice nor embodies both textbook learning and the practice of sporting skills simultaneously. As a complement to video-assisted instruction, AR can apply virtual messages to learning objects so that 3-dimensional models can be superimposed into textbooks, which allows learners to read books while operating 3D character models. To verify the effects of learning outcomes, motor skills, and learning motivation with AR-assisted instruction and the effects of different difficulty levels on instruction materials, two experimental studies were implemented. Simple and basic running actions and more difficult Mark exercise actions were chosen as the teaching content. The experiments adopted a quasi-experimental design. The findings indicate that AR-assisted instruction is more effective than video-assisted instruction, and the effects are better for more difficult motor skills learning.

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Augmented reality; physical education; motor skill learning; video-assisted instruction; 3D model

1. Introduction

In light of the convenience and portability of information technology, integrating information technology into instruction has become a trend that may help students learn effectively. However, most of the learning content facilitates the development of basic disciplines. Relatively little digital content has been developed to teach skills, such as running skills in sport courses. Physical education includes instruction in various sport skills that require precision, coordination and speed (Bailey et al., 2009). Physical teachers emphasize demonstration and rarely allow students to explore and practice various actions. Teachers prefer to give lectures, and students have few opportunities to think about the cause of each action (Ávalos-Ramos, Martínez-Ruiz, & Merma-Molina, 2015). Therefore, information tools are a potential method to assist physical education (Chin, Hsin, Hung, & Yu, 2011; Hwang & Jin, 2016). Computer-based instructional content with an enhanced skill learning effect has been developed for this purpose (Roth, Zittel, Pyfer, & Auxter, 2016).

Many researchers have suggested that in physical education, audio-visual teaching media provides vivid and diverse content to traditional teaching, thereby increasing students' motivation and improving the learning effect (Roche & Gal-Petitfaux, 2014, 2017). Researchers have suggested that visual images may attract students and enhance their learning motivation (Peng, Crouse, & Lin, 2013). The "Video Learning Model" has become a common audio-visual media strategy to integrate into physical education (Roche & Gal-Petitfaux, 2014, 2017). In video-assisted instruction,

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students may repeatedly play and observe specific learning content in line with their own progress and needs. Students can also refer to demonstrations of action to practice and correct their own action. Therefore, teachers can avoid decreasing students' learning motivation and learning effects during physical education teaching with a large group in which the teacher's demonstration may not take into account the needs of individual students (Mu, 2010). In the usual training process, videos are used as instructional materials for observation and discussion to simulate different conditions of games (Mu, 2010), which allows learners to become immersed in the situation and to become familiar with the opportunity to use tactics to increase their chances of winning a game. When integrated with instruction in videos and text, the use of computer multimedia instructional materials may promote learning effects (Tabbers, Martens, & Merriënboer, 2004). Therefore, research has increasingly considered extra functions of video teaching, such as video annotation (Mu, 2010).

Although video-assisted physical education teaching has the aforementioned advantages, some limitations apply as well. Motor skills involve movement in three dimensions, but videos usually present only a single (or limited) visual angle. Learners may not autonomously adopt a variety of different angles to completely observe the demonstrator's actions (Mu, 2010). Making students understand motor skills in three-dimensional (3D) space by explanation and demonstration is an important but difficult task in physical education (Soltani, Figueiredo, Fernandes, & Vilas-Boas, 2016). To overcome this situation, 3D materials of instruction may be adopted to assist teaching, and learners' cognition and memory may be deepened through their observation of different visual angles (Zhier, 2016). They may explore independently, resolve their own problems and improve their motor skills. With the aid of 3D character models, learners may interact with 3D instructional materials, which contribute positively to the understanding and cognition of action. Furthermore, 3D visualization may provide novel insights for learners and attract their attention to enhance their motivation (Hsu, Lin, & Shih, 2013).

Another disadvantage of video-assisted instruction is that the integration of video content with text-based instructional materials is not easy. Physical education involves factual knowledge (such as rules and principles of motor skills) and procedural knowledge (such as the demonstration and operation of motor skills). The former is more suitable for static text or graphic presentation, whereas the latter is more suitable for dynamic or interactive presentation. However, most video-assisted instruction does not effectively integrate static presentation and dynamic presentation to lead learners to consider both types of materials during teaching. Physical education itself is a type of kinesthetic immersive experience (Roth et al., 2016; Sears, Edgington, & Hynes, 2014); that is, learners may follow the movements of the limbs through interaction and demonstration, which helps learners to become immersed in the actual learning environment (Dunleavy, Dede, & Mitchell, 2009; Zhang, Ogan, Liu, Sung, & Chang, 2016). If students learn only in a simple 3D virtual environment, visual effects may be reproduced, but it is impossible to integrate the physical learning environment to provide interactive learning. This may prevent learners from completing the immersive learning experience (Tüzün & Özdinç, 2016).

This problem can be solved by applying the practice of AR to teaching (Wu, Lee, Chang, & Liang, 2013). Klopfer and Squire (2008) defined AR as a representation that uses positioning technology to combine real world and virtual situations. AR is an application of situational awareness that links virtual information and the real world, which may rectify the separation of virtual information and real learning targets in a context-aware structure (Sung, Chang, & Liu, 2016; Van Krevelen & Poelman, 2010). AR-applied education provides a new sensory experience and interaction for learners, deepens learners' immersion and enhances the learning effect (Dunleavy et al., 2009; Klopfer & Squire, 2008; Wang, Chen, Chu, & Cheng, 2009; Wei, Weng, Liu, & Wang, 2015). AR-assisted instruction is also applied more widely, such as in museum-guided tours (Chang et al., 2014; Westin, Foka, & Chapman, 2018; Ghouaiel, Garbaya, Cieutat, & Jessel, 2017), monument changes (Chang, Hou, Pan, Sung, & Chang, 2015; Chiu & Lee, 2017; Gottlieb, 2018; Tom Dieck & Jung, 2018), field trip teaching (Chu & Sung, 2016; Pombo et al., 2017), engineering education (Dinis, Guimarães, Carvalho, & Martins, 2017; Park, Le, Pedro, & Lim, 2016), science education (Bujak et al., 2013; Fleck, Hachet, & Bastien, 2015; Ibáñez, Di Serio, Villarán, & Kloos, 2014; Zhang, Sung, Hou, & Chang, 2014), and other subjects' education (Chang, Wu, & Hsu, 2013; Cheng & Tsai, 2014; Hsiao, 2013). These teaching applications have shown that AR can enhance learning effects, increase learning motivation, strengthen users' concentration and improve learners' attraction to physical objects (Chang et al., 2014; Di Serio, Ibáñez, & Kloos, 2013; Martín-Gutiérrez, Fabiani, Benesova, Meneses, & Mora, 2015; Zhang, Liu, Sung, & Chang, 2015).

When adding the feature of AR virtuality/reality into physical education courses, textual instruction materials (such as the rules and principles of various motor skills) can be integrated with the virtual objects of 3D-assisted instruction materials (such as the demonstration and operation of motor skills). It allows learners to read textual instruction and operate 3D virtual objects in the learning process at the same time, which effectively centralizes factual and procedural knowledge and enhances the immersive learning experience (Roth et al., 2016). This is also a feature that traditional teaching, video teaching and 3D-assisted teaching may be unable to achieve. Moreover, compared to video teaching and 3D-assisted teaching, learners may feel closer to the learning content with the assistance of AR (Orman, Price, & Russell, 2017).

In summary, the features of AR can eliminate the drawbacks of video-assisted instruction and improve learning effects and learning motivation. Therefore, this paper combines the benefits of 3D representation and AR application to implement an assisted learning system for motor skills. A study is designed to explore the impact of different instruction modes (video-assisted instruction and AR-assisted instruction with 3D representation) on motor skills learning. AR-assisted instruction may help learners to establish factual knowledge of running sports, understand running skills, and increase their learning motivation.

2. AR-assisted learning

The AR-assisted learning system for physical education class is called AR-PEclass. AR-PEclass learners need to learn using the instructional materials in the book. After starting the AR-PEclass software, learners only need to align the camera lens of a mobile carrier (such as a mobile phone) with the motor skills picture in the book. The carrier screen automatically displays a 3D character model, as shown in Figure 1, and four functions to operate the 3D character model: (1) zoom in and out (change the size of the 3D model), (2) left and right rotation (change the 3D model viewing angle), (3) direction key (adjust the position of the 3D model in the screen), and (4) the action essentials (provide learners with operating instructions regarding motor skills). Learners follow the teacher's instructions, observe the motor skill changes presented by the 3D character model, and then answer the questions on the study sheet (or worksheet) to complete the learning of each motor skill in the book.

As shown in Figure 2, each function of the AR-PEclass software will be mapped for the main learning purpose. Learners learn motor skills by using the operation function of the 3D character model. For example, the function of zooming in and out may help learners observe motor skills locally or in detail, and the instructions on the action essentials may help deepen learners' memory of the learning content.

3. Experiment

3.1. Experimental design and procedure

In this study, we adopted a pretest-posttest quasi-experimental design with an experimental group and a control group. The experimental group combined the textbook materials with the "AR-PEclass" software to learn, whereas the control group used a motor skills video to learn. Students in both groups used the textbook materials under the guidance of teachers and learned with AR-PEclass and video separately, as shown in the examples in Figures 3 and 4. The students in the experimental group could use the camera lens of the carrier to align the action pictures on the book while reading

Figure 1. AR interface and its function description.

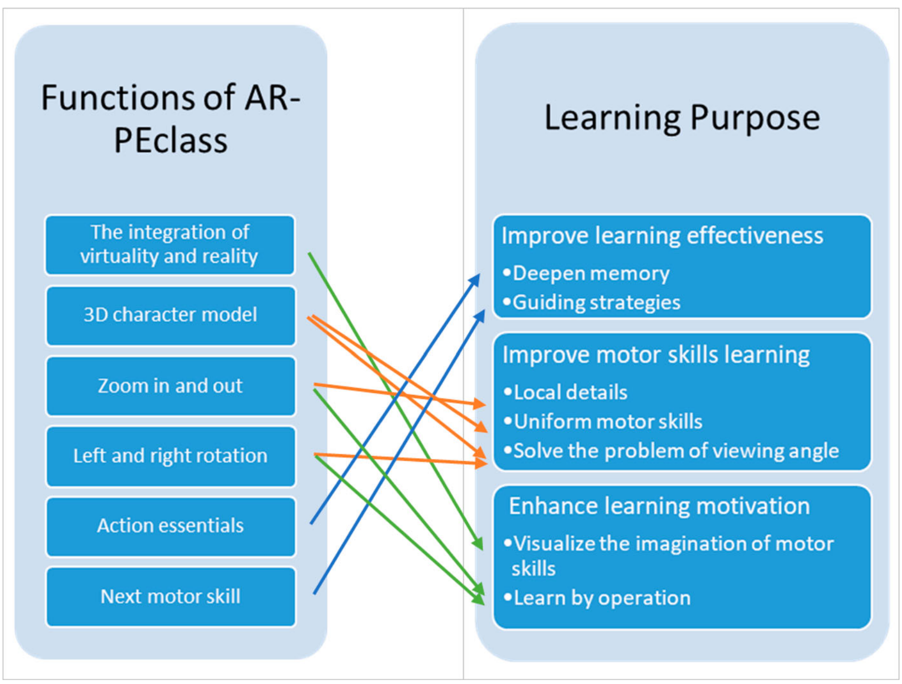

Figure 2. The learning objectives and the functions of AR-PEclass.

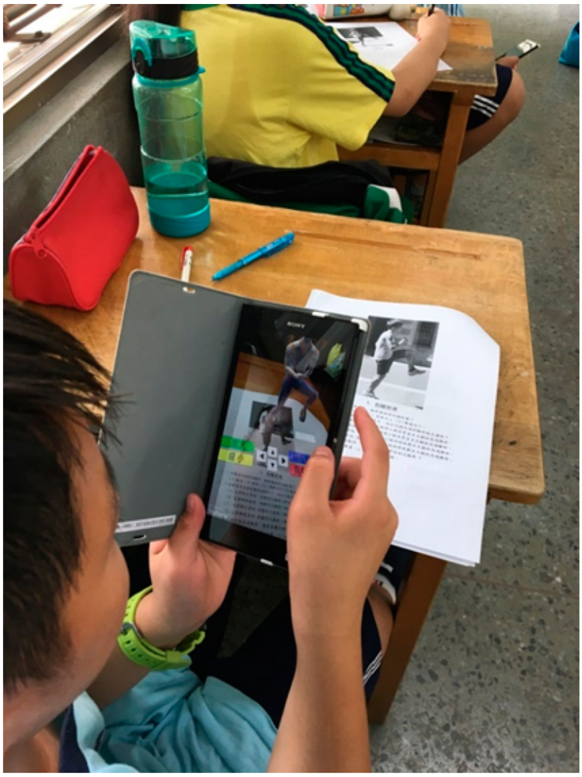

Figure 3. Students in the experimental group are learning via AR materials.

Figure 4. Students in the control group are learning via video materials.

the book materials to call out the 3D character model in AR-PEclass for interactive learning. Students in the control group were led by the teacher in the textbook materials and the video instruction with no interaction between the two different materials. The students in both groups conducted the experimental activity twice for 90 min each time. Two experiments were conducted in two weeks. Except for the learning assisted tool, the activity procedures were the same. The learning content of the two experimental activities was basic running actions and Mark exercise actions, respectively. The difference is that the Mark exercise actions are a disassembling process of running action that break down the entire running action into sub-exercises for practice. Compared to basic running actions, the rhythm and fluency of Mark exercise actions are more difficult. Before each experiment, the learning activities were introduced to the students in both groups so that the students could clearly understand the activities and learning objectives. They completed the achievement test of running knowledge at the same time (pretest for approximately 10 min). The students in the experimental group were additionally trained in mobile carrier operations prior to the first experiment to ensure that technical barriers did not affect the performance of the experiment. Each experimental activity of the experimental group and the control group lasted for 90 min. The teacher in each experiment guided students to learn for 20 min, and then the students practiced by themselves.

The posttest and learning motivation test of running knowledge were conducted after each experiment for 10 min each. After that, three professional teachers provided motor skills ratings and scored the students in each group to assess the students' learning effectiveness of the motor skills. The three teachers rated and scored based on the correctness, fluency, and integrity of the learners' movements.

3.2. Participants

The participants in this study were students in the seventh grade from two classes. They were categorized into a control group with 25 people and an experimental group with 27 people. The students did not receive professional training in motor skills.

3.3. Materials

The learning content of the two experimental activities was basic running actions and Mark exercise actions. The distinction between the two types of content is used to observe whether there are any correlations between the difficulty of the learning content and the effectiveness of using AR learning. Some studies have noted that AR may perform better and that learning effectiveness is more obvious for more difficult learning content (Ferrara, Ponticorvo, Di Ferdinando, & Miglino, 2016; Safadel & White, 2017).

3.4. Tools

3.4.1. Achievement test of knowledge on motor skills

The purpose of the pretest/posttest is to understand whether the learners' cognitive knowledge of motor skills may be enhanced after they are guided to use the 3D character model and motor skills video and to understand the learning effectiveness of the two learning modes. There are two tests (each includes pretest and posttest) for the first and second experiments, respectively, and each test contains 15 questions, one point for each question. The two teachers evaluated the tests and verified the questions on the tests.

3.4.2. Rating scale on motor skills

This scale is based on the motor skills scale of Arnheim and Sinclair (1979), which contains the skills of basic running actions (mushroom promenade, leg-pulling promenade, contralateral kicking promenade, lunge promenade and buttock-kick running, etc.) and Mark exercise actions (leg-raising promenade, leg-stretching promenade, skip step leg-raising promenade, skip step leg-stretching promenade, three-step leg-raising and three-step leg-stretching, etc.). Three teachers scored each skill based on the three parts of correctness, fluency, and integrity of the movements. After each original score is normalized by t-scores, the teachers scored from one to five for each part of correctness, fluency, and integrity of a skill. The total score of a skill is 15 points. The scale uses expert validity, with the teachers verifying the questions.

3.4.3. Learning motivation measure

The measure is based on Keller's (1983, 2010) measure. There are four dimensions, including Attention, Relevance, Confidence, and Satisfaction. There are six questions for each dimension with a total of 24 questions. The Cronbach's alpha values are 0.830, 0.869, 0.846 and 0.862, respectively.

4. Results

4.1. Learning effectiveness

The averages and standard deviations of the pretest and posttest in both experiments are shown in Table 1. We used an independent sample t-test to analyze the pretest scores of the two groups. The result of the pretest in Experiment I was $t = -.485$, $p = .630 > .05$, which did not achieve a significant level. In Experiment II, $t = -0.14$, $p = .989 > .05$, which did not achieve a significant level. Therefore, based on the results of the independent sample *t*-test, we may conclude that there is no significant difference between the two groups in the distribution of students' learning ability.

Through covariate analysis, after excluding the influences of students' pre-ability on their learning effectiveness, the *F* value was 1.48, $p = 0.22 > .05$ in Experiment I, which did not reach the significance level. However, in Experiment II, the *F* value was 15.65, $p = .000 < .05$, reaching the significance level.

4.2. Motor skills

The students' motor skills were rated by the three teachers according to the three parts of correctness, fluency, and integrity of a skill and were scored from 1 to 5 for each part. After the rating was completed, independent-sample t-test analysis was performed to determine the average score of each action of the students in the control group and the experimental group. In Experiment I, for the mushroom promenade ($t = -4.15$, $p = .000 < .05$), leg-pulling promenade ($t = -3.94$, $p = .000 < .05$), contra-lateral kicking promenade ($t = -3.08$, $p = .003 < .05$), lunge promenade ($t = -3.68$, $p = .001 < .05$) and buttock-kick running ($t = -4.97$, $p = .000 < .05$), the experimental group performed significantly better than the control group. In Experiment II, for the leg-raising promenade ($t = -8.64$, $p = .000 < .05$), leg-stretching promenade ($t = -4.78$, $p = .000 < .05$), skip step leg-raising promenade ($t = -6.02$, $p = .000 < .05$), skip step leg-stretching promenade ($t = -5.80$, $p = .000 < .05$), three-step leg-raising ($t = -8.24$, $p = .000 < .05$), and three-step leg-stretching ($t = -7.07$, $p = .000 < .05$), the experimental group performed significantly better than the control group. AR integrates textbook content and 3D character models, which allows learners to observe and operate 3D character models more clearly and freely. Compared to learners using video-assisted materials, those using AR had a better learning effect for the motor skills operation.

Table 1. Average scores and standard deviation of pretest and posttest.

	Group	Number	Average	Standard deviation
Experiment I	Control group	25	7.96	2.62
Total score of the pretest	Experimental group	27	8.29	2.38
Experiment I	Control group	25	12.68	2.19
Total score of the posttest	Experimental group	27	12.03	2.56
Experiment II	Control group	25	8.36	2.78
Total score of the pretest	Experimental group	27	8.37	2.63
Experiment II	Control group	25	10.36	2.41
Total score of the post-test	Experimental group	27	12.40	2.83

4.3. Learning motivation

Learning motivation measures were conducted after the two experimental activities were conducted. After deleting one unqualified subject, the data numbers were 24 for the control group and 26 for the experimental group. The independent-sample *t*-test analysis was conducted via two motivation measures of both groups, and the results are shown in Table 2. In Experiment I, the *t* value was -3.31, $p = .002 < .05$ in the test results of both groups' motivation measures, reaching a significant level. In Experiment II, the t value was -3.31, $p = .002 < .05$ in the test results of both groups' motivation measures, reaching a significant level.

According to the statistical results, the overall average of the experimental group is slightly higher than the control group, and the average score reaches the level of four or more. Then, the learning motivation of the subjects in both groups is divided into four dimensions, namely, attention, relevance, confidence, and satisfaction, for the independent sample t-test analysis, and the result is shown in Table 3.

In the test results for the learning motivation of the control group and the experimental group in Experiment I and Experiment II, the dimensions of Attention, Relevance, and Confidence showed a significant difference. However, in the dimension of Satisfaction, both Experiment I and II did not reach the level of significance.

5. Discussion

5.1. Learning effectiveness and motor skills

The results of Experiment I show that the control group took a slightly different amount of time than the experimental group to operate on the carriers. The experimental group spent more time than the control group. The students in the experimental group were familiar with the operation of mobile carriers with learning software, and the control group could only select the specified video to watch. Therefore, the learning process of Experiment I was conducted more smoothly for the control group than for the experimental group, which also affected the posttest performance of the experimental group; the posttest performance of the control group was better than that of the experimental group. For the difficulty level of the learning materials, the difficulty in Experiment I was lower, so the advantages of AR may not be present in an easier learning situation (Ferrara et al., 2016; Safadel & White, 2017).

For Experiment II, the experimental group conducted the operation process review before class. The operation process was printed as the text materials for the students, which reduced the barriers to using the carrier and the amount of equipment debugging. The learning environment was modified slightly: both the control group and the experimental group initially conducted motor skills learning in the classroom and then went outside for group practice to become familiar with the environment and equipment. Compared to the learning in Experiment I, the students in the experimental group operated the mobile carrier more smoothly. In the covariate analysis results of Experiment II, the students in the experimental group also reached a significant level, which explains why the learners performed significantly better in a more difficult learning content with AR assistance, similar to previous results (Safadel & White, 2017).

Table 2. Independent-sample *t*-test of learning motivation for experimental group and control group.

	Group	Number	Average	Standard deviation	*t*	*p*
Experiment I Motivation scale	Control group	24	3.71	.609	−3.31	.002**
	Experimental group	26	4.20	.421		
Experiment II Motivation scale	Control group	24	3.88	.666	−2.65	.011*
	Experimental group	26	4.33	.520		

$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

Table 3. Four-dimensional independent-sample *t*-test of learning motivation for the experimental group and the control group.

	Motivation dimension	Group	Number	Average	Standard deviation	*t*	*p*
Experiment I	Attention	Control group	24	3.65	.838	−3.42	.002**
		Experimental group	26	4.30	.421		
	Relevance	Control group	24	3.81	.611	−2.44	.018*
		Experimental group	26	4.21	.541		
	Confidence	Control group	24	3.50	.569	−3.68	.001**
		Experimental group	26	4.08	.535		
	Satisfaction	Control group	24	3.89	.644	−2.00	.050
		Experimental group	26	4.21	.484		
Experiment II	Attention	Control group	24	3.77	.776	−3.27	.002**
		Experimental group	26	4.39	.535		
	Relevance	Control group	24	3.94	.689	−2.11	.040*
		Experimental group	26	4.32	.587		
	Confidence	Control group	24	3.75	.627	−3.08	.003**
		Experimental group	26	4.28	.606		
	Satisfaction	Control group	24	4.06	.838	−1.25	.218
		Experimental group	26	4.31	.570		

*$p < .05$; **$p < .01$; ***$p < .001$.

We interviewed the students after the completion of the experimental activities in this study. Based on the interviews, we realized that the students thought that the content of Experiment II was more difficult to comprehend. However, the students in the experimental group performed better than those in the control group in Experiment II. Therefore, AR-assisted instruction may help learners obtain better comprehension of motor skills that are more difficult to operate. Moreover, the learning content of the AR system was presented in 3D, which may provide more help to learners by using more visual angles than the video instruction used in the control group. This finding is in line with the findings of Zhier (2016) that 3D visualized materials enable learners to observe through different visual angles and deepen learners' cognition and memory. This is also evident from the results of the motor skills test conducted by the three teachers, which also reflected the learning effectiveness of AR and 3D for motor skills. The students in the experimental group performed better than the control group in motor skills. In the learning process, learners operate the 3D character model. They may exert more effort because of the novelty of the materials, which also increases learners' memory enhancement and learning retention (Fujimoto, Yamamoto, Kato, & Miyazaki, 2012).

5.2. Learning motivation

Comparing AR-assisted instruction to video instruction, we draw the following conclusions:

(1) In the learning process, AR-assisted instruction integrates the text materials with 3D model materials, which means that students may also use the 3D model while reading the text materials to increase their understanding of pictures of motor skills in the textbook.
(2) AR-assisted instruction provides students with the opportunity for interactive operation so that students may operate the model to observe different angles of the movements presented and may notice more details.
(3) 3D materials may perform better than 2D materials in motor skills learning and are more in line with actual learning situations, so they may be able to attract students to learn.
(4) Due to higher portability, it is easier to take the materials to the playground for practice and observation.

For the above reasons, students using AR-assisted learning materials show a significantly higher effect for learning motivation than those using video-assisted learning materials. In the motivation dimensions of attention, relevance, and confidence, the results of the experimental group were significantly higher than those of the control group, which is also in accordance with previous research (Chiang, Yang, & Hwang, 2014; Estapa & Nadolny, 2015; Riera, Redondo, & Fonseca, 2015).

For the satisfaction dimension for students in both groups, the experimental results did not differ significantly because the assisted materials that the two groups used involved integrating information technology into instruction. This type of learning material was a new experience for students in both groups and differed from previous PE teaching methods, producing higher satisfaction ratings. Keller (1999) claimed that the combination of the learning environment and information-assisted materials enhances the sense of satisfaction, and the results of previous studies have demonstrated similar results (Wasko, 2013; Zak, 2014). Although the satisfaction of the students using AR-assisted instruction in the experimental group was not significantly higher than that of the control group, which did not comply with our assumptions, the experimental group still had higher scores than the control group.

6. Conclusions

Video-assisted instruction is generally used in motor skills demonstration and commentary in physical education, but it has two shortcomings. First, it may not provide interactive operation, so learners may not observe details from different angles. Second, it does not integrate the cognitive knowledge in the book with motor skills. To improve these deficiencies and enhance learning outcomes, AR integrated with 3D materials can assist students in motor skills learning by allowing students to operate the 3D character model while reading textbook material. To verify the effectiveness of AR-assisted learning with the 3D model for motor skills, this study designed two experiments, one based on simple, basic running actions and one with more difficult Mark exercise actions as the learning content. The experimental results show that AR-assisted learning with the 3D model produced better performance than video learning and it demonstrate good results for more difficult motor skills learning. Thus, with regard to sports skills learning, in addition to the materials needed for demonstration, students should have the opportunity to explore and practice, which is an effective condition of the AR-assisted materials. AR-assisted learning with the 3D model may satisfy these conditions and provide opportunities for interactive operation so that students can observe demonstration actions from all angles and participate in an environment of kinesthetic immersive experiences.

The students in the experimental group encountered operating difficulties when using the AR mobile carrier; for example, the pictures in the book contained reflections, dark shadows, or obscure areas resulting in poor image recognition. The image recognition algorithm should be improved to avoid operating with poor lighting and environmental interference.

The AR-PEclass superimposes the 3D character model with text materials, which may be used only in individual student motor skills training. However, in athletic competitions and training experiences, a single 3D character model may not provide learning opportunities. If the AR's overlay message provides the opportunity for situational learning, virtual reality (or VR) may be incorporated into the assistive system to enable situational learning. Mixed reality, combining AR and VR, will become a research direction for athletic training aids and a worthwhile area for future research.

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