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Empowering vocational students: Exploring mobile learning for sustainable high-level cognition in authentic contexts

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Abstract

Early studies show that learning with mobile devices, also known as mobile learning, improves students' learning in authentic contextual learning–i.e., learning connected to the real world. However, no empirical evidence has yet to firmly prove the effects of mobile technology on specific student skillsets such as learning scalability which means learning can be applied in various scenarios and learning sustainability which means learning can be sustained in real-world environments. Therefore, this study aims to explore the effect of learning using a mobile app called mobile Smart-Physics on learning cognitive levels, learning scalability (e.g., number of learning locations and number of experimental data), and learning sustainability (e.g., number of completed assignments). Eleventh-grade vocational high school students volunteered for this quasi-experiment and were divided into an experimental group (EG), which used Smart-Physics, and a control group (CG), which used a mobile Ubiquitous-Physics (U-Physics) app. The findings show that the EG significantly outperformed the CG concerning learning cognitive levels, learning scalability and learning sustainability. Smart-Physics features enabled the students to tackle technical and pedagogical difficulties during physical investigations in real-world environments and, in some cases, improved their task accomplishment and sustained their motivation to learn. Location awareness promoted the students' authentic experiential learning, which sharpened their ability to apply learning in real-world environments and upload more experimental data. Feedback helped the students consolidate their physics theories and practical experiences, thereby generating more learning records with meaningful multimedia content like experimental graphs, tables, and notes in various learning locations. Therefore, we encourage practitioners to use smart learning environment features in their learning tools and activity designs.

Keywords: authentic contexts, mobile learning, learning cognition, learning scalability, learning sustainability, vocational students

INTRODUCTION

In recent years, an increasing amount of research has been conducted on the adoption of authentic contextual learning–i.e., the application of learning from the real world to learning designs (Ahn & Lee, 2016; Fabian et al., 2018; Hwang et al., 2018, 2019; Liang et al., 2021; Purba et al., 2019; Shadiev et al., 2016, 2020). In the process of authentic contextual learning, students are encouraged to connect what they learn in the classroom to real-world environments from the classroom to real-world environments (e.g., surrounding school campus buildings, playgrounds or parks, and houses). Key variables in this study include learning cognitive outcomes, learning scalability, and sustainability. According to Clarke et al. (2006), Jaskyte (2008), Niederhauser et al. (2018), and Wingkvist (2009), Learning scalability and sustainability are essential components of any learning program, similar to cognitive learning outcomes. Learning scalability refers

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Contribution to the literature

- Integrating SLE features into a mobile app and applying them in authentic learning helps students achieve scalable learning.
- Guided hints can enhance the integration of theoretical knowledge with practical application in learning.
- SLE features into a mobile app to support students' physical investigations in authentic contexts enhanced the students' learning cognitive levels—especially the apply level.

to the ability of students to apply learning in real-world environments and generate more learning records that consist of experimental graphs, tables, locations, and notes (Kumpulainen et al., 2014; Lee & McLoughlin, 2007). The learning activity of the present study was designed for a smaller area (e.g., a classroom) and extended to a larger one (e.g., a campus or a school district) to help enhance the students' learning scalability. Learning sustainability refers to the ability of students to sustain their learning motivation to learn and complete learning assignments.

Previous research has extensively explored the use of mobile devices, particularly mobile apps, to support authentic contextual learning. These studies primarily focus on cognitive outcomes, categorized using Bloom's taxonomy (Ahn & Lee, 2016; Fabian et al., 2018; Hwang et al., 2018, 2019; Liang et al., 2021; Purba et al., 2019; Shadiev et al., 2016, 2020). For instance, Purba et al. (2019) developed the mobile app Ubiquitous-Physics (U-Physics), which integrated a location-awareness feature to support students to explore physics phenomena in a school and at a public park. The findings showed that the use of U-Physics in this learning design significantly influenced not only the students' cognitive levels but also their inquiry learning behaviors.

However, until now, none of these studies have solidly examined the effect of mobile devices on specific student skillsets–particularly learning scalability and learning sustainability–in real-world environments. Most existing studies have not thoroughly examined these aspects, focusing instead on cognitive outcomes without addressing the broader applicability and long-term engagement of students with the learning material.

This study addresses these gaps by investigating how smart learning environments (SLEs) can enhance learning scalability and sustainability. An SLE is defined as a learning environment that focuses on learning effectiveness, efficiency, flexibility, engagement, adaptivity, and reflectiveness (Zhu et al., 2016). It provides students with learning features–such as location-awareness, learning progress, feedback, and hints–anytime and anywhere (Hwang et al., 2014; Zhu et al., 2016). Students can identify their current location by activating the location-awareness feature on their learning device, thus promoting their learning experiences in real-world environments (Croy, 2009). This location awareness feature also helps students improve their learning scalability skillset by exploring different locations and creating more user-generated content. Smartphones offer a seamless learning experience with round-the-clock access (Hwang et al., 2018; Purba et al., 2019). Additionally, other learning features that, for instance, allow students to track their learning status or progress in real-time (Hwang et al., 2014; Liu et al., 2017), receive and give feedback (Davis & Sorrell, 1995), and obtain hints to solve problems (Khaliliaqdam, 2014) can also help students improve their learning sustainability skillset.

By filling the gaps identified in prior research, this study contributes to the growing body of knowledge on authentic contextual learning and offers insights into how technology-enhanced learning environments can better support students' educational experiences. This investigation is not a mere replication of existing work but rather an expansion that addresses previously unexplored dimensions of learning scalability and sustainability. Therefore, this study explores how the integration of SLE features in the Smart-Physics app can improve students' ability to apply learning in diverse real-world contexts (learning scalability) and sustain their motivation and engagement with learning tasks over time (learning sustainability). Unlike previous studies, this research extends beyond cognitive outcomes to address these crucial skill sets, providing a more holistic understanding of the impact of mobile devices and SLEs on authentic contextual learning. Additionally, the study examined students' learning behaviors (e.g., interpreting graphs [IG], applying formulas [AF], drawing conclusions [DC], and peer sharing) to solve everyday problems in the real world (Purba et al., 2019). Accordingly, this study aimed to test the following research questions and their hypotheses:

1. Is there any mean difference between the students who use Smart-Physics and those who use U-Physics in terms of their learning cognitive levels?

H0. There is no significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of their learning cognitive levels.

H1. There is a significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of their learning cognitive levels

2. Is there any mean difference between the students who use Smart-Physics and those who use U-Physics in terms of their learning behaviors?

H0. There is no significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of their learning behaviors.

H1. There is a significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of their learning behaviors.

3. Is there any mean difference between the students who use Smart-Physics and those who use U-Physics in terms of learning scalability?

H0. There is no significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of learning scalability.

H1. There is a significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of learning scalability.

4. Is there any mean difference between the students who use Smart-Physics and those who use U-Physics in terms of learning sustainability?

H0. There is no significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of learning sustainability.

H1. There is a significant mean difference between the students who use Smart-Physics and those who use U-Physics in terms of learning sustainability.

5. Is there any correlation between students' learning behaviors and learning cognitive levels?

H0. There is no significant correlation between students' learning behaviors and learning cognitive levels.

H1. There is a significant correlation between students' learning behaviors and learning cognitive levels.

6. Is AF a predictor of learning cognitive levels?

H0. AF is not a predictor of learning cognitive levels.

H1. AF is a predictor of learning cognitive levels.

LITERATURE REVIEW

Mobile Authentic Contextual Learning

Mobile devices can function as supporting tools when using authentic environments to promote contextual learning in various subjects, including English (Nguyen et al., 2018; Shadiev et al., 2016, 2020), mathematics (Fabian et al., 2018; Hwang et al., 2018, 2019), physics (Abu Bakar et al., 2018; Hwang & Purba, 2021; Purba & Hwang, 2018; Purba et al., 2019), and history (Liang et al., 2021). The mobile device offers a seamless learning experience, creating an authentic contextual learning environment within a familiar context rich in learning resources (Hwang, 2014; Hwang et al., 2019; Purba et al., 2019; Shadiev et al., 2016). For instance, Shadiev et al. (2016) developed an annotation mobile app that facilitated students' ability to identify English signs in real-world environments (e.g., such as the school cafeteria) anytime and anywhere. Similarly, Purba et al. (2019) developed a mobile app called U-Physics to help students explore physics phenomena around their school and houses, concluding that the use of a mobile app can indeed assist learning inside and outside the classroom. In addition, mobile devices can be equipped with multimedia tools, such as text, graphs, audio, and various sensors (e.g., acceleration sensor, gyroscope, step detector, and step counter sensors) that can help students explore and apply the knowledge being studied at schools to real world environments (Hwang & Purba, 2021; Purba et al., 2019).

The use of mobile devices has effectively promoted authentic learning, making the overall learning more interactive and information-rich (Hwang, 2014; Hwang et al., 2018; Hwang & Fu, 2020; Lee, 2022). Creating and sharing multimedia-learning content using a mobile device during authentic learning activities enhanced students' cognitive development (Kumpulainen et al., 2014; Lee & McLoughlin, 2007; Shadiev et al., 2016), thereby increasing students' learning cognitive levels (Hwang et al., 2018, 2019). It also enhanced students' learning confidence and satisfaction (Hwang et al., 2018, 2019). Moreover, authentic contextual learning experiences, which involve solving authentic problems or tasks in real-world contexts, can engage students and increase their motivation to learn. This type of learning can also promote deeper understanding and retention of material, as students are able to apply their knowledge to meaningful tasks. Additionally, authentic contextual learning can encourage students to develop and use higher-level thinking skills, such as analysis, synthesis, evaluation, and application (Lee & McLoughlin, 2007; Wang et al., 2019). The inclusion of everyday life problems in learning activities influenced students' learning behaviors (Hwang & Purba, 2021; Purba et al., 2019; Purba & Hwang, 2018).

Learning Cognition, Scalability, and Sustainability

Learning in real-world environments is rooted in authentic contexts, higher-order thinking, and collaborative interaction (Herrington et al., 2014). Students are driven to engage in learning tasks and higher-order thinking skills through the use of advanced technology (e.g., ubiquitous mobile apps) in real-world environments. Innovative technology, such as the smartphone, is an instrument of change in a challenging process that integrates complex phenomena to enhance learning scalability and sustainability (Niederhauser et al., 2018). Additionally, active-collaboration (e.g., peer sharing), opened up students' cognitive space (Shadiev et al., 2016).

Many early studies used mobile devices to support authentic contextual learning, discussing how they influenced learning cognition. However, the learning cognition data collected from these studies was usually evaluated based on pre- and post-test results, without particularly considering students' cognitive levels (Hwang et al., 2018, 2019; Liang et al., 2021; Purba et al., 2019; Shadiev et al., 2016, 2020). According to Anderson and Krathwohl (2001), there are six cognitive levels of students:

(1) remembering refers to retrieving relevant knowledge from long-term memory,

(2) understanding refers to constructing meaning,

(3) applying refers to carrying out or using a procedure in a given situation,

(4) analyzing refers to examining and breaking information into parts by identifying motives or causes,

(5) evaluating refers to presenting and defending opinions by making judgments about information, and

(6) creating refers to compiling information in a different way by combining elements in a new pattern or proposing alternative solutions.

The remembering and understanding levels are classified as low-level cognitive processes, while the applying, analyzing, evaluating, and creating levels are high-level cognitive processes. Crossing the chasm between the understanding and applying levels is a challenging process for students (Hwang et al., 2014), as it requires them to move beyond simply memorizing concepts in abstract and artificial situations toward experiencing concepts in ways grounded in reality (Newmann, 1995). Therefore, in this study, students' learning cognitive levels consisted of the remembering, understanding, and applying levels.

Besides these cognitive levels, learning scalability and sustainability are important in the learning programs (Clarke et al., 2006; Jaskyte, 2008; Niederhauser et al., 2018; Wingkvist, 2009). As previously mentioned, in this study, learning scalability refers to the number of learning locations explored by the students and the number of generated learning records successfully uploaded to an online database. Meanwhile, learning sustainability is the ability of the students to maintain their motivation to learn and complete the learning assignments (Shadiev, 2007). The learning progress feature of Smart-Physics app allows the students to track the progress of their work from one learning assignment to another. Tracking student progress can help students to see their progress and accomplishments, which can increase their motivation and confidence. It can also help teachers to identify areas of strength and weakness, and to tailor their instruction to better meet the needs of individual students (Sanders-Littleton, 2013). Therefore, students' continuous tracking of their learning progress and engagement in a greater number of learning activities helps foster their learning sustainability (Dewey, 1986).

Learning scalability and sustainability information could be potentially obtained with the emergence of the SLE. SLE is a physical environment enriched with digital, context-aware, and adaptive devices to promote better and faster learning (Koper, 2014). Integrating a location awareness feature (e.g., a map location) in a mobile app has helped students easily seek more physics phenomena in authentic contexts by allowing them to view each other's locations on a map (Purba et al., 2019) and track their location history (Lu & Arikawa, 2013; Nguyen et al., 2018). Additionally, Liu et al. (2017) emphasized the importance of providing students with a mobile app that can automatically provide feedback on the results of an assignment; offer hints, clues, or answers to difficult problems; and record students' learning progress or completion. This aids teachers in providing targeted instruction and personalized guidance based on their students' individual needs. The use of a mobile app equipped with SLE features thus makes learning more effective, efficient, and engaging (Hwang, 2014; Hwang & Fu, 2020), thereby improving students' learning scalability and sustainability.

Learning Behaviors in Physics Learning

Physics learning usually requires students to understand and solve related physics phenomena using experimental data, tables, graphs, pictures, and formulas. Physics learning should be delivered via two-way teaching, where teachers give students greater opportunities to directly interact with the phenomena being studied and evaluate their understanding by asking them to solve real-life problems (Ng & Nguyen, 2006). The use of real experiments and everyday problem-solving in physics learning can stimulate students' interest in understanding physics concepts (Hırça, 2017), thus affecting their overall motivation and achievement (Purba & Hwang, 2017, 2018; Wang et al., 2015), as well as enhance their cooperation with peers (Authors, 2019).

When investigating physics phenomena in everyday environments, students employ several learning behaviors that may support them in the investigation process (Purba et al., 2019). The first of these behaviors is *IG*. A graph is a common method used to visually illustrate relationships data. IG is students' ability to interpret the graphs (Purba & Hwang, 2017, 2018) and a basic physics-learning skill. The second behavior is *AF*–that is, the ability to use formulas (Purba & Hwang, 2017, 2018). The third behavior is *DC*–i.e., the ability to accept or reject a hypothesis (Purba & Hwang, 2018; Purba et

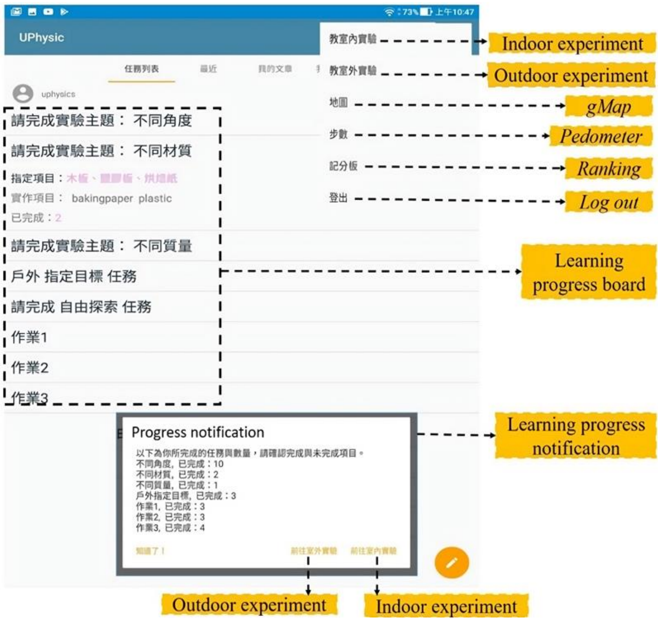

Figure 1. Interface of the Smart-Physics app (Source: Authors' own elaboration)

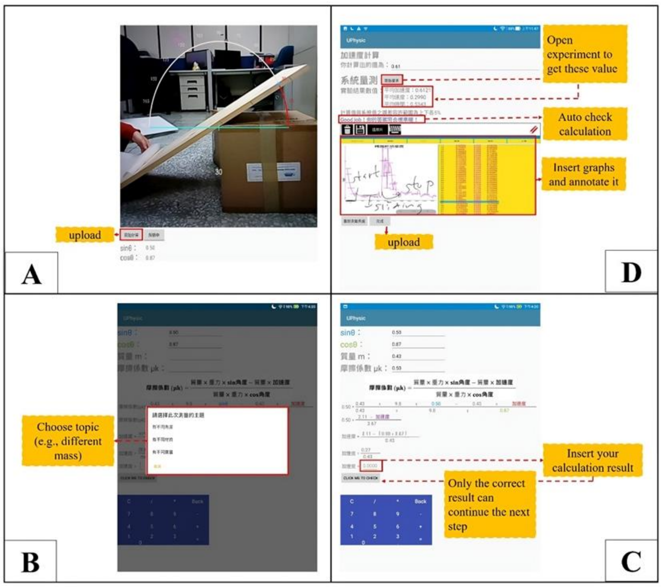

Figure 2. Learning steps of an indoor experiment using the Smart-Physics app (Source: Authors' own elaboration)

al., 2019). The fourth behavior, *peer sharing*, consists of *students' posts and comments* on a discussion board of Smart-Physics app (Purba et al., 2019), which, in turn, invite reflection and enhance high-level thinking and learning motivation (Joksimović et al., 2015; Novakovich, 2016). These posts are beneficial because they enable students to correct each other's mistakes and improve their problem-solving and critical thinking (Novakovich, 2016).

The U-Physics app (Purba et al., 2019) was adopted and upgraded into a new version called Smart-Physics. In 2019, the authors examined the learning differences and inquiry behaviors of the students who used U-Physics and those who used traditional stopwatch to complete physics experiments in and outside of the classroom. The study found that the use of U-Physics app in authentic environments positively enhanced cognitive and affective aspects of learning. The similarity and difference between U-Physics app and Smart-Physics app is shown in **Table A1** in **Appendix A**. Smart-Physics was integrated accessible SLE features, such as location awareness, learning progress, feedback, and hints. The location-awareness feature was embedded in a guided learning map (gMap). The learning progress, feedback, and hints features were integrated via the addition of new functions, such as a learning progress board, learning progress notifications, an automatic calculation check, and learning hints. The interface of Smart-Physics is shown in **Figure 1**. The student's learning progress appears on the screen upon login, notifying them of their current total of completed experiments. To check the details of unfinished or finished assignments, students can access the learning progress board. Additionally, the indoor feature can be used to activate the experimental measurement in indoor settings (e.g., classrooms and laboratories), as shown in **Figure 2**.

Using Smart-Physics, the students measured the angle of an inclined plane (part A in **Figure 2**) and chose an experimental topic (e.g., different mass, different angles, or different surface material) (part B in **Figure 2**). The app automatically asked the students to recalculate their results or repeat the experiment if incorrect results were inserted (part C in **Figure 2**). They then clicked on the measurement button, slid a tablet on an inclined plane, and collected the experimental data. Once this was completed, the app automatically checked the error values between calculated results using physics formulas and recorded results from the sliding tablet (part D in **Figure 2**). This automatic calculation-check function can be used to check calculation formulas and error values between a theory (i.e., a physics formula) and a real experiment (i.e., a sliding tablet). Students can record acceleration, velocity, and time data by clicking the 'start' button, with the 'stop' button used to end the recording (**Figure 3**). Clicking on the 'graph' button displays a graph; clicking on the 'table' button displays a table. Students can mark the start and end points of the graph to find the average value of an inclined plane variable. Additionally, they can insert graphs or tables (part D in **Figure 2**) as well as mark the start time, sliding period, and stop time on the graphs. The 'upload' button can be used to directly upload the experiment information (e.g., graphs and tables) to an online database.

The outdoor feature is used to activate and start the measurement of an inclined plane in outdoor settings (e.g., parks and houses). It is directly linked to the 'gMap' button (**Figure 4**). The function consists of a preset activity (part A in **Figure 4**) and free exploration activity (part B in **Figure 4**). As shown in **Figure 4**, each

Figure 3. Interface of the measurement button (Source: Authors' own elaboration)

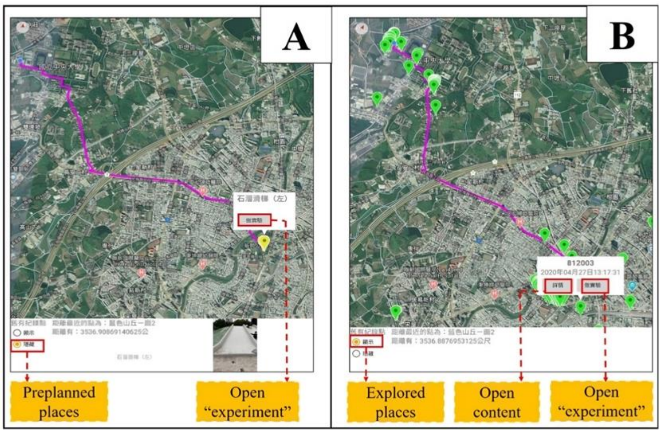

Figure 4. Interface of the outdoor experiment (Source: Authors' own elaboration)

preset place was marked on gMap as a location that allows students to access the 'measurement' button by clicking the corresponding yellow marker on the gMap. The free exploration activity (**Figure 4**) allowed students to explore their surroundings without limitations. It was marked on the gMap, giving students access to the experiment content by clicking the corresponding green marker or the ability to directly conduct an experiment by clicking the measurement button (**Figure 4**).

The gMap helped the students find recommended places based on other students' markers. A 'learning hint' was provided for students when commenting on their peers' posts, drawing a conclusion for each inclined plane experiment, posting experimental data on a discussion board, and doing homework. The hints also appeared when students commented on posts (e.g., Do you recognize any differences between your results and previous records? If yes, what is the difference? Why is it different?).

METHOD

Participants

One 11th-grade class of vocational high school students (n = 34, 16-17-years-old) majoring in English volunteered to participate in a quasi-experimental design (Punch & Oancea, 2014) and divided into two groups using a purposive sample method. Eighteen students were assigned to the experimental group (EG), which used the Smart-Physics app, while 16 students were assigned to the control group (CG), which used the U-Physics app (Purba et al., 2019). The physics teacher reported that the students, as English majors, seldom performed physics experiments and would thus be likely to struggle with the task. Besides, in this study, a physics course is allocated for 50 minutes a week and is not the main course for vocational high school students.

Research Procedure

The research procedure is shown in **Figure 5**. The experiment was conducted within 10 weeks (one lesson, 60 minutes per week). Pre-tests were distributed to students at the beginning of the study. The researchers then introduced an inclined plane experiment and trained both groups to use the apps over one lesson.

The students used the next two lessons to conduct inclined plane experiments in a classroom setting and then find and conduct inclined plane experiments in specific locations chosen by the physics teacher. Certain inclined-plane positions were tested several times to find their standard values (e.g., coefficient fraction, acceleration, and velocity).

The students used the next three lessons to freely find and conduct as many inclined plane experiments as possible around public parks near the school. They completed any incomplete assignments in the eighth week. The first, second, and third homework assignments required students to find and conduct inclined plane experiments in their homes as well as public areas. They were then asked to post their experimental results on a discussion board via the app. The groups then completed a post-test in the ninth week. The EG students were required to complete questionnaires related to scalability and sustainability in the final week of the experiment.

Research Variables

This study investigated several research variables, such as learning cognitions and learning behaviors during and after school. The learning cognitions included *remembering*, *understanding*, and *applying* levels of Bloom's taxonomy. The learning behaviors consisted of IG, AF, DC, and peer sharing (posts and comments).

Research Instruments and Tools

The Smart-Physics and U-Physics apps were distributed to the EG and CG, respectively. The pre- and post-test questions were adopted from Authors (2019) and discussed with the physics teacher. There were 15 multiple-choice questions in each test (five questions related to *remembering*, five questions related to *understanding*, and five questions related to *applying*),

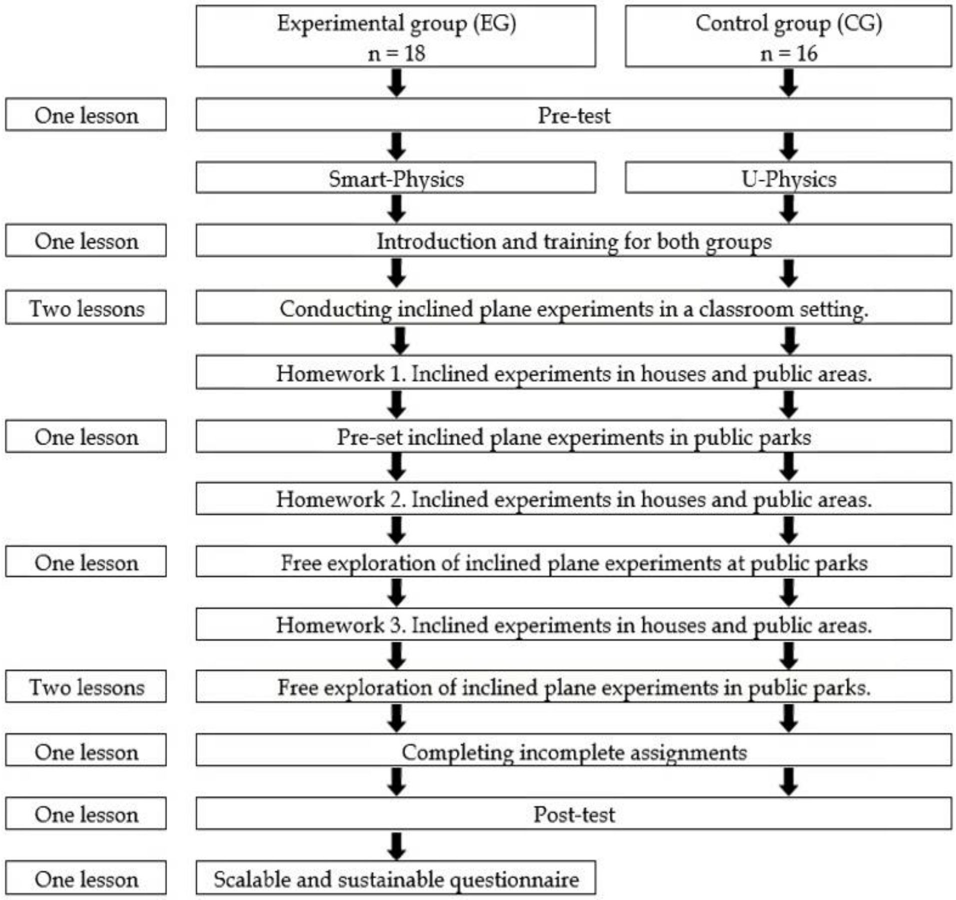

Figure 5. Research procedure (Source: Authors' own elaboration)

resulting in a maximum score of 30 points for each test. The difficulty levels of the pre- and post-test were identical (**Figure B1** in **Appendix B**).

The physics teacher and researchers collaboratively designed homework assignments (n = 3), in-class assignments (n = 3), and park assignments (preset and free exploration assignments, n = 4). All assignments were integrated in Smart-Physics, and the researchers provided the students with paper-based guidance for each week (see example in **Figure C1** in **Appendix C**). Two raters evaluated the students' learning assignments according to the rubric by Purba et al. (2019). The inter-rater reliability achieved a Cohen's kappa value of 0.856, indicating an acceptable reliability (Taherdoost, 2016). A total of 18 students from EG responded to a scalable and sustainable questionnaire that was adopted from (Hwang et al., 2021). The questionnaire used five Likert-scale ranging from 1 = strongly disagree to 5 = strongly agree. The scalable dimension consists of item 1 and item 2 and the sustainable dimension consists of item 3, 4, and 5. The obtained value if each questionnaire item was higher than the Pearson critical value, which means it was a valid item. The Cronbach's alpha of scalability, sustainability, and overall questionnaires were 0.737, 0.860, and 0.854, respectively. These indicated that the scalability, sustainability, and overall questionnaires were high reliability (0.70-0.90) (Taherdoost, 2016).

Learning Activities

The in-class activity asked the students to conduct inclined plane experiments in the classroom setting, aiming to familiarize them with the app before they explored outdoor environments. The inclined plane equipment was configured with boxes and boards. Most of the time, the students had to follow the teacher's instructions to conduct the experiments. While in the pre-set activity, free exploration, activity, and homework activity, students were expected to explore outdoors to identify and investigate real inclines, which could be located in areas surrounding the school, their homes, or public parks. Students can enjoy greater flexibility in selecting the locations they wish to explore, which encourages them to be more independent and engage in discussions on their own.

The preset activity asked the students to conduct inclined plane experiments in a specific place chosen by the teacher at a public park during school hours. The inclined plane phenomenon was tested and had standard values (e.g., acceleration, angle, friction coefficient, and velocity value). The inclined plane was a static inclined plane phenomenon.

The free exploration activity required the students to explore inclined plane phenomena (e.g., sliders and ramps) and conduct as many experiments as possible at parks during school hours. The students had more freedom to decide these investigation locations, facilitating their independence, empowerment to learn on their own, and discussions among each other. Once they clicked the measurement button, the app would record the students' location.

The homework activity required the students to find inclined plane phenomena around their homes (inside or outside) and conduct inclined plane experiments after school hours. This activity aimed to extend the application of the students' knowledge from school to outside school–from small areas to broad areas. It is important to note that in this study, the effects of wind on the results were not considered when students did the physics experiments outside the classroom.

Quantitative Approach for Data Collection and Statistical Analysis

The pre- and post-test were collected in handwritten form (on paper) and analyzed using analysis of variance (ANOVA) and analysis of covariance (ANCOVA) analyses. The results of the Shapiro-Wilk test show that for the pre-test group, the test statistic was found to be W = 0.959 (df = 34, $p > .05$), while for the post-test group, the test statistic was W = 0.948 (df = 34, $p > .05$). These p-values indicate that, based on the Shapiro-Wilk test, there is no significant evidence to reject the assumption of normality for either group's data distribution. This implies that the data in the pre- and post-test can be assumed to follow a normal distribution for the purposes of statistical analysis. The p-value of 0.043 obtained from the linearity test between the pre- and post-test scores suggests the significance of the linear relationship between these two variables. The Levene test results for both the pre- and post-test groups reveal Levene statistics of 0.007 (df = 1, 32, $p > .05$) and 0.015 (df = 1, 32, $p > .05$), respectively, indicating no substantial evidence to reject the null hypothesis of equal group variances. Consequently, subsequent analyses such as ANOVA and ANCOVA can proceed. The learning behaviors, created content, learning places, and learning accomplishments were collected online via the apps and analyzed using an independent t-test to determine group differences in learning behaviors, scalability, and sustainability. The correlations between the learning behaviors and learning cognitions were further analyzed using a Pearson analysis. The p-value of 0.001 for the linearity test between total post-test scores and AF demonstrates a significant linear relationship. Additionally, a p-value of 0.044 for the linearity test between understanding and posts, as well as another p-value of 0.001 for the linearity test between applying and comments, also indicates significant linear relationships in these cases. The Shapiro-Wilk test results indicate that the post-test (W = 0.907, df = 18, $p > .05$), understand (W = 0.920, df = 18, $p > .05$), apply (W = 0.917, df = 18, $p > .05$), AF (W = 0.917, df = 18, $p > .05$), posts (W = 0.915, df = 18, $p > .05$), and comments (W = 0.931, df = 18, $p > .05$) variables conform to a normal distribution. Homoscedasticity, which refers to the equal variance of residuals, is also satisfied when examining the relationships between post-test and AF, understand and posts, and apply and comments. Multiple regression analysis was then performed to identify the predictors of learning cognitions. Furthermore, mean values were utilized to assess students' responses to the scalability and sustainability questionnaire.

This study was conducted following ethical guidelines from Center for Taiwan Academic Research Ethics Education, National Central University. All participants provided informed consent, and their confidentiality was maintained throughout the study. The data collected was used solely for the purposes of this research and handled in accordance with the institution's data protection policies.

RESULT

Testing Hypotheses of Research Question 1

Before testing hypotheses of research question 1, the assumptions of variance and distribution for both pre- and post-test scores were checked. Since the assumptions were not violated, ANOVA and ANCOVA tests were subsequently conducted to test the hypotheses. According to the ANOVA analysis, **Table 1** shows no significant differences between the groups in the pre-test concerning the remembering level ($F[1, 32] = 0.040$, $p > .05$), understanding level ($F[1, 32] = 0.007$, $p > .05$), and applying level ($F[1, 32] = 0.118$, $p > .05$), indicating the groups did not differ in terms of prior knowledge.

Table 1. ANOVA analysis of the pre-test

Cognitive level	Group	N	M	SD	F	Sig.
Remember	Experimental	18	4.27	.75	.011	.916
	Control	16	4.25	.77		
Understand	Experimental	18	4.55	2.35	.007	.934
	Control	16	4.62	2.50		
Apply	Experimental	18	9.00	3.25	.118	.733
	Control	16	8.62	3.07		
Overall	Experimental	18	17.83	4.80	.040	.842
	Control	16	17.50	4.84		

Note. *p < .05; **p < .01; & ***p < .001

Table 2. ANCOVA results of the post-test

Cognitive level	Group	N	M	SD	F	Sig.	Partial eta squared
Remember	Experimental	18	4.83	.38	2.316	.138	.070
	Control	16	4.56	.62			
Understand	Experimental	18	7.11	3.08	.496	.487	.016
	Control	16	6.37	2.94			
Apply	Experimental	18	10.83	4.00	6.112	.019	.165
	Control	16	7.25	4.21			
Overall	Experimental	18	22.77	5.99	4.69	.038	.132
	Control	16	18.22	6.11			

Note. *p < .05; **p < .01; & ***p < .001

Table 3. Independent t-test results of the groups

	Learning behaviors	Groups	N	Mean	SD	Sig. (2-tailed)	t	Cohen's d
School hours	Interpreting graph	Experimental	18	13.77	2.60	.205	1.29	0.439
		Control	16	12.37	3.68			
	Applying formula	Experimental	18	12.77	2.90	.0001	4.26	1.460
		Control	16	8.12	3.51			
	Drawing conclusion	Experimental	18	10.44	3.03	.044	2.10	0.710
		Control	16	7.62	4.70			
	Posts	Experimental	18	10.66	4.39	.158	1.44	0.490
		Control	16	8.25	5.36			
	Comments	Experimental	18	6.44	2.00	.0001	6.54	2.250
		Control	16	2.12	1.82			
After-school hours	Interpreting graph	Experimental	18	1.00	.000	.296	1.06	0.330
		Control	16	.937	.250			
	Applying formula	Experimental	18	1.00	.000	.009	2.77	0.910
		Control	16	.687	.478			
	Drawing conclusion	Experimental	18	.888	.323	.0001	4.15	1.410
		Control	16	.312	.478			
	Posts	Experimental	18	.944	.235	.0001	4.32	1.430
		Control	16	.375	.500			

Note. *p < .05; **p < .01; & ***p < .001

The ANCOVA analysis presented in **Table 2** shows the groups significantly differed in the post-test (F [1, 31] = 4.69, p < .05), with the EG outperforming the CG. Hence, **H0** was rejected and **H1** was supported. There was a significant mean difference between the EG who used Smart-Physics and the CG who use U-Physics in terms of their learning cognitive levels. Specifically, both groups significantly differed regarding items related to the *applying* level (F [1, 31] = 4.69, p < .05, partial eta squared = 0.165). The partial eta squared indicated that 16.5% of the variance could be accounted for by differences among the groups. Consequently, the EG (mean [M] = 22.77, standard deviation [SD] = 5.99) obtained greater overall post-test scores than the CG (M = 18.22, SD = 6.11).

Testing Hypotheses of Research Question 2

The assumptions of variance and distribution for learning behaviors were not violated; therefore, Hypotheses of research question 2 were tested. The result of independent t-test analysis presented in **Table 3** shows that there were significant differences between the groups in terms *AF* (t [32] = 1.29, p < .001), *students' comments* (t [32] = 6.54, p < .001), and *DC* (t [32] = 2.10, p < .05) during school hours. Furthermore, the groups significantly differed in *AF* (t [32][= 2.77, p < .01), *posts* (t [32] = 4.32, p < .001), and *DC* (t [32] = 4.15, p < .001) after-school hours. Based on these significant findings, **H0** was rejected and **H1** was supported. There was a significant mean difference between EG and CG in terms of learning behaviors.

Testing Hypotheses of Research Question 3

Hypotheses of research question 3 were tested by the independent t-test analysis, comparing the means of EG and CG. The results presented in **Table 4** indicate a significant difference between the groups in terms of created content, with a t-value of 5.27 and a p-value less than .01. Additionally, there is a significant difference between the groups concerning different outdoor places, with a t-value of 4.09 and a p-value less than .001. These findings suggest that both created content and the choice of outdoor places vary significantly between the groups. Therefore, **H0** was rejected and **H1** was supported.

Table 4. Analysis of students' created content

Learning activity	CG		EG		t	Sig.
	Mean	SD	Mean	SD		
Total created content	29.37	9.93	38.27	5.27	3.31	**.0020**
Total different outdoor places	3.50	1.54	5.55	1.38	4.09	**.0001**

Note. *p < .05; **p < .01; & ***p < .001

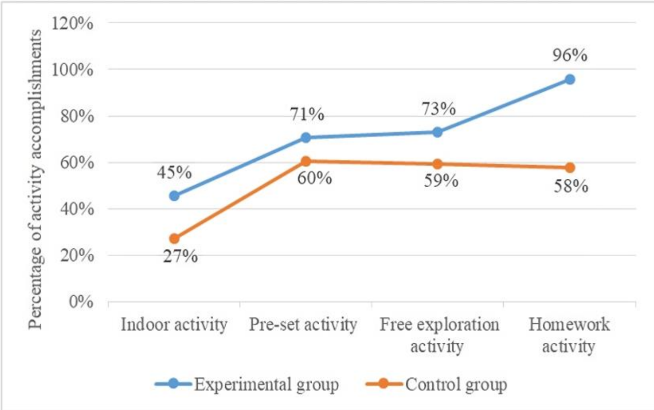

Figure 6. Analysis of the average learning progress in each activity

Testing Hypotheses of Research Question 4

In terms of the quality of assignment accomplishments, descriptive analysis presented in **Figure 6** shows that the EG's accomplishments eventually increased in each activity, whereas the CG's accomplishments eventually decreased in the last two activities. The EG sustained and increased their task accomplishment to the end of the study.

Table 5 further shows a significant difference between the groups concerning the indoor activity (t [32] = 3.36, p < .01), with the students using Smart-Physics outperforming those using the U-Physics app regarding the indoor activity for two lessons. This suggests that **H0** was rejected and **H1** was supported. With the SLEs' features, the EG was able to complete their activity meaningfully and accurately.

Figure 6 shows that the EG finished 45% of the activity, whereas the CG completed only 27%. The indoor activity was the first activity given to the students. Although the students in both groups were trained for one lesson before starting the indoor activity, some were still unfamiliar with the apps and experiments. Thus, their accomplishment percentages were below 50%.

The EG completed 71% of the learning in the pre-set activity, whereas the CG finished only 60%. There was no significant difference between the groups concerning the pre-set activity (t [32] = 1.30, p > .05). The groups were not significantly different concerning the free exploration activity (t [32] = 1.65, p > .05). The CG's accomplishment level slightly decreased to 59%, whereas the EG's accomplishment level continued to increase to 73%. Furthermore, the groups were significantly different (t [32] = 6.27, p < .001) in terms of homework, with the EG's accomplishment level increasing to 96%, while that of the CG eventually decreased to 58%. Similar results were also found in the scalable questionnaire (**Table 6**).

Table 5. Analysis of students' learning progress for each activity

Learning activity	CG		EG		t	Sig.
	Mean	SD	Mean	SD		
Indoor (2 lessons)	9.00	4.92	15.00	5.42	3.36	**.0020**
Preset (1 lesson)	11.00	5.26	13.00	2.90	1.30	**.2020**
Free exploration (3 lessons)	17.87	7.68	22.11	7.28	1.65	**.1090**
Homework	2.31	.087	3.8	.051	6.27	**.0001**

Note. *p < .05; **p < .01; & ***p < .001

Table 6. Analysis of scalable and sustainable questionnaires

No	Dimension	Items	M	SD
1	Scalability	Applying the concept of the inclined plane in my surroundings can motivate me to learn more.	3.61	0.85
2		Using the Smart-Physics app to solve inclined plane problems in my surroundings can help me remember related previous knowledge.	3.94	0.63
3	Sustainability	I will recommend the Smart-Physics app to others to explore inclined plane phenomena in their surroundings.	3.67	0.59
4		I will engage in more tasks in the Smart-Physics app to improve my understanding of inclined plane concepts in my surroundings.	3.50	1.09
5		I will engage in more tasks in the Smart-Physics app to become familiar with inclined plane phenomena in my surroundings.	3.50	0.70

Table 7. Pearson correlations of learning behaviors and learning cognitions of EG

		Total learning behaviors during school hours and after-school hours				
		IG	AF	DC	Posts	Comments
Learning behaviors						
AF	Correlation	.648**	1			
	p-value	.004				
DC	Correlation	.550*	.595**	1		
	p-value	.018	.009			
Posts	Correlation	.759**	.309	.591**	1	
	p-value	.000	.212	.010		
Comments	Correlation	.426	.644**	.270	-.119	1
	p-value	.078	.004	.278	.639	
Learning cognitions						
Overall post-test	Correlation	.381	.660**	.501*	.250	.576*
	p-value	.119	.003	.034	.318	.012
Remember	Correlation	.020	.018	-.338	-.249	.255
	p-value	.938	.945	.171	.320	.307
Understand	Correlation	.399	.424	.524*	.525*	.144
	p-value	.101	.080	.026	.025	.570
Apply	Correlation	.262	.660**	.379	-.007	.727**
	p-value	.294	.003	.121	.977	.001

Note. *p < .05; **p < .01; & ***p < .001

Table 8. Predictors of learning cognitions

Dependent variables	Predictor	B	β	t-value	R^2	Adjusted R^2	F	Sig.
Overall post-test	AF	1.36	0.66	3.51	0.435	0.400	12.33	0.003
Understand	Posts	0.36	0.52	2.46	0.276	0.231	6.096	0.025
Apply	Comments	1.45	0.72	4.23	0.529	0.500	17.97	0.001

Note. *p < .05; **p < .01; & ***p < .001

Testing Hypotheses of Research Question 5

Pearson correlation was used to test hypotheses of research question 5. The assumption to run Pearson correlation was not violated. According to **Table 7**, IG significantly correlated with AF ($r = 0.648$, $p < .01$) and DC ($r = 0.550$, $p < .05$), indicating that IG could enhance these behaviors. A significant correlation was also found between AF and DC ($r = 0.595$, $p < .01$), indicating that students who applied formulas correctly tended to draw right conclusions. Also, DC was significantly correlated with students' posts ($r = 0.591$, $p < .05$), with the implication that the right conclusions could stimulate students to share their experimental findings on the discussion board. IG was significantly correlated with the students' posts ($r = 0.759$, $p < .001$); students who interpreted graphs correctly tended to share their experimental findings on the discussion board, expressing their thoughts fluidly using verbal or visual representation. A significant correlation was found between AF and comments ($r = 0.644$, $p < .001$). Moreover, **Table 7** shows that the overall post-test scores correlated with AF ($r = 0.660$, $p < .01$), DC ($r = 0.501$, $p < .05$), and comments ($r = 0.576$, $p < .05$), with students who applied formulas correctly, drew conclusions correctly, and shared their findings on the discussion boards tending to achieve higher scores on overall post-test.

More specifically, the post-test items related to applying level were significantly correlated with DC ($r = 0.524$, $p < .05$) and posts ($r = 0.525$, $p < .05$). Drawing the right conclusions and sharing their experimental findings helped the students answer the understanding-level questions. AF significantly correlated with applying level ($r = 0.660$, $p < .01$) and applying level also significantly correlated with comments ($r = 0.727$, $p < .01$), which indicated that AF and commenting on peers' posts seemed to help them answer questions concerning applying level. These correlations provide evidence that **H0** was rejected and **H1** was supported, demonstrating a relationship between learning cognitions and learning behaviors in the EG.

Testing Hypotheses of Research Question 6

By the end of the study, a stepwise multiple regression analysis was conducted to test Hypotheses of research question 6. The results presented in **Table 8** shows AF was the most significant predictor of the overall post-test, with a 40% explanatory power in predicting the students' scores. Thus, **H0** was rejected and **H1** was also supported in research question 6. Students' posts on the discussion board had a 23% explanatory power in predicting the understanding level-related items on the post-test and students' comments had a 50% explanatory power in predicting the applying level-related post-test items.

DISCUSSION

Integrating features of the SLE in the Smart-Physics app helped the EG learn about inclined phenomena more meaningfully and reasonably. Creating and sharing meaningful learning content using mobile devices during the authentic learning activities enhanced students' cognitive developments (Shadiev et al., 2016). Creating and sharing learning content with mobile devices allows students to express their understanding in multiple ways (Kumpulainen et al., 2014; Lee & McLoughlin, 2007). The students can choose the mode (e.g., text, table, or graph) that they feel more comfortable to demonstrate their understanding, which can increase their engagement and motivation. This can lead to deeper learning and understanding, thereby causing EG students to outperform CG students in terms of learning cognition, as reflected in their post-test scores.

Particularly, when it came to applying physics formulas, EG students demonstrated a better understanding than CG students in correctly applying the formulas to solve physics phenomena. These findings might have occurred because the EG, which used the Smart-Physics app, was trained to apply physics formulas and confirm physics theories in authentic environments. The automatic calculation-check and hint functions of Smart-Physics encouraged the EG to consolidate the results from both the physics theories and real experiments. The automatic calculation-check allows the students in EG to immediately check their work and identify any mistakes they may have made. This automatic calculation-check can be particularly useful in math and science classes where calculations are an important part of understanding the material. By providing immediate feedback, an auto-check feature can help students stay engaged and on track with the material, rather than becoming frustrated or disengaged when they are unable to complete a problem correctly. Additionally, it saves students time from waiting for teacher for corrections and able to correct their mistakes in more efficient way which can help students to learn effectively (Almalki & Elfeky, 2022; Davis & Sorrell, 1995). Moreover, when students commented on another groups' work, they might have been unsure about what to mention. So, we gave guiding hints like asking them to compare their results with others'. With these hints, students crafted more relevant responses, encouraging the EG to combine physics theory and real-world experiment findings. Meanwhile, the CG, which used the U-Physics app, did not have automatic calculation-check and hint functions, resulting in an inability to consolidate the physics theories and experiments.

Furthermore, in terms of learning behaviors, students who used the Smart-Physics app were able to apply physics formulas to solve everyday problems. This is because the Smart-Physics app provides the automatic calculation-check function that can check students' AF automatically. Without correct calculations, the EG was not allowed to continue onto further steps of the experiment. Meanwhile, the CG did not have an automatic calculation-check function, which thus allowed them to complete the experiment without checking their results. Therefore, the CG made more mistakes in applying the formulas compared to the EG. Moreover, students in the EG drew more meaningful conclusions than those in the CG. This was due to the Smart-Physics app's provision of hints (e.g., 'Does a different mass influence the friction coefficient for inclined planes?'). These hints were consistently visible while the EG drew their conclusions; meanwhile, U-Physics did not provide a hint function for the CG. During school hours, the EG received help from the Smart-Physics app itself. The app provided the EG with hints for each activity, including how to post the findings, draw conclusions, comment on peers' posts, and complete the homework. Meanwhile, the CG could ask the teacher or their peers for assistance with the assignments (e.g., via face-to-face or WhatsApp, etc.). Therefore, the CG could offset the score of the EG in terms of posts during school hours.

Even after after-school hours, the EG always received hints. Hints can help students to develop their problem-solving skills by providing guidance and direction without giving away the entire solution. It also can reduce the level of frustration that students may feel when they are stuck on a problem (Khaliliaqdam, 2014). In comparison, the CG found it difficult to ask the teacher for help, since their posts were usually completed during after-school hours. Consequently, they had to finish their posts by themselves, thus unable to offset the EG in terms of posts during after-school hours. The hint function can guide students on how to comment on their peers' posts correctly and adequately. Unfortunately, we did not collect the students' comments after-school hours for both groups due to insufficient time.

Integrating SLE features in a mobile app and applying them in authentic learning helped students achieve scalable learning. Similar findings could also be gathered from the scalable questionnaire results. A plausible reason for these findings is that key SLE features were embedded in the Smart-Physics app. For instance, location awareness–integrated in Smart-Physics' gMap function–was able to guide the students in finding the positions of the inclined-plane phenomena in real time while also allowing them to check their own or classmates' experimental findings. It also promoted the students' authentic-experiential learning (Croy, 2009), thus, consequently, leading to the achievement of learning scalability via the creation of user-generated content and learning contexts. Moreover, the feedback embedded in the automatic calculation-check and error-checking functions helped the students generate more meaningful content and reasonable findings (Ahn & Lee, 2016). Specifically, it assisted the students in consolidating their physics theories and practical experiences, thereby increasing the number of created learning records and learning contexts.

Smart-Physics also provided the EG with hints guiding them in effective and efficient engagement during the learning activities (Khaliliaqdam, 2014). The EG tackled the difficulties faced in investigating the inclined plane phenomena in authentic contexts using the feedback and hint features, which motivated them to create more learning records and explore more places. In contrast, the CG lacked these features in their investigations, which reduced their interest in exploring more places, conducting more experiments, and creating more meaningful learning records.

Throughout the study, the EG continued to achieve and even enhance their task accomplishment. This was perhaps because the EG had access to SLE features that smoothly helped them accomplish each activity. The SLE features conveniently enabled these students to tackle technical and pedagogical difficulties during the real-world, inclined-plane investigations, thus improving their task performance and sustaining their learning motivation. Allowing students to track their learning progress in real time (Hwang, 2014; Liu et al., 2017) as well as providing feedback (Davis & Sorrell, 1995) and hints (Khaliliaqdam, 2014) during their learning process helped sustain their learning performances and motivation. Authentic learning activities, which mostly take place beyond the classroom and are related to daily life, can motivate students to observe and learn more (Hwang et al., 2018, 2019; Purba et al., 2019). By interacting and solving everyday problems in real-life environments, students no longer merely memorize facts in abstract and artificial situations but instead experience concepts in ways grounded in reality (Newmann, 1995). Thus EG students reported that applying physics knowledge using the Smart-Physics app in authentic contexts helped motivate them to learn more and remember their previous knowledge.

When IG, students must read the data presented and translate them to explain phenomena described (Purba et al., 2019). By doing so, they could learn how to apply and use the formulas correctly (Purba & Hwang, 2017, 2018). The students could construct long explanations to represent their conclusions using the information provided by the graphs. By interpreting the graphs, they could minimize the use of complex physical formulas. In applying the formulas, the students did not simply insert and calculate the values but had to understand the reasons for using these formulas and their meanings. The students typically clarified their peers' findings by conducting the same experiments before commenting on their peers' posts. This allowed them to practice applying the formulas more often and accurately.

Frequent, regular practicing of the ability to apply formulas enhanced the students' understanding. When AF, students need to analyze the problem, identify the appropriate formula to use, and then solve the problem. This process can help to develop critical thinking skills, such as problem-solving and reasoning. Repeatedly AF can help students to become more proficient and confident in their use. This can lead to more automaticity and fluency in their application, which is a fundamental component of mastery of a subject, thereby increasing their learning achievements. In addition, sharing of findings on the discussion board could hone the students' understanding of the inclined plane concepts.

CONCLUSION

In conclusion, hypothesis 1 of research question 1 was supported, indicating a significant mean difference in the cognitive learning levels of students using Smart-Physics compared to those using U-Physics. Hypothesis 1 of research question 2 was supported, indicating a significant mean difference in learning behaviors between students using Smart-Physics and those using U-Physics. Hypothesis 1 of research question 3 was supported, indicating a significant mean difference in learning scalability between students using Smart-Physics and those using U-Physics. Hypothesis 1 of research question 4 was supported, indicating a significant mean difference in learning sustainability between students using Smart-Physics and those using U-Physics. Hypothesis 1 of research question 5 was supported, indicating a significant correlation between students' learning behaviors and cognitive learning levels. Hypothesis 1 of research question 6 was supported, indicating that AF is a predictor of cognitive learning levels. SLE features into a mobile app to support students' physical investigations in authentic contexts enhanced the students' learning cognitive levels–especially the apply level. It also helped the students reach scalable learning (e.g., learning content and learning contexts), enhancing their accomplishments and sustaining learning motivation. Moreover, the automatic calculation-check, error-checking, and hint functions helped hone the students' ability to consolidate physics theories and practical experiences. Learning behaviors, such as AF, played the most important role in predicting the students' learning cognition.

Suggestion

Based on our findings, we strongly suggest that teachers and researchers consider the integration of SLE features in their learning tools and activity designs. Additionally, they should also encourage and give students more opportunities to sharpen their formula application skills and thereby honing students' physics theories and practical experiences.

Limitations of the Study

Several constraints were also found in this study. The findings cannot be generalized abroad due to the small sample size and the experiment's duration. The findings of the questionnaire are limited in this study since they rely entirely on EG responses and may ignore crucial insights from the CG. Therefore, a more comprehensive examination of this aspect should be considered in future studies. Besides, statistical data regarding the SLE features in this study was not collected and studied. Therefore, future studies are needed to address these issues. Specifically, they should consider larger sample sizes and perform longer-term investigations (e.g., ≥ 1 year), as these could lead to different findings. An in-depth investigation of each individual SLE feature's effect on learning cognition, scalability, and sustainability would also be worth investigating.

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APPENDIX A

Table A1. The difference between U-Physics and Smart-Physics

Description	U-Physics	Smart-Physics
Experiment button	√	√
Automatic check calculation	x	√
Discussion board		
Post including pictures	≤ 3 pictures per posting	±10 pictures per posting
Comment	Text only	Text and picture
Map	Partial	Complete
Marker/pin on the map	√	√
Route on the map	x	√
Description of the marker	x	√ (include title of assignment, date, and name of user)
Pre-planned places button	x	√
Explored places button	x	√
Hints	x	√
Learning progress board	x	√
Ranking	x	√
Pedometer	x	√
Indoor experiment button	x	√
Outdoor experiment button	x	√

APPENDIX B: EXAMPLE OF QUESTIONS FROM THE PRE-AND POST-TESTS

The example of pretest:

1. If fk= 0.98 and normal force (N) = 9.8, how is the coefficient friction (μk)?
   a. 0.01 Newton
   b. 0.1 Newton
   c. 1 Newton
   d. 9.8 Newton
2. Which factors will affect acceleration (a) in inclined plane?
   a. Mass (m)
   b. Angle (Θ) and different material/surface (μk)
   c. Weight
   d. Gravity

The example of posttest:

1. Which statement below is incorrect?
   a. Acceleration (a) will change if angle (Θ) changed.
   b. Acceleration (a) will change if material/board surface changed.
   c. Acceleration (a) will not change if mass (m) changed.
   d. Acceleration (a) will not change if angle (Θ) changed.
2. If μk= 0.2 and normal force (N) = 9.8, how is the force friction (fk)?
   a. 4.9 Newton
   b. 19.6 Newton
   c. 1.96 Newton
   d. 49 Newton

Figure B1. Example of questions from the pre- and post-tests (Source: Authors' own elaboration)

APPENDIX C: EXAMPLE OF PAPER-BASED GUIDANCE IN THE OUTDOOR ACTIVITY

Student ID: __________ /__________ Name: __________ /__________

Outdoor Experiment in public parks

Location 1:

Please tick each step when you completed it.

Step 1: take a picture first ______

Step 2: Measure the angle of inclined plane is ______ degrees

Step 3: Slide your tablet on an inclined plane experiment and fill acceleration value, velocity value, and time using Smart-Physics app ______

Step 4: Calculate the coefficient of friction ______

Step 5: Annotate your experimental graph provide using Smart-Physics ______

Step 6: Fill the description by answering following questions:

- The name of location 1 is _______ (← fill in the location name)
- Material of inclined plane is ______
- The angle of inclined plane is _____ degrees, and the acceleration is _____
- The coefficient of friction is ______

Location 2:

Please tick each step when you completed it.

Step 1: take a picture first ______

Step 2: Measure the angle of inclined plane is ______ degrees

Step 3: Slide your tablet on an inclined plane experiment and fill acceleration value, velocity value, and time using Smart-Physics app ______

Step 4: Calculate the coefficient of friction ______

Step 5: Annotate your experimental graph provide using Smart-Physics ______

Step 6: Fill the description by answering following questions:

- The name of location 2 is _______ (← fill in the location name)
- Material of inclined plane is ______
- The angle of inclined plane is _____ degrees, and the acceleration is _____
- The coefficient of friction is ______

Conclusion:

Does angle of inclined plane affect coefficient friction (uk) of sliding tablet?

Does angle of inclined plane affect acceleration of sliding tablet?

Figure C1. Example of paper-based guidance in the outdoor activity (Source: Authors' own elaboration)