The Physical Educator Vol. 81 • pp. 687–710 • 2024
https://doi.org/10.18666/TPE-2024-V81-I6-11953

METHODOLOGY

Physical Education Teacher and Students' Perceptions of Using Motion Analysis App Technology

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Abstract

In schools, digital technology has been used to record students' motor skill performance to create records of skill execution and the tactical dimension of game performance. Informed by the Technological Pedagogical Content Knowledge framework, this study determined a physical education teacher and students' perceptions about using a motion analysis mobile application during 20 lessons of a middle school badminton unit. The critical incident technique with students and the semi-structured interviews with the teacher were conducted to gauge their perception of technology. Seven major categories and 48 sub-categories were established from the critical incident sheets. The thematic analysis was applied to understand the teacher's perception of the app. Along with the three themes that describe the perceptions of the mobile app: (a) Survival to Impact, (b) Teacher's student-centered Pedagogical Skill, and (c) Not Always 'APP'ropriate, the app provided stakeholders with innovative teaching and learning opportunities on game performance.

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Physical Education Teacher and Students' Perceptions of Using Motion Analysis App Technology

Physical Education Teacher Education (PETE) programs have evolved to integrate technology into the programs (Jones et al., 2017). A variety of ideas have been proposed in the professional literature to provide pre-/in-service teachers with opportunities to enhance their pedagogical experiences with technology: (a) mobile applications to motivate students to move, (b) video recording as an aid to formative assessments, (c) web-enabled tablets as a tool for teaching, and (d) digital movement analysis software for feedback and assessment (Baert, 2015; Leight et al., 2009; Martin et al., 2015; Phillips et al., 2014; Rosenthal & Eliason, 2015; Sinelnikov, 2012; Trout, 2013). There is also a growing body of educational literature that students benefit in various ways in their classes where digital video is integrated, such as motivation, enjoyment, and learning (Hoffenberg & Handler, 2001; Koekoek et al., 2018; Koekoek et al., 2019; Palao et al., 2015; Weir & Connor, 2009).

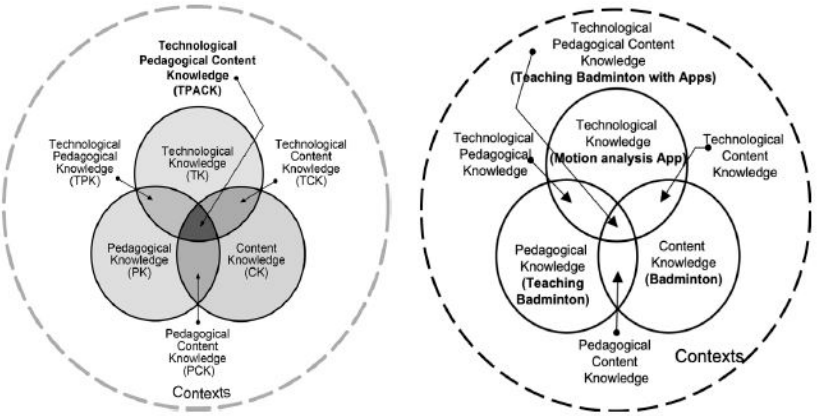
Traditional types of video technology have been used in schools to record students' motor skill performance to create permanent records of skill execution and provide visual feedback to students (Hastie, 1998; Hastie et al., 2013). The recent advance in digital devices has enabled teachers to use more compact and portable cameras that may contribute to improved quality of instruction. Today, mobile application (app) technology, as advanced video technology, enables teachers to record and edit simultaneously with their smartphones or tablets even while teaching. Baert (2015) gave examples of video technology applications (e.g., mobile devices) in teaching to accomplish the national standards, such as creating open space and returning to a midcourt position in a net/wall unit (SHAPE America, 2014). Domingo and Garganté (2016) found various impacts on learning with mobile technology from previous research: (a) providing new ways to learn, (b) increasing engagement in learning, (c) promoting autonomous learning, (d) facilitating access to information, and (e) promoting collaborative learning. However, even though the use of app technology by physical educators has resulted in students' improved learning, little is known about the perceptions of physical education teachers and their students on the use of apps. Therefore, it is crucial to evaluate teachers' and students' views of the

integration of video technology using apps for appropriate guidelines for new instructional strategies to support the use of mobile technology in schools.

Based on Shulman's (1987) framework of pedagogical content knowledge, Koehler and Mishra (2009) viewed technology as a separate domain of knowledge acquired by teachers, content knowledge, and pedagogical knowledge. As shown in Figure 1, technological pedagogical content knowledge (TPACK) encompasses all three domains (content, pedagogy, and technology). Koehler and Mishra (2009) insisted that TPACK represents pedagogical techniques using technologies in innovative ways to teach certain content. The successful infusion of technology relies on teachers' attitudes and beliefs, such as their self-confidence, self-efficacy, and willingness to change pedagogical strategies (Vannatta & Nancy, 2004; Watson, 2006). Teachers' positive views of technology were related to their opportunities for employing different types of technologies, which means that if teachers receive adequate training and support in technology, they are more likely to try it out in their teaching (Crowe & van 't Hooft, 2006; Keiper et al., 2000; Mason & Berson, 2000).

Figure 1

Application of Technological Pedagogical Content Knowledge Framework



Despite the usability and potential benefits of technology-integrated pedagogy to enhance student learning, instructional practice, and overcoming pedagogical challenges (Casey et al., 2017), there

remains a paucity of research on using mobile app technology in Physical Education (Kretschmann, 2015). Also, despite the broad support in the professional literature on the potential of digital technologies to enhance teaching and learning, there remains a dearth of evidence on the actual impact of the technologies, especially within the context of Physical Education. Therefore, this study aimed to assess both a teacher's and students' perceptions of digital technology (a motion analysis app) used in physical education classes. These stakeholders' experiences in the study are important for developing a deeper understanding of mobile video technologies' effectiveness and role in students' motor skill development and game performance in Physical Education.

Table 1
Badminton Lesson Outline for Intervention Classes Using a Mobile App

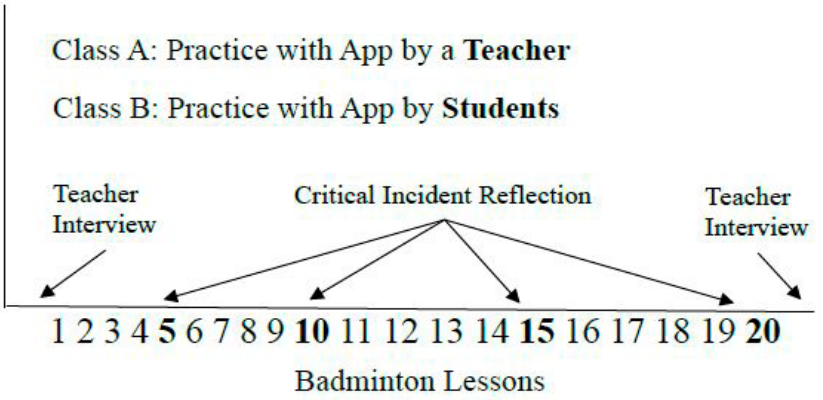
Lesson	Focus	Teacher's role	Students' role
1	Introduction to badminton (Rules & beginning skills)	Program director	Performer
2-3	Team allocation Practice competition Skill instruction using mobile App (Whole class) Video recording for gameplay assessment	Head coach Umpire advisor App user (Class A)	Performer Scorekeeper App user (Class B)
4-20	Formal competition Video recording for game play assessment	Program director App user (Class A)	Performer Scorekeeper App user (Class B)

Methods

Participants and School Setting

The participants (N=36; 27 boys, nine girls) were recruited from two randomly assigned eighth-grade classes from one charter school in the southwestern US. The physical education teacher (male, Caucasian) in the school had taught secondary school students for over seven years and implemented a variety of sports using the Sport Education curricular model (Siedentop et al., 2020). As students

Figure 2
Alternate Control Treatment Group (ACTG) Research Design



have already become familiar with this model, some features of sports education, such as a longer unit, team affiliation, and formal competition, were employed in the study. Table 1 indicates the badminton lesson outlines throughout the intervention. The school had adequate physical activity facilities, including four indoor badminton courts and equipment for this study.

Research Design

As part of a large study (Figure 2), the alternate control treatment group (ACTG) research design (Borg, 1984) with two intervention classes was used to determine if it affected the teacher and students' perceptions of the app use during the 20-day badminton lessons. A slow-motion video analysis app (*Hudl Technique)* allowed a teacher to give students immediate feedback on their skill execution. Three features of the app were implemented in the intervention: (a) adjustable slow-motion speed (1/8, 1/4, or 1/2), (b) a zoom function that helped the teacher examine specific skill movements in badminton, and (c) drawing tools with a voice recorder that allowed students to record peers' techniques, highlighting students' motion with different lines and shapes on the videos. The research team trained the physical education teacher on how to employ the motion analysis app in his teaching before the intervention. Based on the instruction complexity (Figure 3) and teaching and learning process with the app (Figure 4), the training included (a) a review of the planned con-

Figure 3
Teacher Instruction Complexity

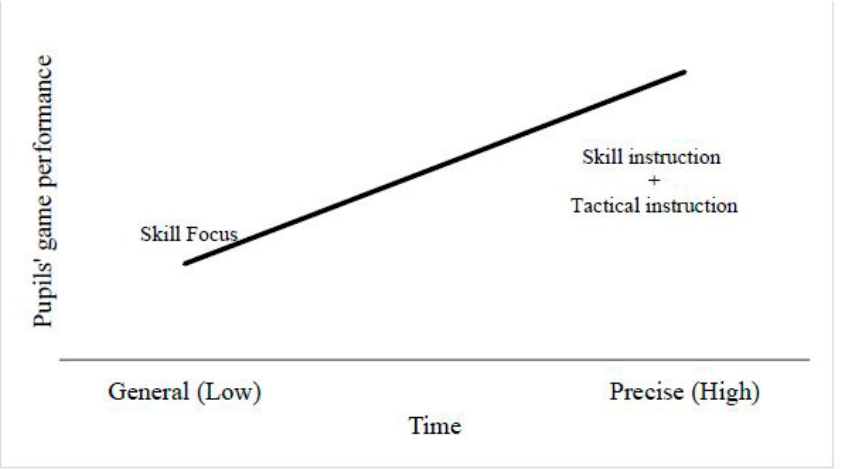
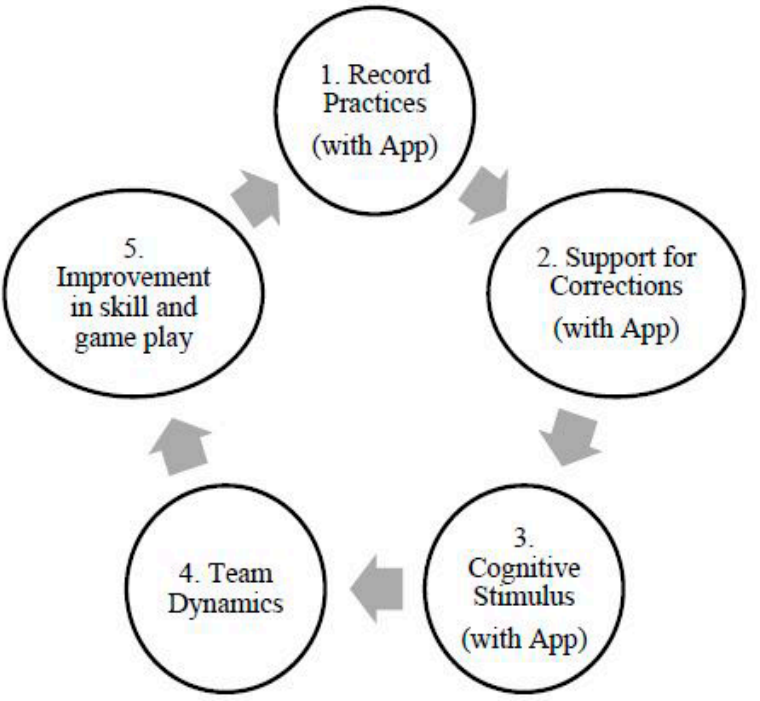


Figure 4
Teaching and Learning Process While Using the App



tent, format, and organizational procedures for the badminton lessons, (b) clear shot skill test protocol, (c) use of the *Hudl Technique*.

While only the teacher used the *Hudl Technique* in class A, students in class B were introduced to using the app starting on Lesson Day 2. The teacher explained the app features to the whole class, and each team started using the app with an iPad mini during their team practices. Students in the two classes received regular (non-)verbal skill feedback and prompts from the teacher or peers, as well as opportunities for feedback using the motion analysis app. They used the voice recording feature of the app when reviewing videos.

Data Collection

Critical Incidents

The critical incident technique (Flanagan, 1954) was used to investigate the aspects of the *Hudl Technique* that the student participants thought were significant during the badminton lessons. After five lessons throughout the badminton unit, students completed a critical incident reflection sheet with instructions similar to those used by Hastie and Curtner-Smith (2006). They were asked to write on two topics: (a) "Your experiences with the motion analysis app. What feedback did you get from your teacher or what feedback did you give your classmates using the video clips? When you have described what happened, try to explain why it was important." and (b) "One thing that happened during your lesson this week that you found important. It may have been important because it made you excited, made you bored, made you worried, or because it was something you learned that was really new. When you have described what happened, try to explain why it was important."

Pre- And Post-intervention Semi-structured Interviews With the Teacher

An interview protocol was developed based on previous research on teachers' perception of technology integration (Baek et al., 2018; Domingo & Garganté, 2016; Holland, 2001). This pre-intervention interview aimed to gauge the teacher's overall interest, perception of technology, and whether/how video technology might help him in his teaching. The perception of technology question focused on his thoughts on adopting technology in general, *Hudl Technique* train-

Table 2
Teachers' Developmental Levels in Technology

Developmental levels	Teachers' characteristics
Non-readiness	Have little interest in technology
	Have little knowledge and skills of technology
	Be resistant to using technology
Survival	Focus on their own learning of technology
	Have limited knowledge and skills of technology
	Need technological supports in their classroom
Mastery	Have knowledge and skills of technology in limited areas
	Need to expand knowledge and use of technology
	Have limited approaches to instructional use of technology
	Need personal assistance rather than formal in-service training
Impact	Integrate technology into teaching and curriculum
	Use technology as an instructional tool
	Have challenges to management for monitoring pupils
Innovation	Use a variety of technology applications in teaching
	Substantially change ways to teach with technology

ing, and his developmental level in his physical education program. As shown in Table 2, the questions were based on the developmental levels in technology use proposed by Holland (2001).

After completing the badminton unit, the teacher's experiences and perceptions about using the *Hudl Technique* were explored through the post-intervention interview. The interview questions included: (a) the experiences that were the most influential to you when using the *Hudl Technique*, (b) ways that the use of the *Hudl* app impacted students' skill and gameplay development, (c) (compared to teaching without the *Hudl Technique)* changes in the instruction when using the *Hudl Technique*, (d) the main advantages and disadvantages of the app, (e) reasons why you want to continue to

use the *Hudl Technique* or not, (f) challenging aspects of using *Hudl Technique* and why, and (g) suggestions for other teachers who are considering using the motion analysis app.

Daily Reflection Interviews

The physical education teacher also participated in a daily reflective interview after each of the 20 lessons taught to both classes A and B. The teacher briefly reflected on what went well and the challenges that arose after each class. The lead researcher captured the teacher's daily reflections with audio recordings. A research team member also took daily field notes to support evidence of the teacher's reflections and process of using video technology across both classes A and B following each of the 20 lessons.

Data Analysis

Critical Incidents

Students completed 178 critical incident sheets (one each about every five lesson days). Six major data categories were pre-determined for analysis according to the previous study's findings that informed the design of the current project (Hastie & Curtner-Smith, 2006). During the first phase, the ideas for categorization were considered to see if the data collected in this study fit into the pre-determined categories (shown in Table 3). One major category (app-related) was added to the codes for this study. The comments were coded and categorized using the analytic induction technique (Preissle & Le Compte, 1984). Two trained reviewers independently reviewed and coded all of the critical incident sheets. After coding, the two reviewers discussed and negotiated any critical incidents that were not coded the same until a consensus was reached. All codes not appearing in the critical incident sheets were deleted, and the codes with the same aspects in the data set were incorporated into several categories. The critical incident data were sorted into participants' perceptions that were consistently stated with a single idea within the seven major categories. Once the coding process was finished and negotiated by the two coders, the frequency for each code was calculated for each category to identify the students' perceptions from their critical incident comments.

Pre- And Post-intervention Interviews With the Teacher and Daily Reflection

The lead researcher transcribed Interview recordings verbatim to preserve a record of the meaning of passages. For the first phase, a deductive process was used to categorize the raw data themes detected from the interview transcriptions. Using the repeated reading method for data immersion (Braun & Clarke, 2006), the lead researcher first read the transcriptions five times. Next, the lead researcher and a second coder reviewed the transcripts independently to categorize the raw data themes. The two reviewers negotiated themes until three final overarching themes emerged. Following the identification of the three themes, the researchers assessed the transcriptions by questioning the teacher's answers to make explicit reasons guiding content and thematic data analysis. The researcher and the second coder's interpretation involved reviewing the transcripts to find meaningful and specific segments representing the teacher's experiences. The three data themes generated by the researchers provided a detailed sense of data on how and why the teacher's perceptions of the technology integration had changed.

Data Trustworthiness

Trustworthiness of critical incidents and the teacher's daily reflection/interview data were established through an audit trail kept by the research team, who independently reviewed all transcripts and member-checking with the teacher. The confirmability audit was conducted as a dependability process by asking the physical education teacher if the students' self-reported datasheets, interview recordings/transcripts, and the interpretations (i.e., themes) made by reviewers were internally coherent and represented more than just "figments of the imagination" (Guba & Lincoln, 1989, p. 243). The teacher agreed with the themes and data from the critical incident sheets and interview transcriptions. Further, data triangulation took place by comparing data generated by the interviews, informal interviews, and field notes and by comparing similarities between the student critical incidence reports and the teacher interview data.

Table 3

Frequency of Pupils' Perceptions in Critical Incidents

Class	Lesson											
	Day 5		Day 8		Day 11		Day 14		Day 17		Total	
	A	B	A	B	A	B	A	B	A	B	A	B
General comments about lesson												
Enjoyed/ Excited	4	6	0	1	0	1	1	0	4	2	9	10
Fun	0	0	2	0	0	0	0	0	0	1	2	1
Don't like/annoyed	0	0	0	0	0	1	1	0	0	1	1	2
Tiring/boring	0	1	0	0	0	0	1	0	0	0	1	1
Hard to learn	0	0	1	0	0	0	0	0	0	0	1	0
Subtotal	4	7	3	1	0	2	3	0	4	4	14	14
Team-related												
Teamwork	1	0	1	2	0	1	0	0	0	0	2	3
Affiliation	0	0	1	0	0	0	1	0	1	0	3	0
Subtotal	1	0	2	2	0	1	1	0	1	0	5	3
Affective												
Cool	0	0	2	0	0	0	1	0	1	0	4	0
Worried	1	3	0	0	0	0	0	0	0	1	1	4
Not be Cocky/Salty	1	0	0	0	0	0	0	0	0	0	1	0
Being with friends	1	0	0	0	0	0	0	0	0	0	1	0
Effort	1	0	0	0	0	0	0	0	0	0	1	0
Confident	0	0	1	0	0	0	0	0	0	0	1	0
Fair Play	0	1	0	0	0	0	0	0	0	0	0	1
Encourage pupils	0	0	1	0	0	0	0	0	0	0	1	0
Subtotal	4	4	4	0	0	0	1	0	1	1	10	5
Skill-related												
Enjoy skills	2	0	0	0	0	0	0	0	0	0	2	0
Learning/ Performing skills	18	10	5	1	3	2	4	2	1	0	31	15
No feedback from teacher	0	0	1	0	0	0	0	0	0	0	1	0
Subtotal	20	10	6	1	3	2	4	2	1	0	34	15
Game-related												
Enjoy in general	1	0	0	0	0	0	0	0	0	0	1	0
General success	0	0	0	0	0	0	2	0	0	0	2	0
Specific success	0	0	1	0	4	4	1	2	0	0	6	6
Employing tactics	1	1	4	1	6	2	6	6	3	0	20	10
Specific failure	0	0	0	0	1	0	0	1	0	0	1	1

Table 3 (cont.)
Frequency of Pupils' Perceptions in Critical Incidents

Winning	4	4	1	0	2	3	4	5	0	1	11	13
Losing	2	1	0	0	2	0	0	0	2	0	6	1
Enjoy because team sport	1	0	0	0	0	0	0	0	0	0	1	0
Rules	1	0	0	0	0	0	0	0	0	0	1	0
Teacher involvement	1	0	0	0	1	0	0	0	0	0	2	0
Subtotal	11	6	6	1	16	9	13	14	5	1	51	31
App-related												
Helpful/effective	0	0	3	5	5	7	2	7	3	7	13	26
Useful	0	0	2	0	2	0	0	0	2	2	6	2
Get more ideas	0	0	0	0	0	0	0	1	0	0	0	1
Excited/fun	0	0	0	0	0	0	0	0	3	1	3	1
Motivated	0	0	0	0	0	0	0	0	1	0	1	0
Good/Cool/Like	0	0	2	4	3	2	3	0	4	3	12	9
Bored/was ok	0	0	0	0	0	0	0	0	1	1	1	1
Don't like it/worried	0	0	0	0	0	0	1	0	0	1	1	1
Not helpful	0	0	0	0	0	0	0	0	1	1	1	1
Action and motion	0	0	1	1	0	0	0	0	0	0	1	1
Feedback	0	0	2	1	0	1	0	1	0	0	2	3
See myself/team	0	0	7	3	5	4	2	2	5	2	19	11
Fix mistakes in motion (skill)	0	0	5	2	0	1	1	0	2	3	8	6
Tactics with App	0	0	0	0	4	2	2	5	4	4	10	11
Get better/ Improve	0	0	3	6	2	3	3	2	3	6	11	17
Subtotal	0	0	25	22	21	20	14	18	29	31	89	91
Others												
Didn't learn new	0	0	0	0	1	0	1	0	0	0	2	0
Being alert	0	0	1	0	0	0	0	0	0	0	1	0
Injury/Sick	0	0	1	0	0	0	0	0	0	0	1	0
Subtotal	0	0	2	0	1	0	1	0	0	0	4	0
Total	40	27	48	27	41	34	37	34	41	37	**207**	**159**

Results

Critical Incidents

Skill- and Gameplay-related Comments

The proportion of statements between the app-related and the Other Sub-categories is shown in Figure 5. Among the 366 perceptions about the badminton lessons using the app (207 for class A; 159 for class B), 92.6% of the comments (339) were positive. Table 3 includes data for students' skill- and gameplay-related categories during the season. Students made 49 skill-related comments throughout the season (34 in class A; 15 in class B). The teacher taught students specific components of basic movement and skills such as 'good stance,' 'backhand serving,' 'form,' 'grip,' 'drop shot,' and 'keeping an eye on the birdie all the time.'

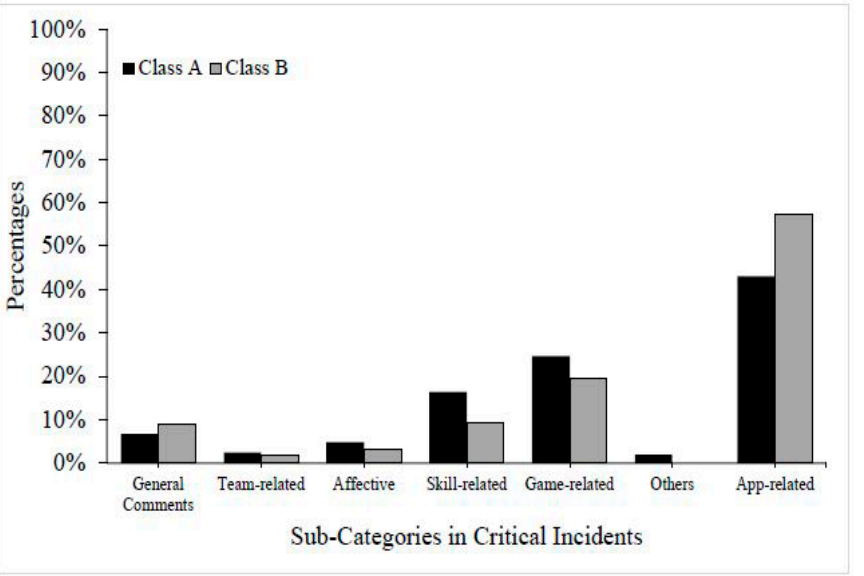
Students also produced 82 game-related comments (51 in class A; 31 in class B). They focused deeply on employing tactical moves (30 comments) to win (24 comments), such as 'made the opponent move around the court' and 'go to the center after every hit,' rather than complaining about the rotating play system or the number of courts. They also expressed their specific successes (12 comments), such as 'only missed 2 shots today', 'my form and serves went well,' and 'one that worked very often is hitting close to the net.'

App-Related Comments

A total of 180 app-related comments were made throughout the badminton season (89 in class A; 91 in class B). Nine subcategories for the general perceptions of the app and six subcategories for the performance-related comments were established. Students produced 73 positive comments regarding general perceptions that the app was 'helpful/effective (39),' 'good/cool/like (21),' 'useful (8),' and students were 'excited (4)' and 'motivated (1).' Conversely, some students felt 'bored (2),' 'did not like (2)' the app, and thought the app was 'not helpful (2):'

> I like using a great video app because it made everything more visible and cooler.

Figure 5
The Proportion of Statements Between the App-related and the Other Subcategories



> I was very excited to join the app and use all the things it had. I learned many things such as skills and strategy.

> It made me worried because it is always too bad when I am recorded.

> I didn't like using the voice…

Students also made 100 performance-related comments (51 in class A; 49 in class B). For the skill-related topic, the comments showed students' positive impressions regarding their skill development. Examples include being able to see themselves (30 comments) on the app to fix their skills (14 comments). Notably, the *Hudl Technique* app was used to employ tactical moves (21 comments) in students' gameplay, showing that their self-reported game performances improved (28 comments):

One thing that I learned today is that your posture affects the way that the birdie goes. If you turn sideways then it's easier for you to hit the birdie.

One thing that happened during this lesson is that I got to see where and how to improve my serve and how to serve a rally.

Our team did very well in the game and that was important because the app helped us with teamwork and brand-new skill throughout the badminton class.

What I learned with the app was to keep the opponent moving. A player and I have to go to the middle, every time I hit the birdie.

I learned from the app how to observe my opponent and try to hit the birdie soft on hand when I need to.

I wasn't getting under the birdie, the app also helped me learn many strategies to use against my opponent.

Interviews With the Teacher About the Use of the *Hudl Technique*

The thematic analysis process that was applied to the physical education teacher's daily reflection and two formal interviews generated three themes that describe the teacher's understanding and perceptions of the mobile app. The themes were (a) Survival to Impact, (b) Teacher's Student-centered Pedagogical Skill, and (c) Not Always Appropriate. However, even though three different categories were defined, they were all related to each other.

Survival to Impact

The teacher was interested in tools to benefit his students and their skills. His first daily reflection opened with the comment, "The kids seem to respond to it." Also, it was clear that his perception of the app would be tied to the students' use of it and benefit from its use:

> I was explaining to some of the kids how to use the app so I would show them how I did it and how I recorded the videos, and they seemed excited to use it during our next class (Day 2, daily reflection)…When you're using the app, you have to give them something specific to look for and to improve on because I can't just show them the video and not give feedback and instruction (Post-intervention interview).

As a teacher who has already noted his preference for technology that would help his students, it was clear that he liked how this app allowed students to learn more of the details of the skills, which resulted in improving their gameplay performance:

> …definitely, the gameplay was pretty good today. The games were close and everybody played well…I don't know if there are any students that aren't fairly comfortable at this point with the game, which is nice to see (Day 16, daily reflection).

Pre/Post-intervention interviews indicated that the teacher's technological developmental level moved from 'Survival' to 'Impact.' He noted that with more exposure, what he was recording and the feedback he gave through the app were better:

> I definitely need help…I think as long as I can get it down, you know, definitely help (Pre-intervention interview).

> …from the first day to the last day I definitely, you know, the quality of what I was able to produce was definitely a lot better (Post-intervention interview).

The teacher was the only one who used the *Hudl Technique* app in class A, while students in class B used the app within their team. It is evident that the teacher preferred the teaching environment in class A:

> I felt like the first-hour class (class A) showed more improvement throughout the day (Day 4, daily reflection)… It was probably easier for me to use it myself and teach the kids because there's a lot to learn…they're still learning the

rules of the game and also learning to play the game and then adding the app in there (Day 3, daily reflection).

Teacher's Student-Centered Pedagogical Skill

The teacher was optimistic about using technology in Physical Education. Before this intervention, he had integrated digital technology, such as pre-recorded music or Google Classrooms, to give students more individual instructions during and outside of class. Specific to the use of the *Hudl Technique*, the teacher's perceptions of the integration of the app into his badminton season were overall positive:

> … [this experience] points me toward the possibility of using it because before I would have never even considered it. But it's definitely something that can be valuable and useful and worthwhile (Post-intervention interview).

The teacher shared thoughts about how his normal teaching style followed a standard order of teacher demonstration of skills and students practicing the skills. During the intervention, the teacher felt very successful in his ability to teach students badminton skills and tactics. Using the app, he provided students with different ways of learning, which he promoted by asking students to plan their strategy (i.e., he was referring to strategy as a game plan for students to win), enact the plan in the rally, and reflect on the outcome of their planning by talking through the play using the app. Rather than just talking about winning or losing through skills, the teacher found out that the app added the ability to review videos and watch how a student's play caused the opponent to react:

> (I was able to) focus on things that normally we kind of skip through…it became more about strategy and we focused mainly on that. Because at that point, the students were able to get some pretty good rallies going, so they could see, you know, an entire progression of what they thought about their strategy and they were able to watch and see if they actually were able to implement this strategy (Post-intervention interview).

Not Always "APP"ropriate.

It took time for the teacher to learn the app so he could teach it. It also took time for students to learn how to use it:

> It takes a lot of time to film and put together and then once I figured it out, and was able to make some decent videos, it was definitely time-consuming and not easy to capture what I was looking for…when I would film a rally, they wouldn't have a good rally I think sometimes they were nervous… (Post-intervention interview).

The teacher expected that the students would naturally be excited about having the app available. However, sometimes, they indicated that they would rather just be playing and practicing. It challenged the students to do more thinking and reflecting, which they were not entirely comfortable with:

> When our second hour (class B) had to use it, that was tough to get them to use it the right way. They just wanted to blow through it and not really take the time to make good videos. They definitely started to pick it up, but I just felt like they would rather just be practicing and competing (Post-intervention interview).

Discussion

This study focused on the physical education teacher and students' perceptions of using the *Hudl Technique* to understand better the effectiveness and the role of app technology on students' skill development and gameplay in a badminton season. Consistent with previous research (Casey & Jones, 2011; Hastie et al., 2010; Rossing et al., 2012), the use of technology influenced students' learning and positive perceptions of badminton classes in Physical Education. The details in the findings were helpful not only in identifying the effectiveness of the app but also in determining its clinical aspects.

Within the TPACK framework (Koehler & Mishra 2009), the current study represented the teacher's pedagogical skill in using technology in an innovative way to teach badminton content knowledge (See Figure 1). Therefore, it is important to see how the use of the app affected the teacher's badminton teaching. The findings

from the interviews with the teacher represent evidence that the three components of knowledge in Figure 1 (i.e., badminton content knowledge, teaching skill in badminton season, and the ability to use the *Hudl* app) appear to be complementary to enhancing the TPACK for teachers.

The progression of what the teacher focused on through the app started from learning to play badminton. As shown in Figure 3, the teacher's instruction complexity (Koekoek et al., 2018) was initiated by focusing on each student learning proper form and execution of individual skills. Figure 4 describes the specific teaching and learning process while the teacher and students used the app. The *Hudl* app was used during the first three phases, and as shown in Figure 4, this recurring process occurred throughout the season. The teacher gained confidence in teaching with TPACK, and students had positive perceptions of improving their skill and game performance while using the app. Based upon this finding, it is suggested that this teaching and learning process using the app could be applied to other types of racquet sports, such as tennis or racquetball.

Instant feedback from the live recordings (i.e., self-/peer-/teacher's feedback) is a unique feature of the *Hudl* app to develop skills, game strategies, and tactical moves. The specific focus on using angles and skill performance was only available from the app's slow-motion playback with a drawing tool. Students' *app-related* comments in the critical incident sheets supported the positive effects of self-feedback. In addition, following the team play feature of Sport Education, students could provide peers with feedback on their gameplay performance through the app. From the teacher's point of view, the teacher focused the video playback on the movement of the opponent team by leading students to critical thinking to see what happened on the other side of the net during rallies. Bringing a very cognitive and reflective aspect of team gameplay allowed the students to analyze their tactical moves during the games and develop new strategies to play against specific opponents. The teacher gave the students specific tasks to watch the video with a particular question depending on their performance, and accordingly, students were critically commenting on specific aspects of gameplay. Students' prompting right after their performance is available only in the learning environment using live recordings. Even though app technology offers potential in the sense of instructional

strategies and positive views in this study, more research is needed to investigate mobile learning and the application of teaching strategies of mobile learning in physical education. Also, given that the most attention has been placed on higher education (Baran, 2014; Franklin & Smith, 2015), further research investigations for mobile technologies in K-12 settings are recommended (Gubacs-Collins & Juniu, 2009; Rosenthal & Eliason, 2015).

It is worth considering having a video analytics team as one of the non-player roles in sports education. Even though a total of 180 *app-related* comments in the critical incident sheets provided strong evidence that pedagogical aspects of the *Hudl Technique* influenced students' skill development and gameplay, inevitably, there were also some negative comments regarding the use of the app. Some students were not motivated every time and wanted more time for practice and gameplay. In contrast, some students were motivated to play with the app, being more likely to use it. Considering there are non-player roles in Sport Education, teachers could recruit video technicians who have more passion for using video analysis to develop more expertise in video analysis for both skills and gameplay.

In addition, further study is needed to determine the appropriate amount of time and proper timing for using the app. The teacher pointed out the periodic use of the app instead of using it in every class with every student, especially when students need to learn new skills and find their issues to focus on during gameplay. Time is critical in determining the development of technique execution and game-based decision-making (Miller, 2015). Even though a longer unit was used in the study, recording video clips and learning how to effectively use the app require time. However, there is no doubt that this would become less of an issue once students gain more experience.

Given that motor/movement skill competency has been emphasized for learning to play games and sports as the national standard number one in Physical Education over time (Department for Education, 2014; NASPE, 2004; SHAPE America, 2014), further research is warranted to determine whether students show benefit in their skill execution and gameplay as a result of their active use of app technology in different sports in K-12 Physical Education settings over and beyond the regular instructional efforts by teachers. Also, since little is known about the research on authentic assess-

ment of technique and game performance (Harvey & Jarrett, 2014), keeping track of physical education teachers' and students' process of teaching and learning through the app technology may contribute to authentic assessments as well as the development of instructional use of technology in Physical Education.

Conclusion

Within the design and the limitations of this study, the following conclusions are warranted: (a) when trained to do so, physical educators can effectively integrate the use of a motion analysis app and strengthen instructional skills during regular instruction in a secondary school badminton context, (b) students were also effectively able to integrate the use of a motion analysis app and mainly reported positive perceptions about using it, and (c) the app provided students with active learning opportunities through instant feedback on skill and aspects of gameplay performance. Further research is needed for implementing innovative and authentic teaching and learning environments with app technology.

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