Check for updates

III International Conference on Technology in Physical Activity and Sport

Institution of MECHANICAL ENGINEERS

Journal of SPORTS ENGINEERING AND TECHNOLOGY

Proc IMechE Part P:
J Sports Engineering and Technology
1–8
© IMechE 2023
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/17543371231185913
journals.sagepub.com/home/pip
Sage

A technology-based experience to improve badminton skills: A challenge-based learning application

Alba González-Peño[1], Luis Simón-Chico[2], Leonor Prieto[2] and Evelia Franco[2]

Abstract

In recent years, it has become evident that technologies are part of daily life and can be useful and helpful to improve teaching and learning processes in education. Specifically, this evidence has highlighted the positive effect of technologies on improving motor skills. This study presents a technology-based learning (TBL) proposal and analyses how the implementation of such a proposal in physical education (PE) might affect students' academic performance (theoretical knowledge and practical competence). A quasi-experimental study was carried out with experimental and control groups. A total of 84 participants (35 males and 49 females) between 13 and 15 years of age ($M_{age} = 13.35$, SD = 0.62) took part in the experience over a period of 6 weeks ($n_{control} = 49$; $n_{experimental} = 35$). The teacher assessed students' practical competence level in both the experimental and control groups to verify homogeneity. Theoretical knowledge and badminton-specific motor skill tests were performed in both groups after the intervention. Analysis showed that, after the intervention, students in the TBL group significantly increased their levels of badminton-specific motor skills ($M_{contol} = 7.01$ vs $M_{experimental} = 7.73$) compared with students in the control group. No significant changes were observed for theoretical knowledge. The findings of this study highlight that the integration of technologies in PE might be a valid and effective methodological approach for PE students to achieve adaptive learning outcomes and improve their academic performance.

Keywords

Technologies, ICT, challenge-based learning, badminton, innovative methodology, PE, physical education, QR codes

Date received: 15 February 2023; accepted: 18 June 2023

Introduction

Student learning in physical education (PE) is a concern shared by the educational community. In the field of education, there is a demand for new ways of teaching that bring new paradigms and educational models. Badminton is one of the specific contents presented in PE curriculum that could be addressed through new technological approaches. Information and Communication Technologies (ICT) are an excellent resource to apply to this new reality. Following Roig,[1] it can be said that ICT are integrated in the teaching task 'when they are naturally used to support and enlarge curricular objectives as well as to enhance students' learning'. However, integrating ICT in PE can be a challenging task as a result of certain characteristics of the subject, such as its eminently practical nature or the few weekly hours devoted to it. Different authors have suggested practical strategies to incorporate the content using technology.[2,3] Research evidence has pointed out the benefits implementing ICT in PE could have on different students' outcomes, such as academic performance, including skills execution, technique, learning knowledge,[4–6] motivation and enjoyment.[7]

A variety of technology resources are being introduced,[8] at the present time, implementing ICT in PE to involve students in the learning processes. Evidence shows that including these technologies promotes motivation, autonomy and interactions with other students and the teacher in class.[9–11] For example, teachers can

[1]Social Sciences applied to Sport, Physical Activity and Leisure Department, INEF-Universidad Politécnica de Madrid, Spain
[2]Education, Research Methods and Evaluation Department, Universidad Pontificia Comillas, Madrid, Spain

Corresponding author:
Evelia Franco, Facultad de Ciencias Humanas y Sociales, Universidad Pontificia Comillas, Calle Universidad de Comillas, 3-5, Madrid, CP: 28049, Spain.
Email: efalvarez@comillas.edu

use different mobile applications that deliver content and assist with teaching (e.g., Gooru, SloPro, Virtual Heart, VSB Physical Education, etc.) or implement specific applications for students that allow them to engage in the lesson through different activities (e.g., C-Fit Dance – Classroom Fitness, MyFitnessPal, Dartfish Express, etc.).[12,13] Another use of technologies is the inclusion of didactic videos that can deliver content or be used as instructional videos to give feedback to the students.[14,15] Specifically, recent studies relate the use of YouTube videos to a better understanding of concepts and instructional contents in recent studies.[16,17] Lastly, as another use of technologies in education, QR codes have now emerged as an interesting resource that can be used to share information such as link switching, location information, time stamp or user IDs for different activities.[18] These technology resources are being included in PE classes through different methodological approaches that focus on the students and their learning. Innovative methodologies such as Teaching Games for Understanding (TGfU),[19,20] Gamification[6] or Flipped Classroom[9] may be successful integrating ICT in the PE context. Specifically, with TGfU, it was found that technological resources contributed to understanding tactical elements of the game, and students were able to think about their own performance to make decisions.[19] As far as gamification is concerned, findings showed that students' intrinsic motivation, satisfaction of basic psychological needs, cooperative learning and academic performance increased after integrating games and technologies in PE.[21] With the Flipped Classroom methodology, which involves the use of ICT, students improved interactions with the teacher and their classmates, as well as autonomy, motivation in the learning process and motor skills.[9,15]

Challenge-based learning has emerged as a learning methodology in which the use of technology plays a fundamental role.[22] The scarce literature in the PE context has shown that this methodology is effective for students to achieve adaptive motivational, behavioural and learning outcomes.[23] It consists of posing a challenge as a didactic element to promote meaningful and individualised learning among students.[24] In the PE context, Franco et al.[25] proposed an implementation in which the adaptation of the complexity of the challenges and the design of well-structured activities are key to promoting students' autonomy and competence. The differential elements of challenge-based learning according to this proposal concern the methods used, teaching strategies and teaching techniques to integrate ICT, the grouping, the implementation of individualisation, specific features in task presentation, students' involvement in their own evaluation and the presence of collaborative work. Specifically, the use of technology is inherent to the methodology, which uses ICT from the start to provide educational content, allow students to develop innovative solutions to the problems and facilitate learning through the different challenges proposed by the teacher.

Considering the above, there is previous evidence that the implementation of ICT through certain methodologies can improve students' academic performance in the PE context.[19] However, there is no evidence of the impact of using ICT through this approach on secondary education students' academic performance in the PE context. The present study aims, first of all, to analyse how the use of technologies might affect students' practical competence and theoretical knowledge; and secondly, to analyse the effects of a technology-based learning (TBL) methodology through challenge-based learning in comparison with a traditional teaching (TT) methodology. This study thus adds to the existing literature by answering the following question: are there differences in students' practical competence and theoretical knowledge according to the methodology they experience in class (TBL vs TT)? Considering the challenge-based learning features, it is hypothesised that the use of ICT through a challenge-based learning experience, such as TBL, can positively impact students' academic performance given that they would be engaged in a more individualised experience.

Materials and methods

Participants

The sample comprised 84 students (35 males and 49 females) between the ages of 13 and 15 years (M = 13.35, SD = 0.62) from four secondary education school classes in Toledo (Spain). The classes participating in the study were randomly selected from those taught by the teacher. All the students were in their third year of secondary education. A total of 49 students from two different classes followed a traditional teaching methodology; and 35 students from two other classes followed a TBL methodology. The groups were split by keeping their class groups. The PE teacher who implemented all these sessions was 25 years of age and had received extensive training on different methodologies and how to implement specific methodological approaches in real practice both with and without the implementation of technologies.

Instruments

Different technological resources were used during the intervention in the PE classes: apps for mobile phones (e.g., QR scan, GoClass), QR codes, didactic videos and the YouTube platform. With an interest in considering the potential value of these resources to improve learning, theoretical knowledge and practical competence were assessed at the end of the intervention.

- Theoretical knowledge: the test consisted of six multiple-choice questions in which the students were asked about the rules (e.g., 'If a set is tied at

Table 1. Summary of the contents of the sessions for the control and experimental groups.

	Traditional teaching (TT) group	Technology-based learning (TBL) group
Session 1	Both groups did the same activities to familiarise themselves with the materials and the most basic elements of badminton.	
Session 2	Participants began to work on the most basic technical skills (such as forehand and backhand low-handed strokes) following the teacher's instructions.	Participants began to work on the most basic technical skills (such as forehand and backhand low-handed strokes) using different challenge cards with a QR code through which students could access the instructions.
Session 3	Students learned to serve, working individually and repeating the technical movement over and over.	Students learned to serve in pairs, using QR cards that went from level one to level four, all of which had to be completed.
Sessions 4, 5 and 6	Participants worked on the different badminton strokes (net-drop, lob, clear, drop and smash) using the method, teaching strategies and techniques and groupings following the traditional methodology.	Participants worked on the different badminton strokes (net-drop, lob, clear, drop and smash) using the method, teaching strategies and techniques and groupings following the challenge-based learning methodology.
Sessions 7 and 8	Students reviewed all the elements listed above. They continued with the same dynamics as the previous sessions.	Students reviewed all the elements listed above. A challenge activity was designed to work autonomously via the use of QR codes that linked each track to different technical-tactical videos available on YouTube.
Session 9	Singles competition. Practical test (Practical competence)	Mixed doubles competition.
Session 10	Theoretical test (Theoretical knowledge)	

29 points, what happens?'), materials (e.g., 'What is the shuttlecock used in official competitions is made?') and the basic game system. Additionally, the students were asked questions about definitions, types and open-ended questions about technical-tactical aspects, such as the progression of exercises and the anticipation of situations to gain advantage over the opponent.

- Practical competence was evaluated through a rubric created to assess different aspects related to racquet skills and technical strokes. In the racquet skill part, the students were given four attempts to pick up the shuttlecock from the ground with the racquet and in the second exercise they had to hit the shuttlecock and keep it in the air for at least ten seconds. In the technical exercises part, they had to serve five times as if they were playing a singles match (they got the highest score if they made three good serves), they had to do at least six clear strokes consecutively with a partner and they had to do at least six net-drop strokes consecutively with the same partner.

Design and procedure

Firstly, this study aims to analyse how the use of ICT could affect students' practical competence and theoretical knowledge; and secondly, to analyse the effects of a TBL methodology through challenge-based learning in comparison with a TT methodology.

The study is designed as a quasi-experimental pre-test/post-test aimed at comparing TBL (experimental group) and a more TT experience (control group). It should be noted that both groups had the same PE teacher, and all students were previously informed about the research project and gave their consent to participate.

To verify the homogeneity of the groups before the intervention, the teacher assessed the levels of practical competence of the students in both the experimental and the control group. Both groups had homogeneous levels of competence in badminton.

Description of the intervention. The intervention was carried out across a total of 10, 50-min sessions from April to June 2022, which were compulsory according to the curriculum. All classes were held at the secondary school's sports facilities, specifically, in a covered pavilion containing seven badminton courts.

As shown in Table 1, within the didactic unit created for the experimental group, 4 of the 10 sessions were designed integrating ICT under the challenge-based learning methodology. These four sessions were Sessions 2, 3, 7 and 8. Figure 1 shows the process for creating the material used in the sessions.

The didactic objectives set for both groups were the same. However, the session objectives were modified for the experimental group when the sessions included challenges.

This study obtained approval from the ethics committee of a Spanish university. All participants were treated in agreement with the ethical guidelines of the American Psychological Association[26] with respect to consent, confidentiality and the anonymity of their answers. The questionnaires were given by a member of the research group before and after the

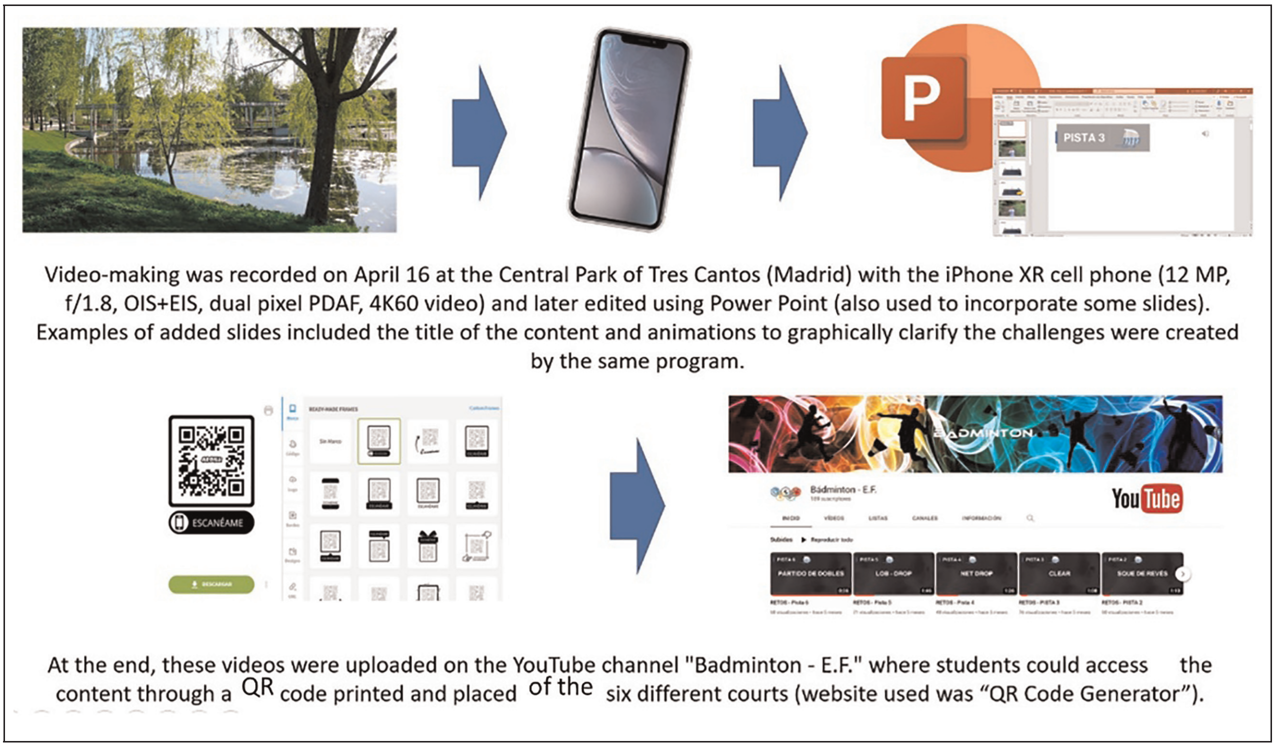

Figure 1. Process for creating the material used in the CBL sessions in the experimental group.

intervention. The researcher explained the purpose of the project, emphasised that the participants' anonymity would be maintained and encouraged the participants to answer the questions as honestly as possible. The students completed the questionnaire in the classroom via a Google form in a setting that allowed them to concentrate without distraction; its duration was about 20 min.

Elaboration and use of technological resources. For the Didactic Unit focused on teaching badminton in secondary education, both the didactic unit itself and the session objectives were set considering the various contents and evaluation criteria of the course. In both groups, during the first six sessions, seven badminton-specific strokes and their tactical connection were practised (backhand serve, forehand serve, net-drop, lob, clear, drop and smash). After that, two more sessions were designed to review all these strokes. Then a mixed doubles competition was held, followed by the theoretical exam in the last session.

As shown in Table 1, the main difference between the TT and TBL groups were the resources used to work in class and the way in which the activities were presented. While in the TT group all the sessions were developed following analytical strategies and traditional teaching techniques without using any technology, students in the TBL group had to use their mobile phones for two purposes: firstly, the GoClass app was required to check the lesson plan and organise the challenges; and secondly, a QR scan app was necessary to access links to specific information. For Sessions 2 and 3 with the TBL group, different cards were designed and provided through QR codes. Specifically, in Session 2, 12 cards were created with different challenges. The challenges on the cards increased in difficulty as the students progressed to working on different racquet skills both individually and in pairs. Following the same procedure in Session 3, two cards were created, each including four challenges to work on forehand and backhand serves. The cards were created using text boxes that included the description of each exercise and different images to illustrate the challenge they had to overcome (the images used were also created for this program). Then, the cards were provided to the students during the sessions by means of the QR codes. Additionally, for Sessions 7 and 8, six videos were designed and recorded to further enhance the different strokes seen so far (serves, lobs, drops, clears and smashes). As an easy way for the students to have access to these videos during the review sessions, each video was linked to a QR code using the 'QR Code Generator' website. The resulting QR codes were then printed and placed on each of the six different courts. The videos used for instruction were recorded by one of the authors of this work at the Central Park of Tres Cantos (Madrid) using the iPhone XR mobile phone (12 MP, f/1.8, OIS + EIS, dual pixel PDAF, 4K60 video). Then, the films were downloaded and edited with the PowerPoint program, which was also used to incorporate a number of slides in the final videos. Examples of added slides include the title of the content to be worked on and animations to clarify the challenge the students had to overcome. Once finished, the videos were uploaded to the

Table 2. Entry level indicators.

Low level	Intermediate level	High level
The student has difficulty keeping the shuttlecock in play (in the air).	The student is able to keep the shuttlecock in the game even if it occasionally falls to the ground.	The student is able to keep the shuttlecock in the air both when playing individually and when playing with a partner.
The student is not able to change the racquet from one hand to the other.	The student is able to change the racquet from one hand to the other in some cases.	The student is able to change the racquet from one hand to the other depending on whether he/she has to hit forehand or backhand.
The student shows difficulty lifting the shuttlecock off the ground using only the racquet.	The student is able to lift the shuttlecock off the ground with the racquet even if he/she does not maintain control of the shuttlecock when doing so and occasionally drops it.	The student is able to lift the shuttlecock off the ground with the racquet.

YouTube channel 'Badminton – E.F.' (https://www.youtube.com/@badminton-e.f.8429).

Finally, regarding the theoretical assessment of the subject in the experimental group, videos were uploaded to the secondary school's platform with all the information related to the basic rules of badminton, the different types of strokes, the materials and facilities (also created with the Microsoft PowerPoint program). The exercises proposed were as follows: keeping the shuttlecock in the air individually, changing the racquet from one hand to the other after each stroke, keeping the shuttlecock in the air with the partner, hitting it from below the waist and above the head and picking up the shuttlecock from the ground using only the racquet.

Data analysis

Firstly, descriptive statistics (mean and standard deviation) and correlations among all the study variables were calculated. A Kolmogorov–Smirnov test was then performed to verify the normality of the data and show that it was normally distributed ($p > 0.05$). Accordingly, parametric tests were used to analyse differences between groups. To test whether the groups behaved similarly before the intervention, independent *t*-tests were performed to analyse possible differences between them in terms of practical competence and theoretical knowledge. The effect sizes of the comparisons were estimated using Cohen's *D*. The students' initial level was evaluated following the procedure described in the Results Section. For this analysis, the Pearson χ^2 test was completed with the observation of standardised adjusted residuals and to assess differences between the control and experimental groups in the distribution of students, categorised as low, medium and high level. The SPSS 24.0 software program was used to process the data.

Results

Preliminary analyses and descriptive statistics

The homogeneity of the groups was ensured by means of a prior assessment. To carry out the initial evaluation, one of the members of the research team, who was also the PE teacher, classified all the participating students into three levels. Each student's skill and ability with the racquet, both individually and in pairs, were the determining factors for the classification: low level, intermediate level and high level (Table 2). Figure 2 shows a graphical representation of the percentage of students corresponding to each level for each group. Non-significant differences emerged between groups according to the participants' level ($\chi^2{}_2 = 0.277$, $p = 0.870$).

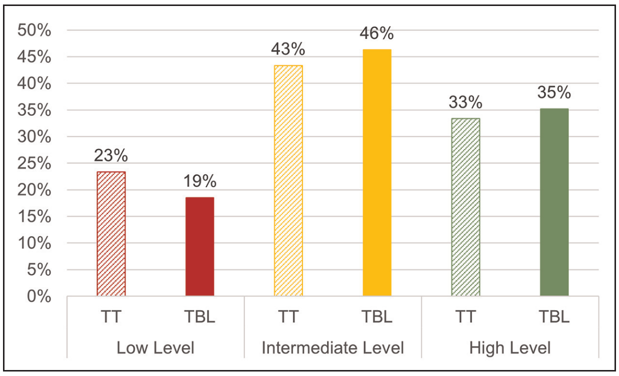

Figure 2. Percentage of students corresponding to each level.

The descriptive statistics and bivariate correlations after intervention are reported in Table 3. The scores were slightly higher for practical competence than for theoretical knowledge. The relation between theoretical knowledge and practical competence was positive after the intervention.

Differences between groups after the intervention

Differences between control and experimental groups are shown in Table 4. The results showed that the TT group had higher levels of theoretical knowledge after the intervention; however, this difference was not significant. For practical competence, the TBL group showed higher and significant levels than the TT group after the intervention.

Table 3. Descriptive statistics and bivariate correlations between study variables.

	Theoretical knowledge	Practical competence
Theoretical knowledge	–	0.239*
Practical competence	–	–
M (SD)	6.51 (2.21)	7.31 (1.83)

*$p < 0.05$.

Table 4. Differences between groups after the intervention.

	TT ($N = 49$) *M* (SD)	TBL ($N = 35$) *M* (SD)	*t*	*p*	Cohen's *D*
Theoretical knowledge	6.71 (2.26)	6.24 (2.14)	0.963	0.169	0.07
Practical competence	7.01 (1.89)	7.73 (1.67)	−1.839	0.035	0.22

Discussion

The first aim of this study was to analyse how a TBL-based experience might affect students' theoretical knowledge and practical competence in comparison with the implementation of TT within a PE context. The proposed hypotheses were partially fulfilled. On the one hand, as hypothesised, students in the experimental group showed higher scores in their practical competence after the intervention. On the other hand, no significant differences were found in theoretical knowledge in the scores after the TBL-based experience.

These findings are in line with previous studies that have found a positive association between the integration of ICT through a challenge-based learning experience and students' practical competence in PE classes. At the end of the intervention, the teacher assessed students' badminton-specific motor skills in both groups through different activities to evaluate the acquisition of skills. The increase in almost one point in the students in the TBL group could be related to the perception of competence nurtured among them by the integration of technologies. If students perceive that using ICT as part of a challenge-based learning methodology is more challenging because they can establish their own goals and receive feedback and praise for their performance, as well as instructions to foster a deeper understanding, they are more likely to enjoy and engage in the activities proposed. This fact will result in better competence and motor skills.

The present study adds interesting insights to the scarce literature by testing whether a TBL experience in PE through challenge-based learning methodology has an impact on students' academic performance. In line with the present findings, the inclusion of technologies with characteristics of a challenge-based learning methodology, such as suggesting individual progression or identifying students' interests, might be significant for the students to feel they are competent in PE classes. These findings are in keeping with existing studies that suggest that perceived competence might be related to the learning process.[27–29] These authors pointed out that the promotion of active participation through the use of technologies, and the provision of choice in the form of a challenge-based learning methodology might improve significant learning and, in turn, strengthen their perceptions of competence, which may be also related to students' engagement. Therefore, the fact that this pedagogical approach (challenge-based learning) fosters the clear establishment of evaluation processes or the provision of optimal challenge,[30–32] might explain how this methodology is more likely to promote feelings of competence among students than the TT methodology.

Accordingly, it has been suggested that the implementation of technologies can promote not only skills and knowledge about the task,[6] but also enjoyment, motivation and engagement.[33,34] In other words, the inclusion of ICT combined with certain CBL features could be effective tools for improving students' engagement, which is related to their perception of competence and, consequently, with their skill levels. Different authors have already pointed out the positive association between students' engagement and other performance and learning outcomes.[35,36] When teachers appreciate, encourage and enthusiastically invite students' initiative, students are more likely to respond in kind and become more willing to participate in activities.[37–39] In this study, it is plausible to think that the provision of optimal challenges and clear guidance might make students more likely to be active, participate and follow the teachers' instructions or put more effort into their tasks. Given the positive association between technologies, the challenge-based learning approach and learning outcomes,[27,28] it is possible to highlight the potential of ICT for improving educational processes.

This experience represents an interesting ICT approach to an innovative pedagogical model that integrates a challenge-based learning approach, and it has been shown to improve different motivational outcomes in physical education with university students.[25] Although there are still many restrictions in most schools regarding students' use of ICT, the existing literature highlights the mobile phone as a valid methodological resource for promoting learning, motivation and academic performance in both educational and PE contexts.[40] However, the literature is still scarce in studies that analyse the effects of integrating technology in PE contexts following an experimental design.

Limitations and future lines of research

This study has some limitations worthy of note. A first limitation concerns the sample size of both the control and experimental groups. The small group sizes were due to the difficulties inherent to conducting an intervention study in a PE context. It would be interesting to use a large sample size for future research to gain more understanding in such a current relevant topic. A second limitation relates to the use of different methodologies between the groups, the inclusion of ICT in only one of them, and the effects of using technologies on students' performance. It would be interesting for future studies to further explore whether the effect on students' performance comes from the methodology or the use of ICT. Further research to analyse the effects of TBL experiences on psychological outcomes such as motivation and engagement would also be of interest.

Conclusions

This study aimed to examine the influence of a TBL intervention on students' theoretical knowledge and practical competence in PE. The findings of the study highlight the TBL model's potential to foster students' competence and suggest that students might improve their badminton-specific motor skills when implementing this methodology. Overall, the work suggests that embracing the key features of TBL through a challenge-based learning approach can be a promising avenue for improving PE contexts from an academic perspective.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This publication is part of the I + D + I project PID2020-114051RA-I00 funded by MCIN/AEI/ 10.13039/501100011033 and the project PP2021_03 funded by Universidad Pontificia Comillas.

ORCID iD

Evelia Franco https://orcid.org/0000-0002-6713-2767

References

1. Roig R. Innovación educativa e integraciónde las TIC: un tándem necesario en la sociedad de la información. In: Roig R and Fiorucci M (eds) *Claves para la investigación en innovación y calidad educativas: la integración de las tecnologías de la información y la comunicación y la interculturalidad en las aulas*. Alcoy: Marfil, 2010, pp.329–340.
2. Juniu S. Pedagogical uses of technology in physical education. *J Phys Educ Recreat Dance* 2011; 82: 41–49.
3. Gawrisch DP, Richards KAR and Killian CM. Integrating technology in physical education teacher education: a socialization perspective. *Quest* 2020; 72: 260–277.
4. Palao JM, Hastie PA, Cruz PG, et al. The impact of video technology on student performance in physical education. *Technol Pedagogy Educ* 2015; 24: 51–63.
5. Zhou Y, Shao WD and Wang L. Effects of feedback on students' motor skill learning in physical education: a systematic review. *Int J Environ Res Public Health* 2021; 18(12): 6281.
6. Ferriz-Valero A, Østerlie O, García Martínez S, et al. Gamification in physical education: evaluation of impact on motivation and academic performance within higher education. *Int J Environ Res Public Health* 2020; 17(12): 4465.
7. Fernandez-Rio J, de las Heras E, González T, et al. Gamification and physical education. Viability and preliminary views from students and teachers. *Phys Educ Sport Pedagogy* 2020; 25: 509–524.
8. Cheng F and Yin Y. Application of computer data analysis technology in the development of a physical education examination platform. *Int J Emerg Technol Learn* 2019; 14: 75–86.
9. Hinojo Lucena FJ, López Belmonte J, Fuentes Cabrera A, et al. Academic effects of the use of flipped learning in physical education. *Int J Environ Res Public Health* 2020; 17(1): 276.
10. Batez M. ICT skills of university students from the faculty of sport and physical education during the COVID-19 pandemic. *Sustainability* 2021; 13(4): 1711.
11. Legrain P, Gillet N, Gernigon C, et al. Integration of information and communication technology and pupils' motivation in a physical education setting. *J Teach Phys Educ* 2015; 34: 384–401.
12. Phillips A, Rodenbeck M and Clegg B. Apps for physical education: teacher tested, kid approved! *Strategies* 2014; 27: 28–31.
13. Eberline AD and Richards KAR. Teaching with technology in physical education. *Strategies* 2013; 26: 38–39.
14. Botella GA, Garcia-Martinez S, Garcia MN, et al. Flipped learning to improve students' motivation in physical education. *Acta Gymnica* 2021; 51: 1–8.
15. Lin Y-N, Hsia L-H and Hwang G-J. Fostering motor skills in physical education: a mobile technology-supported ICRA flipped learning model. *Comput Educ* 2022; 177: 104380.
16. Trabelsi O, Souissi MA, Scharenberg S, et al. YouTube as a complementary learning tool in times of COVID-19: self-reports from sports science students. *Trends Neurosci Educ* 2022; 29: 100186.

17. Friskawati GF and Supriadi D. Video analysis with YouTube platform for physical education, health, and recreation student's higher order thinking skills (HOTs). *J Sport Area* 2022; 7: 96–103.
18. Firmansyah G and Hariyanto D. QR code based teaching materials for organizational classes and game systems. *J Phys Educ Health Sport* 2019; 6: 6–10.
19. Sarruge CL, Ginciene G and Impolcetto FM. Teaching the logic of volleyball: a proposal from teaching games for understanding and the use of technologies. *Movimento* 2020; 26: e26006.
20. Gil-Arias A, Claver F, Práxedes A, et al. Autonomy support, motivational climate, enjoyment and perceived competence in physical education: impact of a hybrid teaching games for understanding/sport education unit. *Eur Phys Educ Rev* 2018; 26: 36–53.
21. Pérez-Muñoz S, Sánchez Muñoz A, De Mena Ramos JM, et al. Mario and Sonic at the Olympic games: effect of gamification on future physical education teachers. *Appl Sci* 2022; 12(19): 9459.
22. Leijon M, Gudmundsson P, Staaf P, et al. Challenge based learning in higher education: a systematic literature review. *Innov Educ Teach Int* 2021; 59: 609–618.
23. Simón-Chico L, González-Peño A, Hernández-Cuadrado E, et al. The impact of a challenge-based learning experience in physical education on students' motivation and engagement. *Eur J Investig Health Psychol Educ* 2023; 13(4): 684–700.
24. Nichols M, Cator K and Torres M. *Challenge based learning guide*. Redwood City, CA: Digital Promise, 2016.
25. Franco E, Martínez-Majolero V, Almena A, et al . Efectos de una experiencia de aprendizaje basado en retos para la enseñanza deportiva en alumnos universitarios. In: Gázquez JJ, Molero MM, Martos A, et al. (eds) *Investigación en el ámbito escolar Nuevas realidades en un acercamiento muldimensional a las variables psicológicas y educativas*. Madrid: Dykinson, 2020, pp.399–414.
26. American Psychological Association. *Ethical principles of psychologists and code of conduct (Amended August 3, 2016)*. Washington, DC: American Psychological Association, 2002.
27. Ojasalo J and Kaartti V. Fostering learning with challenge-based innovation in higher education: case CERN Bootcamp. *CERN IdeaSquare J Exp Innov* 2021; 5: 11–21.
28. Ogbuanya T, Okeke C and Hassan A. Effects of challenge-based and activity-based learning approaches on technical college students' achievement, interest and retention in woodwork technology. *Int J Res Bus Soc Sci* 2021; 10: 330–341.
29. Gallagher SE and Savage T. Challenge-based learning in higher education: an exploratory literature review. *Teach High Educ*. Epub ahead of print 26 December 2020. DOI: 10.1080/13562517.2020.1863354.
30. Almolda-Tomás FJ, Sevil J, Julián Clemente JA, et al. Aplicación de estrategias docentes para la mejora de la motivación situacional del alumnado en Educación Física. *Electron J Res Educ Psychol* 2014; 12: 391–418.
31. Franco E and Coterón J. The effects of a basic physical education intervention to support the satisfaction of basic psychological needs on the motivation and intentions to be physically active. *J Hum Kinet* 2017; 59: 5–15.
32. Kirby S, Byra M, Readdy T, et al. Effects of spectrum teaching styles on college students' psychological needs satisfaction and self-determined motivation. *Eur Phys Educ Rev* 2015; 21: 521–540.
33. Casey A and Jones B. Using digital technology to enhance student engagement in physical education. *Asia Pac J Health Sport Phys Educ* 2011; 2: 51–66.
34. Chiu TKF. Applying the self-determination theory (SDT) to explain student engagement in online learning during the COVID-19 pandemic. *J Res Technol Educ* 2022; 54: S14–S30.
35. Skinner E, Furrer C, Marchand G, et al. Engagement and disaffection in the classroom: part of a larger motivational dynamic? *J Educ Psychol* 2008; 100: 765–781.
36. Fredricks JA, Filsecker M and Lawson MA. Student engagement, context, and adjustment: addressing definitional, measurement, and methodological issues. *Learn Instr* 2016; 43: 1–4.
37. Reeve J, Cheon SH and Yu TH. An autonomy-supportive intervention to develop students' resilience by boosting agentic engagement. *Int J Behav Dev* 2020; 44: 325–338.
38. González-Peño A, Franco E and Coterón J. Do observed teaching behaviors relate to students' engagement in physical education? *Int J Environ Res Public Health* 2021; 18: 2234.
39. Leo FM, Mouratidis A, Pulido JJ, et al. Perceived teachers' behavior and students' engagement in physical education: the mediating role of basic psychological needs and self-determined motivation. *Phys Educ Sport Pedagogy* 2022; 27: 59–76.
40. López-Moranchel I, Franco E, Urosa B, et al. University students' experiences of the use of Mlearning as a training resource for the acquisition of biomechanical knowledge. *Educ Sci* 2021; 11: 479.