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Technology-Supported Physical Activity Course for Increasing Physical Activity Levels of University Students: System Development and Pilot Implementation

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Abstract This paper investigates and pilots design principles focusing on developing a technology-supported physical activity course for increasing university students' physical activity levels. Four initial design principles from a previous systematic review were confirmed and validated in a series of Focus Group discussions with twenty-two participants (10 lecturers and 12 students) from one public university in Bandung, Indonesia. As a result, an additional three initial design principles were created. A technology prototype was developed based on the seven initial design principles. A prototype LMS (PESSPA), incorporated within a smartphone application (PESAPA), was designed, validated, and built on during this phase. A pilot study was conducted involving two physical education classes at the public university in Bandung, Indonesia to test and evaluate the prototypes. Two lecturers and 39 students participated in the pilot study. One lecturer implemented the technology prototype in the intervention group (n=22). The control group (n=17) was taught with a control lecturer with the same content but without PESSPA and PESAPA for 16 weeks. Findings showed that there were no significant differences in post-test scores between the intervention and control groups in all outcomes except for amotivation (P = 0.022). Positive small to medium effect sizes were found for intervention participants, compared with control participants, for all outcomes including physical activity outcomes (moderate intensity [d=0.09], total physical activity [d=0.21], and vigorous intensity [0.37]), motivation outcomes (introject regulation [0.14], intrinsic regulation [d=0.25], identified regulation [d=0.74]), and physical activity knowledge (d=0.20). The class observations and feedback from the intervention lecturer and students during the pilot study were analysed, resulting in nine revised design principles. The prototype should be modified based on the revised design principles and tested with a larger sample size in a randomised controlled trial.

Keywords Educational Research, Learning Management System, Mobile App, Physical Education, Physical Activity, University Students

1. Introduction

The transition to university from high school is a unique and challenging phenomenon experienced by students [1]. This period coincides with an essential developmental stage, in which their brain achieves accelerated growth and is highly sensitive to stress [2], especially when experiencing transitions such as leaving home and becoming independent adults [3]. Coinciding with these changes, this period may be the final opportunity for establishing lifelong actions such as psychosocial, personal, and movement behaviours [3-5]. The latest global findings show that early and late adolescent physical activity decreases significantly with increasing age [6]. Physical activity tends to sharply decline after high school when students enter higher education settings, like universities [7-10], with this decrease particularly highlighted in first-year university students [4,11]. Another study found a significant increase in the number of first-year students who did not meet physical activity guidelines during this transition [12]. These results suggest that it is essential to promote physical activity among students within a university setting.

In response to this issue, several universities have designed a physical activity program as a mandatory course or as an elective [13-16]. For example, the US Appropriate Instructional Practice Guidelines for Higher Education Physical Activity Programs stated that the ultimate goal of a physical activity program in a university setting is "to help students gain the skills and knowledge to be physically active throughout their lives" [17]. Furthermore, empirical evidence supports that physical activity courses in the university setting improved students' motivation towards leisure-time physical activity [18,19], health-related fitness [20], and nutritional knowledge [21]. Therefore, providing a physical activity course as a tool for improving physical activity among university students is important for developing lifelong PA knowledge and behaviours.

However, it is also crucial to design, implement and maintain the quality of physical activity courses in the university setting. One potential strategy for improving the quality of university physical activity courses is the utilisation of technology as it has been shown to optimise the organisation and administration of the course [22]. From the perspective of teacher/instructor, a Learning Management System (LMS) as a pedagogical tool could be used to manage students learning, such as taking attendances, posting announcements and study materials, and managing individual and group assignments [23]. From a student's perspective, a survey conducted by Bice, Ball [24] shows that utilising technology significantly impacted university students' physical activity levels. Using technology presumably makes students more aware of their physical activity levels. Hence, using technology to support physical activity courses to increase university students' physical activity levels could be a viable option.

Our recent systematic review [19], which focused on studies incorporating technology into physical activity course-based interventions and impact on students physical activity levels, found that several types of technology optimised the learning process and increased university students' physical activity levels. Okazaki, Okano [25] and Everhart and Dimon [26] incorporated an online website; Rote [27] used wearable devices such as activity trackers; and Wang, Guo [28] used social media. The systematic review also generated four design principles for developing technology-supported university courses to increase student's physical activity levels. These are: (1) provide physical activity knowledge with extensive feedback and interaction between teachers and students; (2) utilise a simple and familiar technological device; (3) allow students to create individual goal setting, track their achievement, and receive personalised feedback from the teacher; (4) provide exercise examples that guide students to do more physical activities in their own time, independently and outside of the dedicated course time. As yet, these initial design principles have not been tested. Therefore, this paper reports on the validation of these initial design principles through focus group discussions with key stakeholders, the design of a prototype, and the evaluation of the prototype in a pilot study.

2. Materials and Methods

2.1. Research Context and Participants

This study is being conducted in one public university in Bandung, Indonesia. The physical activity course is offered to first-year or second-year students as a compulsory or as an elective course. The seven phases of the Design-Based Research (DBR) approach were adapted from the four steps of the Reeves DBR model to guide the research project [29]. The full protocol for the project has been published elsewhere [30]. The paper focuses on the validation of the initial design principles through a series of focus group discussions (FGD) (Phase 1), design of a prototype based on the initial design principles (Phase 2), and development of a pilot study to test the feasibility and acceptability of the prototype and intervention (Phase 3).

Twenty-two participants from two groups of the physical activity course were recruited into four FGD. The first FGD was with four lecturers including a: 1) lecturer who is part of the curriculum development team; 2) physical activity course coordinator; 3) senior physical activity course lecturer; 4) the Dean of the Faculty of Health and Sport Education. The second FGD had six lecturers who currently teach the physical activity course, and the third and fourth FGD was with 12 students, six each, who have completed the physical activity course previously (2020/2021). In the development process, we recruited three internal physical education experts to validate the paper-based design of the prototype. In the pilot study, we recruited two lecturers and 39 students (32 males, seven females). Participation in this study component was voluntary, and all participants were given Participant Information Statements and consented to participate. This study was approved by The University of Sydney Human Research Ethics Committee (Project No. 2021/071).

2.2. Focus Group Study

The purpose of the focus group study was to verify the four initial design principles derived from the previous systematic review [19]. The lead researcher (KS) ran all FGD in Bahasa Indonesia. Three semi-structured FGD questions were used to navigate the discussions. The FGD schedule for the first group explicitly asked about the content of the initial design principles and whether the principles were appropriate or not considering the learning outcomes and current technologies provided and supported by the university. The second FGD focused on the system and content of the course from the lecturer's perspective. The third FGD included students who had previously enrolled in and completed the physical activity course with questions focusing on the best technologies for their learning. All FGDs were conducted online using a video conferencing platform (https://zoom.us/) since face-to-face gatherings were restricted during the COVID-19 pandemic. The audio recordings were performed with the Zoom recording function and then transcribed. Thematic analysis followed the six-step approach outlined by Braun and Clarke [31]: (1) familiarising the data, (2) generating initial codes, (3) identifying themes, (4) reviewing themes, (5) deciding on theme names, and (6) producing the report.

2.3. Development

There were three main activities in Phase 2, including: 1) paper-based prototypes design; 2) expert validation; 3) building the prototypes. The LMS and mobile app paper-based prototypes were built based on the initial design principles generated from the systematic review and FGD. Three physical education experts based in Indonesia reviewed the paper-based prototype in the expert validation meeting guided by a validation rubric confirming the alignment of the user interface of the LMS and mobile app with the initial design principles. Then an IT developer was commissioned to build the LMS and mobile app based on the revised paper-based prototypes.

2.4. Pilot Study

2.4.1. Aims, Participation

The pilot study aims to implement and test the prototype from the previous phases and examine the feasibility and acceptability to inform a larger-scale randomised controlled trial to be conducted in Phase 6. Two lecturers and 45 students (38 males, seven females) were invited to participate in the pilot study. One lecturer ran the intervention class (n=26), and another lecturer ran the control class (n=19). The intervention group received 16 weeks of a physical activity course incorporating the prototype, whilst the control group received the non-technology-supported physical activity course. Both groups received the same content that was standardised by the course coordinator. This phase also includes developing the research instruments to determine validity and reliability.

2.4.2. Measures

Three primary outcomes were measured in the pre-and post-intervention. First, The International Physical Activity Questionnaire-Short Form (IPAQ) was used to measure the students’ physical activity levels. IPAQ is internationally recognised as a valid and reliable questionnaire for measuring physical activity levels [32,33]. Then, to measure students' physical activity motivation, the Behavioural Regulation Exercise Questionnaire (BREQ-2) was used, which has 19 questions using a 5-point Likert scale for responses. BREQ-2 is a valid and reliable measure of five subscales of physical activity motivation: Amotivation, External Regulation, Introjected Regulation, Identified Regulation, and Intrinsic Regulation within the university students population [34]. Lastly, to measure physical activity knowledge, we developed physical activity knowledge quizzes consisting of 20 multiple-choice questions based on the learning outcome of the physical education course. Two physical education experts reviewed the quizzes to determine whether the questions were aligned with the learning outcomes and to demonstrate construct validity. Then, test-retest reliability was performed to measure the consistency of the quizzes with 20 university students within two weeks. The coefficient correlation between test and retest was high $r=0.833$ ($P < 0.05$). The secondary outcome in the pilot study was semi-structured class observations and a fidelity check. The semi-structured class observation protocol was based on the ISO 9126 evaluation model for e-learning [35] that focuses on functionality, reliability, efficiency, usability, maintainability and portability of the prototypes that will be analysed for refining design principles. The intervention teacher reflected on each session and provided a fidelity check as to what they implemented in the online class, (e.g., whether the implementation was synchronised with the lesson plan). Another purpose of the fidelity check was to capture the lecturer's voice on the feasibility of the prototype.

2.4.3. Statistical Analysis

Descriptive statistics are presented (mean and standard deviation) for each group separately. A series of Analysis of Covariate (ANCOVAs) were used to analyse the difference between groups on all outcomes at post-test, using pre-test data as the covariate. ANCOVA adjusted for pre-test results was employed to compare the post-test results of the two groups [36]. ANCOVA was used because these models usually provide a more appropriate and informative analysis [37]. To perform ANCOVA, two assumptions were needed. Firstly, we assume that pre-test scores were not significantly different between each group. The other assumption is the homogeneity of regression slopes. All analyses were conducted using SPSS 28.0

(Chicago, IL, USA). The level of significance was set at *P* < 0.05. To demonstrate effects and trends, *Cohen's d* standardised effect sizes were calculated with values 0.2 (small), 0.5 (medium) and 0.8 (large) using Microsoft Excel [38].

3. Results

3.1. Focus Group Study

Four FGD were conducted as part of Phase 1 of the project. Thematic analysis for the FGD was conducted to confirm initial design principles from a systematic review and if needed, add new design principles. As a result of these discussions, seven initial design principles were created (see **Table 1**). An example of how the quotes were coded and linked to the sub-theme and theme is represented in **Table 2**.

3.2. Development

Phase 2 of the research was the development phase which involves developing a prototype of a technology-supported physical activity course for increasing physical activity levels of university students based on the initial design principles created from Phase 1. Three main activities were conducted in Phase 2: Paper-based prototype design, experts' validation and the building of prototype.

3.2.1. Paper-Based Prototypes Design

There were two steps in the design of the paper-based prototype: aligning design principles to prototype features (See **Table 3**) and designing the user interface based on the features required in the student mobile app and web-based lecturers' site (see **Figure 1**).

Table 1. Initial Design Principles

DP	Summary	Source
DP1	Technology-supported university courses for increasing students' physical activity levels should provide physical activity knowledge with extensive feedback and interaction between teachers and students. (19)	SR
DP2	Technology-supported university courses for increasing students' physical activity levels should utilise a simple and familiar technological device. (19)	SR
DP3	Technology-supported university courses for increasing students' physical activity levels should allow students to create individual goal setting, track their achievement, and receive personalised feedback from the teacher. (19)	SR
DP4	Technology-supported university courses for increasing students' physical activity levels should provide exercise examples that guide students to do more physical activity in their own time, independently and outside of the dedicated course time. (19)	SR
DP5	Technology-supported university courses for increasing students' physical activity levels should allow students to assess individual physical activity and fitness levels independently and receive frequent personalised feedback.	FGD
DP6	Technology-supported university courses for increasing students' physical activity levels should allow students to access the technology after they complete the course.	FGD
DP7	Technology-supported university courses for increasing students' physical activity should provide an opportunity for the inclusion of a variety of supporting tools.	FGD

Note: DP= Design Principle; SR = Systematic Review; FGD = Focus Group Discussion

Table 2. Example of FGD data analysis

No	Quote	Code	Subtheme	Theme
1	The implementation of RPS [lesson plan] is giving education about healthy lifestyles, such as what physical activities are, exercise and what physical education is, and how to differentiate between sport and physical activities. (FGD2-L4)	Physical activity knowledge	Should provide physical activity knowledge	Design principle one (DP1)

Table 3. Initial design principles alignment to prototypes feature

DP	Interpretation	Alignment to LMS features	Alignment to Mobile App features
DP1	1.1. Should provide physical activity knowledge	1.1.1. Upload physical activity knowledge in various materials: Video, Audio, Slides, Poster, Article and Review students' access	1.1.2. Access physical activity knowledge in various materials: Video, Audio, Slides, Poster, Article
	1.2. Should provide extensive feedback on physical activity knowledge	1.2.1. Create physical activity knowledge quizzes & create physical activity knowledge assignment	1.2.2. Complete quizzes & Upload/write assignment
	1.3. Should provide interaction between teachers and students on physical activity knowledge	1.3.1. Create a discussion forum	1.3.2. Access discussion forum
DP2	2.1. Should utilise a simple and familiar technological device	2.1.1. Website-based device	2.1.2. Mobile-based device
DP3	3.1. Allow students to create individual goal setting on physical activity and receive personalised feedback from the teacher	3.1.1. Review and give feedback on student's goal setting	3.1.2. Create physical activity goal setting
	3.2. Allow students to track their achievement in physical activity and receive personalised feedback from the teacher	3.2.1. Review and give feedback on student's physical activity record	3.2.2. Record GPS-based activity, aerobic activity, muscular activity, flexibility activity, and add activity manually
DP4	4.1. Provide exercise examples that guide students	4.1.1. Upload exercise example: workout video	4.2.1. Access exercise example
DP5	5.1. Allow students to assess individual physical activity levels independently and receive personalised feedback on physical activity level in the various stages throughout the course	5.1.1. Review and give feedback on student's physical activity level	5.1.2. Asses individual physical activity levels independently
	5.2. Allow students to assess individual physical fitness levels independently and receive personalised feedback on physical activity levels in the various stages throughout the course	5.2.1. Review and give feedback on student's physical fitness level	5.2.2. Asses individual physical fitness level independently
DP6	6.1. Allow students to access the technology after they graduate from the course	6.1.1. Teach students how to use technology for non-course purposes	6.1.2. Use the technology after completing the course
DP7	7.1. Provide a food diary to calculate calorie balance	7.1.1. Review/feedback on the calorie balance and food diary (healthy food/nutrition)	7.1.2. Input food diary (breakfast, lunch, etc.)

Table 4. An example of the specifically designed rubric for experts to assess the alignment of the initial design principles with features in the paper-based prototype

DP	Interpretation	Lecturers' site features	Students' app features	Outline	Score				Comments
					1	2	3	4	
DP1	1.1. Should provide physical activity knowledge	1.1.1. Upload physical activity knowledge in various materials: Video, Audio, Slides, Posters, Articles and Review students' access (how many times students access materials)	1.1.2. Access physical activity knowledge in various materials: Video, Audio, Slides, Posters, Articles	Figure 1					

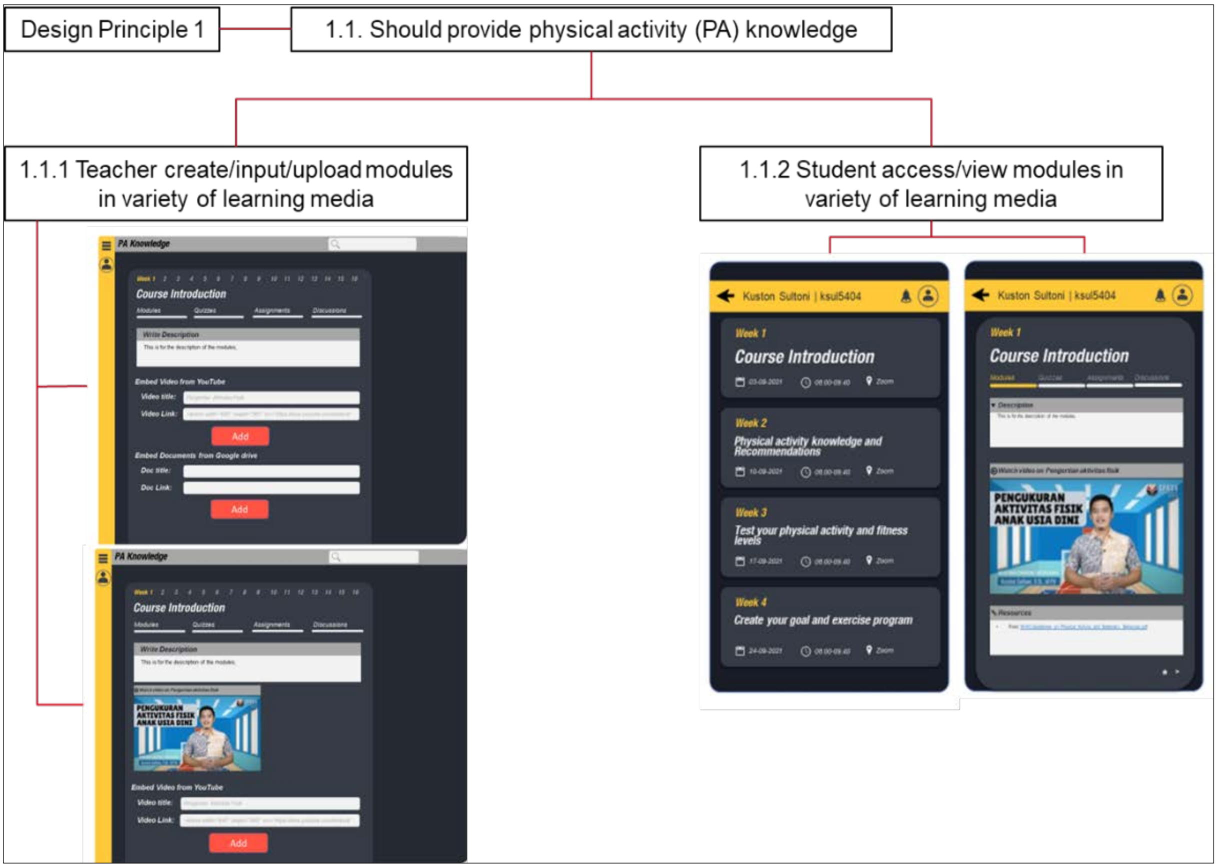

Figure 1. Example of feature alignment to the paper-based prototype of LMS and mobile app

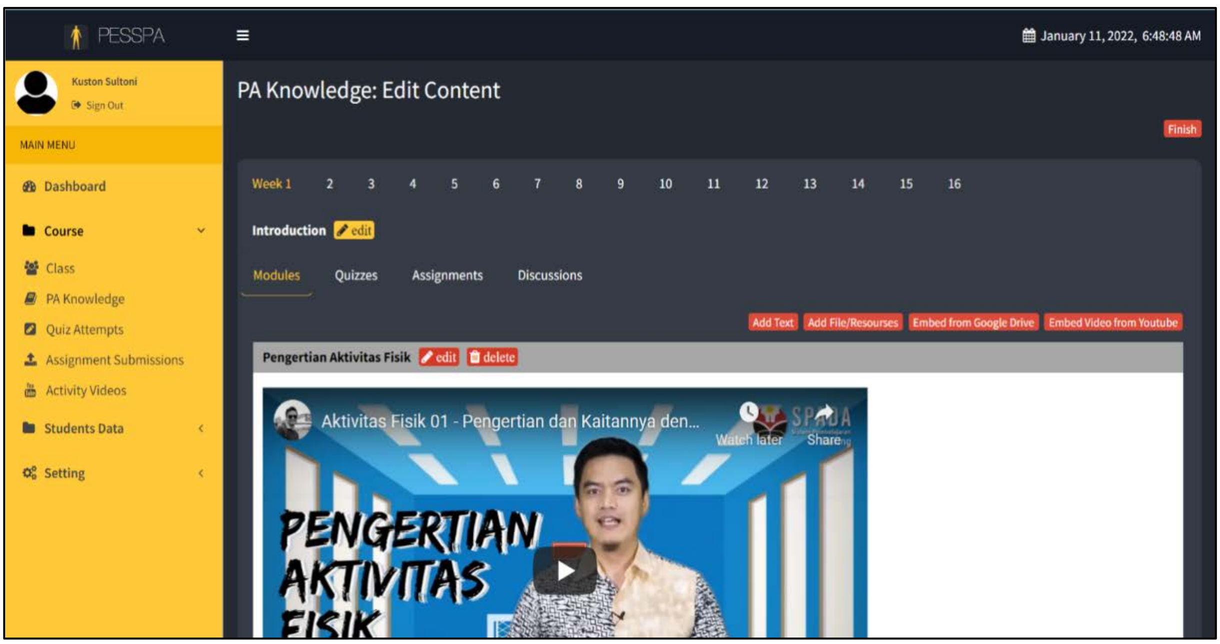

Figure 2. Screenshot of LMS features on PESSPA

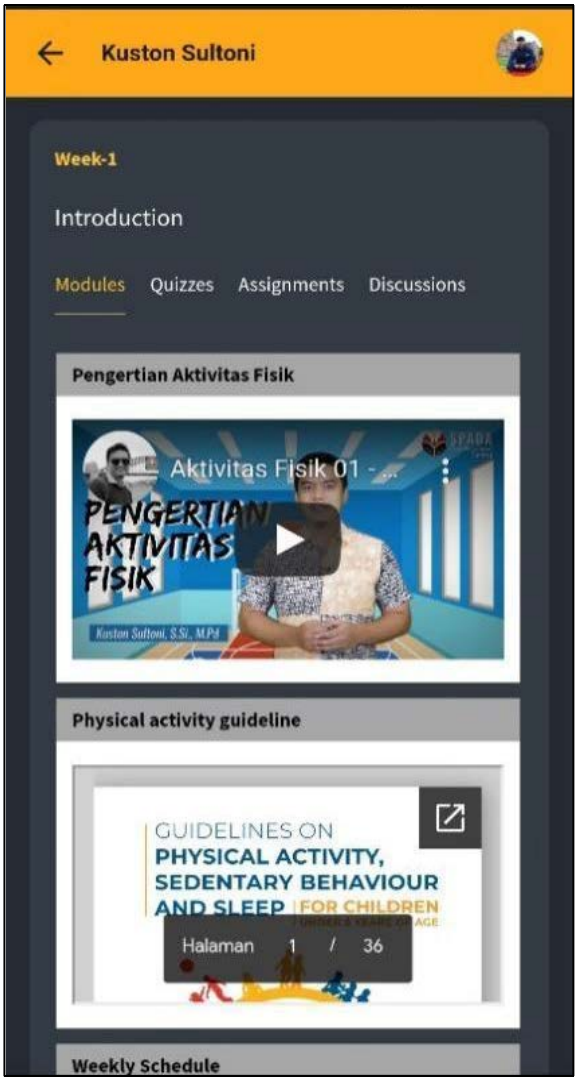

Figure 3. Screenshot of LMS features on PESAPA

3.2.1. Expert Validation

The paper-based prototype was validated by FGD with three physical education experts and a specifically designed rubric (see **Table 4**). Before completing the rubric, the three experts were given a 60-minute presentation covering the study's background, objective, and design, as well as the initial design principles and how the initial design principles were derived and embedded into the developed LMS and the developed mobile app. Following the FGD, the three experts were invited to give general comments on aligning the initial design principles to features in the paper-based prototype. After the meeting, the three experts were asked to complete the specifically designed rubric by scoring all items in the rubric (see **Table 4**) using the following criteria:

- 1=Not Acceptable (major modifications needed);
- 2=Below expectations (some modifications needed);
- 3=Meets expectations (no modifications needed but could be improved with minor changes); and
- 4=Exceeds expectations (no modifications needed).

The experts were asked to provide comments if they scored three or below. The average score for all items was 3.83, 3.00, and 3.89 from experts one, two, and three. The average from all three experts was 3.56. This indicates that the physical education experts were able to identify how specific features aligned with the initial design principles in the paper-based prototype. There were features that scored below 3. This resulted in no major modifications to the prototype. though minor improvements were made to the paper-based prototype (e.g., student's data needing to be reviewed by lecturers and the students themselves via a discussion feature).

"What does review mean? Maybe, there needs to be space (features) within the LMS for student discussion" (Expert#2 09082021).

3.2.3. Building the Prototype

After addressing the expert's feedback, an IT developer was commissioned to build the first version of the lecturer's website and the student's app based on the revised paper-based prototype. This version was built on CodeIgniter (https://codeigniter.com/), and the student's app was built on The Flutter Framework (https://flutter.dev).

The lecturers' website was entitled PESSPA (Physical Education Supporting Site for Physical Activity), while the student's app was entitled PESAPA (Physical Education Supporting App for Physical Activity). The PESSPA included the following features: (1) LMS features such as uploading course materials (text, pdf, picture, video, direct link), creating quizzes, creating assignments, creating discussions for every lesson week; (2) Reviewing student's goal settings, physical fitness test results, dietary and physical activity records; and (3) Uploading exercise examples and exercise video guidelines.

The PESAPA included the following features: (1) Access course materials (informative texts, pdfs, pictures, videos, etc.), quizzes, assignments submission, and weekly discussions; (2) Goal settings opportunities, physical fitness testing protocols, dietary and physical activity recording opportunities; and (3) Access exercise examples and exercise video guidelines.

Figure 2 shows the screenshot of the PESSPA where lecturers can manage their physical activity course, such as adding text, adding file resources, embedding files from google drive and embedding videos from YouTube. Students can access course material uploaded by lecturers via PESAPA (see **Figure 3**). These figures show only one of the features of PESSPA and PESAPA that was informed by an initial design principle.

3.3. Pilot Study

One class enrolled in the physical activity course (N=60) was invited to participate in the pilot study and was randomly assigned into two groups (i.e., intervention or control group). Since the app is Android-based, students who did not have an Android-based mobile phone in the intervention group were randomly exchanged with Android-based students in the control group. The recruitment rate was 95%. Three students in the control group declined to participate in the study. The participants' retention rate was 68%. 18 students (n=8 intervention group, n=10 control group) did not complete the course. Therefore, the number of students completing the course and pre- and post-test measurements was 39 students (n=22 intervention group, n=17 control group). (See **Table 5**).

Table 5 show the mean and standard deviation of pre-test and post-test for intervention and control group. A series of ANCOVAs were performed on the post-test scores with pre-test scores as covariate (P values were presented). Table 5 also shows that 95% confidence index (95% CI) was calculated from ANCOVAs' parameter estimates. Lastly, this table also presents the result of Cohens d intervention effect size.

3.3.1. Physical Activity Levels

As shown in **Table 5**, there were no significant differences in all physical activity post-test scores after adjusting for pre-test scores between the intervention and control groups, including Total metabolic equivalents (MET) physical activity (P=0.617), walking activity (P=0.548), moderate-intensity activity (P=0.214), as well as vigorous-intensity activity (P=0.708). Positive medium intervention effect sizes were found for vigorous-intensity physical activity (d=0.37) and total physical activity (d=0.21). Positive small intervention effect sizes were evident for moderate-intensity physical activity (d=0.09). Negative small intervention effect sizes were found for walking activity (d=-0.24).

Table 5. Mean (SD) of physical activity levels, motivation, and knowledge

Variables	**Intervention (n=22)**		**Control (n=17)**		***P***	**95% CI**	***d***
	Pre-test	**Post-test**	**Pre-test**	**Post-test**			
Physical activity levels – IPAQ (MET (min/week))							
Total (Mean (SD))	2838.7 (3002.7)	4298.8 (5606.2)	2650.9 (2383.3)	3353.2 (2646.6)	0.617	-1451.1 to 2741.48	0.21
Walking activity (Mean (SD))	917.7 (845.6)	878.8 (1189.3)	749.7 (610.2)	1156.9 (1088.1)	0.548	475.97 to 1825.78	-0.24
Moderate intensity (Mean (SD))	930.5 (1210.7)	1350.9 (1877.2)	1248.7 (1467.8)	1209.4 (1297.5)	0.214	-582.55 to 536.4	0.09
Vigorous intensity (Mean (SD))	990.5 (1544.4)	2069 (3805.7)	652.5 (969.9)	986.8 (899.1)	0.708	-949.4 to 1940.1	0.37
Physical activity motivation - BREQ-2							
Amotivation (Mean (SD))	0.52 (0.37)	0.33 (0.34)	0.65 (0.54)	0.96 (1.03)	0.02*	-0.019 to 0.899	-0.86
Intrinsic regulation (Mean (SD))	2.89 (0.78)	3.00 (0.62)	2.71 (0.64)	2.85 (0.57)	0.844	0.678 to 1.860	0.25
Identified regulation (Mean (SD))	2.86 (0.53)	3.05 (0.47)	2.66 (0.62)	2.67 (0.56)	0.086	0.586 to 2.003	0.74
Introject regulation (Mean (SD))	1.69 (0.72)	2.09 (0.86)	1.74 (0.75)	1.96 (0.98)	0.600	-0.062 to 1.385	0.14
External regulation (Mean (SD))	0.84 (0.56)	0.80 (0.63)	1.17 (0.78)	1.38 (0.94)	0.141	0.176 to 1.264	-0.74
Physical activity knowledge (out of 20)							
Score (Mean (SD))	9.76 (3.68)	13.4 (4.9)	10.5 (4.41)	12.41 (4.8)	0.207	0.184 to 7.415	0.20
Percentage (%), (Mean (SD))	48.81 (18.43)	67 (24.57)	52.50 (22.06)	62 (24)	0.207	0.920 to 37.08	0.20

*Statistically significant (p<0.05)

3.3.2. Physical Activity Motivation

After adjusting pre-test scores, students in the intervention group reported significantly lower scores in amotivation at post-intervention with a large effect size (P=0.022, d=-0.86). There were no significant intervention effects on the rest of the physical activity motivational variables, including intrinsic regulation (P=0.844), identified regulation (P=0.086), introjected regulation (P=0.600), and external regulation (P=0.141). Positive medium to large intervention effect sizes was evident for identified regulation (d=0.74). Negative medium to large intervention effect sizes was evident for external regulation (d=-074) and motivation (-0.86). Positive small intervention effect sizes were found for intrinsic regulation (d=0.25) and introject regulation (d=0.14).

3.3.3. Physical Activity Knowledge

There was a positive small intervention effect size and no significant difference in physical activity knowledge at post-test between the intervention and control groups (d=0.20; P=0.207).

3.4. Design Principles Evaluation and Refinement

The structured class observation and the fidelity check also gave extensive, meaningful, and more in-depth data on how the technology was utilised in the learning process. The structured class observation captured the lecturer' and students' comments and feedback, focusing on the LMS and mobile app used in terms of functionality, reliability, efficiency, usability, maintainability, and portability. These comments and feedback become the foundation to evaluate and revise the initial design principles using systematic evaluation. In this analysis, the seven initial design principles evolved into nine revised design principles shown in table 6.

Table 6. Revised design principles

Initial design principles	Revised design principles
DP 1: Technology-supported university courses for increasing students' physical activity levels should provide physical activity knowledge with extensive feedback and interaction between teachers and students (19).	DP 1: Technology-supported university courses for increasing students' physical activity levels should provide physical activity knowledge with extensive and interactive Learning Management System features. [Class observation, PESSPA]
DP 2: Technology-supported university courses for increasing students' physical activity levels should utilise a simple and familiar technological device (19).	DP 2: Technology-supported university courses for increasing students' physical activity levels must utilise a simple and familiar technological device. [Class observation]
DP 3: Technology-supported university courses for increasing students' physical activity levels should allow students to create individual goal setting, track their achievement, and receive personalised feedback from the teacher (19).	DP 3: Technology-supported university courses for increasing students' physical activity levels should provide automatic weekly pop-up notifications to create and review goal setting. [Class observation, PESAPA]
New Design Principle Created	DP 4: Technology-supported university courses for increasing students' physical activity levels should allow students to record their physical activity duration and calories burned, including GPS activity, moderate to vigorous-intensity aerobic activity, and step count. [Class observation, Pilot study data, PESSPA, PESAPA]
DP 4: Technology-supported university courses for increasing students' physical activity levels should provide exercise examples that guide students to do more physical activity in their own time, independently and outside of the dedicated course time (19).	DP 5: Technology-supported university courses for increasing students' physical activity levels should provide exercise examples that guide students to do more physical activity in their own time, independently and outside of the dedicated course time. [Class observation]
DP 5: Technology-supported university courses for increasing students' physical activity levels should allow students to assess individual physical activity and fitness levels independently and receive frequent personalised feedback.	DP 6: Technology-supported university courses for increasing students' physical activity levels should allow students to assess individual physical fitness levels independently. [Class observation]
DP 6: Technology-supported university courses for increasing students' physical activity levels should allow students to access the technology after they complete the course.	DP 7: Technology-supported university courses for increasing students' physical activity levels should allow students to access the technology after they complete the course. [Class observation]
DP 7: Technology-supported university courses for increasing students' physical activity should provide an opportunity for the inclusion of a variety of supporting tools.	DP 8: Technology-supported university courses for increasing students' physical activity should provide an opportunity for the inclusion of a variety of supporting tools. [Class observation]
New Design Principle Created	DP 9: Technology-supported university courses for increasing students' physical activity should be embedded in the course as class activities, assignments, and requirements. [Class observation]

Initial design principle one (DP 1) was created from a systematic review [19] and then confirmed in focus group discussions. The main idea of initial DP 1 is to provide the interactive physical activity knowledge that was represented through LMS in the prototype. The lecturer was able to upload course materials through PESSPA, including the knowledge of physical activity. Students were able to access the content through PESAPA. This LMS also provides quizzes, assignments and discussion features that intertwine interaction between lecturers and students. According to PESSPA data, the lecturer uploaded 15 texts, 11 pdfs, three videos, six links, two quizzes, eight assignments and post four discussions throughout 16 weeks course. A student's course view was 80 times on average. These data indicate that the learning process managed by the PESSPA and integrated with PESAPA worked. However, only 7 of 22 (30%) students were engaged in discussion forums created by the lecturer. Hence, the initial DP 1 will need to be modified by adding the word "interactive". Also, the phrase "learning management system" should be included in the DP 1 as most of the features utilised in the prototype are LMS features. Accordingly, revised DP 1 is now "technology-supported university courses for increasing students' physical activity levels should provide physical activity knowledge with extensive and interactive Learning Management System features".

The second initial design principle (DP 2) focuses on the technological device suggested when designing and building a technology to support the learning process in physical activity courses at university. DP 2 indicates that the technological device should be "simple and familiar". The lecturer was familiar with the website-based learning management system, and so were students with the mobile phone app. However, making the device’s operation simple was another challenge. During class observations, several difficulties or technical issues occurred in the technological device's operation. This situation seems to strengthen the DP 2 as "simple and familiar" as lecturers and students need in a technological device. Hence, the revised DP 2 is "technology-supported university courses for increasing students' physical activity levels must utilise a simple and familiar technological device".

Initial design principle three (DP 3) suggested that the technology-supported physical activity course should have goal setting, track achievement for physical activity, and receive personalised feedback from the teacher. The PESAPA prototype's goal-setting feature represents an exercise schedule for seven days in advance. The lecturer was able to demonstrate how to create goal-setting, and so students were able to generate the exercise plan. However, this feature was accessed by students only during the week of the introduction of this feature meaning that students did not use this feature again. Also, the only feedback from the lecturer on students' goal-setting was during the introduction session of this feature. Hence, more engaging goal-setting features are needed more often. For example, a feature such as an automatic weekly pop-up goal-setting review will be a reminder to students to evaluate their week. Therefore, the revised DP 3 is "technology-supported university courses for increasing students' physical activity levels should provide automatic weekly pop-up notifications to create and review goal setting tasks".

The initial DP 3 should be expanded into two separate features. The second feature of DP 3, "track their achievement", should be a stand-alone design principle. To accommodate a variety of physical activities that can be recorded via the mobile app, every possible physical activity record should be added to PESAPA. For example, type of activity, intensity, duration, calorie burned, GPS activity (walking, jogging, running, and biking), and step count. Subjective pilot study data analysis shows that students in the intervention group's physical activity levels increased between pre-test and post-test except for walking. Step count will be the additional feature of PESAPA, as suggested by previous research [39,40]. Thus, the revised DP 4 is "technology-supported university courses for increasing students' physical activity levels should allow students to record their physical activity duration and calories burned, including GPS activity, moderate to vigorous-intensity aerobic activity, and step count".

Initial design principle four (DP 4) suggested that the technology-supported physical education should provide exercise examples that guide students to exercise at home. In the pilot study, the lecturer embedded three-level aerobic exercise videos, three types of muscular strengthening workout videos, and one flexibility training video from YouTube channels to PESSPA. Students were able to access the video via PESAPA. If students performed the same exercise as the ones in the video guide, the activity intensity, duration and calories burned are automatically recorded in the PESAPA. However, students did not voluntarily use this feature. They only used it when the lecturer put this feature as an assignment. Therefore, the initial design principles are still relevant but only need encouragement to use the feature, for example, a pop-up reminder to try the exercise video. The only change for initial DP 4 is the DP's number as the previous DP split into two. Hence, DP 5 is "technology-supported university courses for increasing students' physical activity levels should provide exercise examples that guide students to do more physical activity in their own time, independently and outside of the dedicated course time".

Initial design principle five (DP 5) suggested that the technology-supported physical education should have a feature that can independently assess students' physical fitness and activity status. The prototype of PESAPA has a physical fitness test guideline feature. There are four items of field test guidelines, including PACER (aerobic fitness), Push-up, Curl-up (muscular fitness) and V-sit and reach test (flexibility). The test result will be recorded in the PESAPA, and the lecturer can access it via PESSPA. PESSPA data shows that all students used this feature in the introduction week of the feature as this was part of an assignment. The physical activity assessment will overlap with the revised DP 4, which are physical activity records. So the phrase "physical activity" was removed from this initial DP. Therefore, the revised DP 6 is "technology-supported university courses for increasing students' physical activity levels should allow students to assess individual physical fitness levels independently".

Initial design principle six (DP 6) suggested that the technology-supported physical activity course should be able to be accessed after the course is completed. However, because we used a limited server for the pilot study, the prototype of PESSPA and PESAPA was not able to be accessed after the course was completed. This indicates that an unlimited server will be needed to run the technology-supported physical activity course in the future. There is no need to refine design principles. Therefore, the DP 7 is "technology-supported university course for increasing students' physical activity levels should allow students to access the technology after completing the course".

Initial design principle seven (DP 7) suggested that the technology-supported physical education should provide an opportunity to include a variety of supporting tools. The supporting tool embedded in the prototype of PESAPA is a food diary feature that can allow students to record their food and calculate their calorie intake. This tool enables students to estimate the calorie balance between calorie intake and calorie burn. However, the PESAPA does not have visual displays to show the calorie balance. Hence, the prototype needs to be improved to optimise the feature, but the design principle does not need to be revised. Therefore, the revised DP 8 is "technology-supported university courses for increasing students' physical activity levels should provide an opportunity for the inclusion of a variety of supporting tools".

To increase students’ engagement with the prototype PESAPA, a new design principle should be added. One possible way to improve student engagement with PESAPA is to embed the features of the app in the course activity. Therefore, the new DP 9 is "technology-supported university courses for increasing students' physical activity levels should be embedded in the course as class activities, assignments, and requirements". This new design principle is supported by previous research showing that well-prepared integration of technology into the learning process is crucial [41,42].

4. Discussion

This paper reports the system development and the pilot implementation of the technology-supported physical activity course for increasing university students' physical activity levels, motivation, and knowledge. Three out of seven phases of the design-based research model [30] were discussed in this paper. The first set of results is from the series of FGD that confirmed and added to the initial design principles derived from a recent systematic review [19]. Another set of results presented in this paper focuses on developing the technology prototypes in Phase 2. Finally, this paper reports the findings from the pilot implementation of the technology prototype, leading to the refinement of design principles for future studies.

The four initial design principles generated from the recent systematic review were confirmed in all FGDs. The key stakeholders, lecturers, and students who participated in the FGDs supported the four initial design principles and suggested three more design principles. The seven initial design principles were created to inform how the prototype of a technology-supported physical activity course should be developed to increase university students' physical activity.

The pilot study found that the intervention positively influenced all outcome variables. For the physical activity levels variable, the students increased their physical activity levels between pre-test and post-test except for walking. In the initial design principle, it should be noted that the technology should include a physical activity record. The PESAPA feature also includes this physical activity feature. However a step count feature was not included for the pilot study. Step counting features as measured by pedometers can increase physical activity [39]. Fortunately, mobile phones also have a feature for step count, such as the Google Fit app that reported the highest reliability coefficient compared with accelerometers [40]. Therefore, the revised version of PESAPA will need to include a step count feature.

Despite total MET findings, the intervention group's moderate to vigorous physical activity levels increased during the course, compared with the control group (P=0.214, d=0.09; P=0.708, d=0.37). The ANCOVA showed that these results were not statistically significant. The intervention group’s motivation and physical activity knowledge scores were also not significantly different from the control group. A possible explanation might be that the control group was an active control group, who also received the physical activity course. Another possible explanation for this is a small sample size in the pilot study. Recruiting a small sample size in a trial leads to low statistically significant and high risk of inconclusive results [43,44]. Hence, the randomised controlled trial should consider sample size calculation to adequately address research questions.

The mean score of students in the intervention groups' amotivation (Mean=0.33, SD=0.34) was lower than the control group (Mean=0.96, SD=1.03). The ANCOVA showed that this result was statistically significant (P=0.022). The effect size also indicates a negative large effect size for amotivation (-0.86). This result may be explained by the fact that the intervention group received an exercise-motivation strategy (e.g., goal setting) embedded into the course, which can be practised using a mobile app outside the course time. This finding was also reported by Müftüler and İnce [45] study, which includes physical activity goal-setting in the course-based intervention. The results show that students' motivation increased after receiving the intervention.

The pilot study results show that technology-supported physical activity courses have the potential to increase university students' physical activity levels, motivation and knowledge. Based on the present findings and analysis, there are key implications of this study for a larger-scale randomised control trial. However, before a randomised control trial begins, the prototype should be modified based on the nine revised design principles presented in this paper.

This paper also presents the nine revised design principles as a result of class observations and fidelity check data analyses. Future research should consider including other data to evaluate design principles. For example, interview or focus group discussion with students after completing the technology-supported physical education course.

5. Conclusions

This paper highlights the first to four phases of a seven-phase DBR framework exploring technology-supported physical education course for increasing university students' physical activity. The goal of utilising technology in the physical activity course is to promote an active lifestyle by increasing students' physical activity levels, knowledge, and motivation. This technology aims to support the learning process and help students understand physical activity and the health benefits of performing a sufficient amount of physical activity according to physical activity recommendations, as well as planning, recording and evaluating physical activity inside and outside of class activity. In the project's next phase, we will modify the prototype based on the revised design principles and then test and evaluate the modified prototype on the three outcome variables of physical activity, motivation and knowledge. A final set of design principles will be created based on the results of the randomised control trial to guide practitioners, developers and researchers in developing future technology-supported physical activity courses aiming to increase the physical activity levels of university students.

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