Interest in physics after experimental activities with a mobile application

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DOI:
10.1007/s10763-021-10228-4

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Document Version
Peer reviewed version

Citation for published version (Harvard):
Carreño, MJ, Castro-Alonso, JC & Gallardo, MJ 2022, 'Interest in physics after experimental activities with a mobile application: gender differences', *International Journal of Science and Mathematics Education*, vol. 20, no. 8, pp. 1841-1857. https://doi.org/10.1007/s10763-021-10228-4

figure 1

Click here to access/download;colour figure;Interest in Physics After Experimental_Fig1.eps

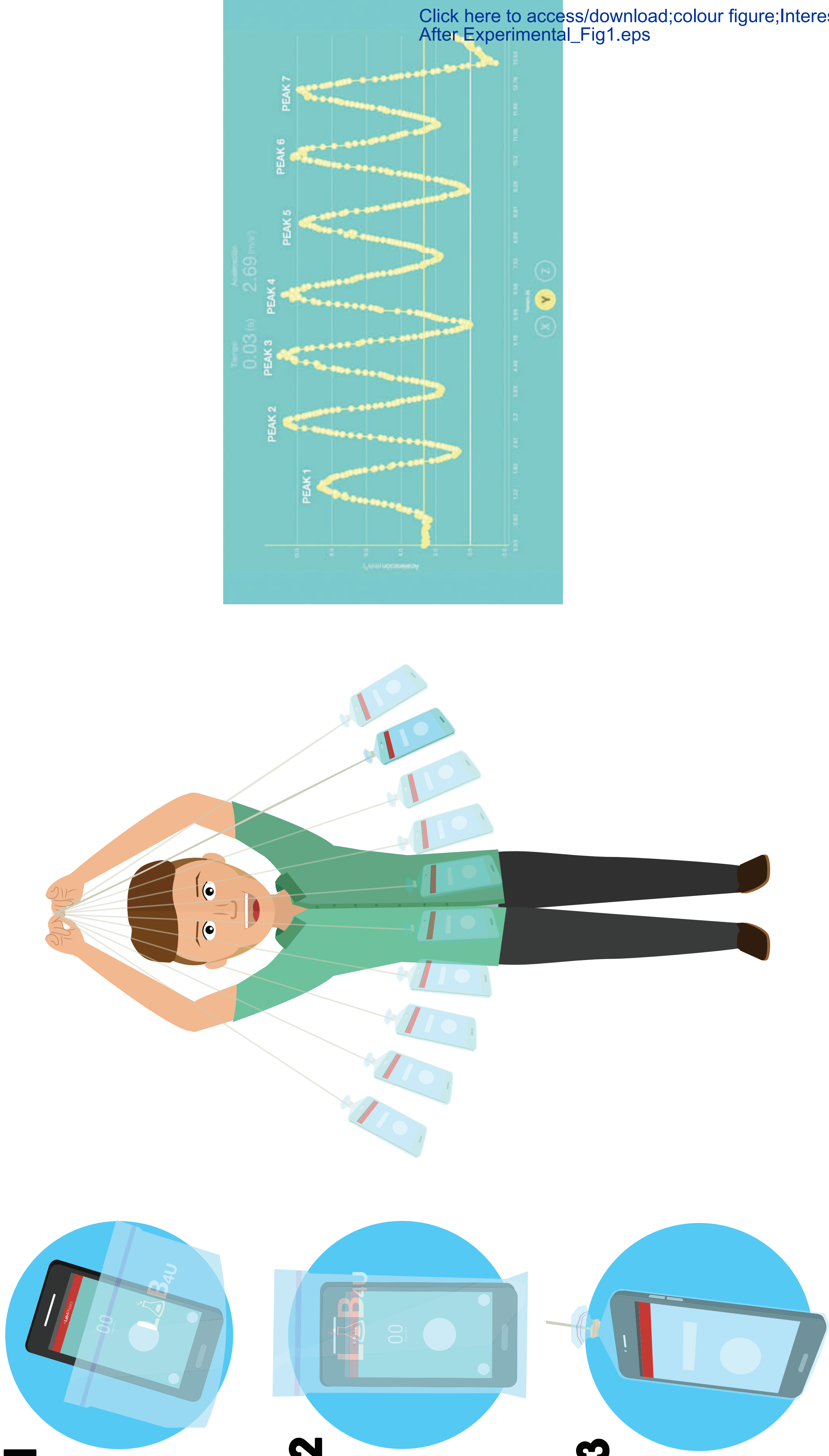
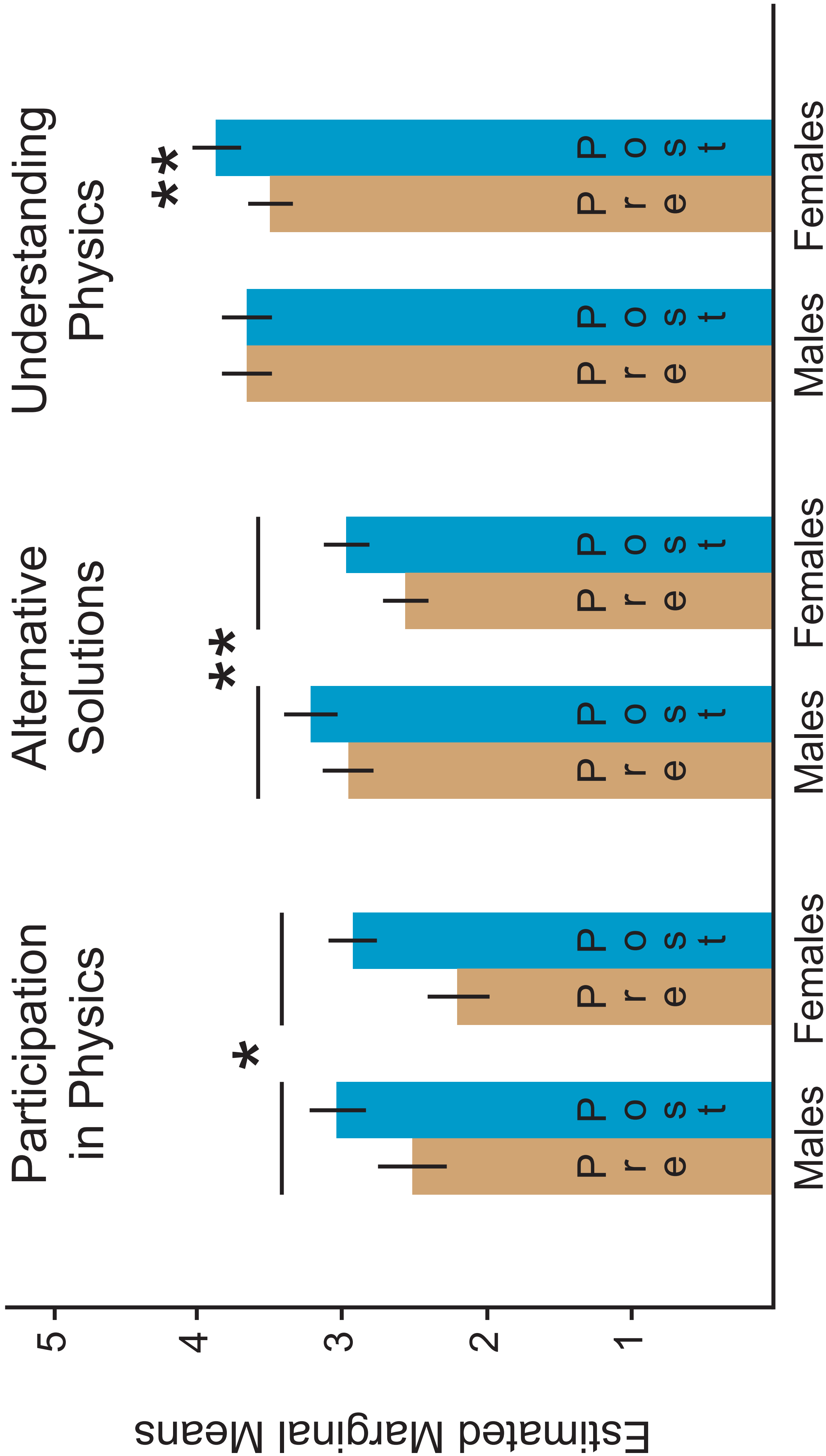


figure 2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Interest in Physics After Experimental Activities with a Mobile Application: Gender Differences

Abstract

Currently, the physics disciplines are represented by a significantly larger number of professional males, compared to females. Although the problem of underrepresentation of female physicists has several causes, one likely reason is the lower interest that female school students have in physics activities. Several instructional solutions have been proposed to spark girls' interest in physics, including recent ones with mobile devices. However, mobile devices could be problematic technologies for school students and teachers, particularly if guidance in their use is not provided. In the present study, we investigated the effectiveness of a novel mobile application guided with laboratory reports to increase high school students' interest in physics. We also investigated whether the intervention with mobile laboratory activities facilitated learning about an important physics topic, namely, understanding graphics. The study was conducted in eight eligible schools, totaling data from 268 high school students (57% females). Results showed that all seven measures of self-rated interest in physics received higher scores in the posttest than in the pretest. One of the items, which assessed changes in understanding physics, showed greater effects on females than on males. Hence, the instructional mobile application under consideration helped to spark students' interest in physics, and the effect was somewhat greater in schoolgirls. But the intervention did not change the test scores about understanding graphics, failing to demonstrate an association between increased interest in physics and changes in physics educational outcomes. The instructional implications for these findings, as well as limitations and future research directions, are discussed.

Keywords: gender differences; interest in science and physics; making and understanding graphics; physics laboratory education; STEM mobile learning

Introduction

Although at present many scientific disciplines do not show a gender imbalance, there is still a problematic female underrepresentation in the more mathematically oriented sciences, such as physics and computer science (Ceci et al., 2014; Hazari et al., 2013; Mauk et al., 2020). This is a persistent issue, as there are not enough young females wanting to pursue a career in these science disciplines. For example, the analysis by Sikora and Pokropek (2012) of PISA (Program for International Student Assessment) results from 50 countries showed that the average number of adolescent females planning to pursue scientific-mathematical careers was markedly lower than that of males. This is noticeably problematic for Chile, the country of the present study, which was shown to be in the top four (out of 30 developing countries) with the largest gender disparity.

Concerning physics, the underrepresentation of female physicists has many explanations (see Wang & Degol, 2017). We investigated here one that links this adult underrepresentation to lower interest in physics and related topics in schoolgirls as compared to boys. As such, girls’ interest in science may depend on the discipline (see Bybee & McCrae, 2011) and is usually lower in physics than in other areas (e.g., Baram-Tsabari & Yarden, 2011). For example, the systematic report of 228 articles investigating school students conducted by Potvin and Hasni (2014) showed that physics and technology were preferred by boys, whereas biology was often preferred by girls.

Consequently, schoolgirls should be given activities that spark their curiosity in physics (cf. Bindis, 2020; Wang & Degol, 2017). An example of this approach is reported by Wulff et al. (2018), who conducted a single-day intervention about radiation physics for school students. The intervention seemed to result in schoolgirls showing higher self-ratings in interest and competence in physics, compared to the schoolboys.

Beyond helping to tackle the female underrepresentation problem, sparking physics interest in schoolgirls may lead to a greater achievement in this discipline, as diverse studies show a connection between interest and performance in science topics (e.g., Glynn et al., 2009; Tuan et al., 2005), and this connection can be larger for physics than other sciences (e.g., Jansen et al., 2016). Although these studies show that the association between interest and achievement can be observed for both genders, it is particularly important for girls, as they tend to present lower physics scores than boys (e.g., Hoogerheide et al., 2018).

Our instructional approach to spark interest in school physics entails laboratory activities that we codesigned with a novel mobile application called Lab4Physics (see https://lab4u.co/en/lab-in-your-pocket/lab4physics). The application uses the built-in sensors of mobile devices to transform them into science labs. Lab4Physics utilizes several tools, including an accelerometer, a speedometer, a camera, a sonometer, and a graph plotter. All the tools allow for running different data measurements and producing graphs for analyses.

Also, our approach includes laboratory reports to guide classroom teachers and students through the students' inquiry process during the physics experiments with the mobile devices. This means that we foster a beneficial balance between active inquiry learning (e.g., Holmes et al., 2015) and guided instruction (e.g., Jerrim et al., 2019).

The aim of the present study was to investigate the effectiveness of guided inquiry physics laboratory activities undertaken by high school students using a novel mobile application and lab reports. In particular, we analyzed whether boys and girls using this application with reports changed their interest in physics activities, and if these effects on interest levels were associated with performance on a physics test about understanding graphs. Our guided inquiry approach is based on mobile devices, as these relatively recent tools have shown to be effective in learning science and physics. However, they may also present potential drawbacks, as described next.

Learning Science and Physics through Mobile Devices

There are several investigations supporting the use of mobile devices for learning science in school (e.g., Burden et al., 2019; Crompton et al., 2016; Sung et al., 2016; Yang et al., 2020; Zimmerman et al., 2019; Zydney & Warner, 2016). In the discipline of physics, there are also studies reporting enhancements in interest (e.g., Hochberg et al., 2018) and learning (e.g., Becker et al., 2020) associated with completing school activities using mobile devices. In addition to these and other benefits described below, there are also potential problems when learning physics through mobile devices (see Table 1).

Table 1

Benefits and Potential Problems of Using Mobile Devices for Learning School Physics

Benefits	Potential Problems
Increased interest in physics	Decreased technology confidence in girls
Increased learning about physics	Discouragement of some teachers
Help making physics graphics	
Help understanding physics graphics	

Benefits

Regarding the advantageous effect of using mobile devices to increase students' interest in school physics, Hochberg et al. (2018) provided an example with 245 high school students. In their study, the authors used a 6-point Likert scale to measure interest in physics classes in general. A comparison was made between employing mobile devices or objects (e.g., screws) to solve pendulum problems. Results showed that the mobile group demonstrated a significantly higher interest in physics than the control group. However, the groups did not show different learning gains, indicating that interest was not associated with learning performance.

A study by Nikou and Economides (2016) is an example of using mobile devices to increase both interest (motivation) and learning in a physics topic. The authors investigated 66 high school students (49% females) learning electromagnetism. The participants were randomly allocated to one of three learning conditions: paper-based, computer-based, and mobile-based. In addition, a questionnaire assessed their motivation in physics, including overall, intrinsic, and extrinsic motivation in physics. Comparing pretest and posttest scores, it was observed that the computer- and the mobile-based conditions, but not the paper-based, were effective to increase motivation in physics and knowledge of electromagnetism.

Similarly, Purba and Hwang (2017) reported on an effective mobile application which used the accelerometer of the devices to help female high school students learn about physics pendulum problems. Recently, Becker et al. (2020) conducted a study, with 294 secondary students from 11 schools, which compared learning about uniform motion under a mobile condition and a traditional condition. The mobile group executed the tasks through different representations on the same mobile devices, while the traditional group had to use separate instruments. Results showed that the mobile condition outperformed the traditional condition, in both conceptual understanding and lowering cognitive load.

A particular aspect of learning physics is making and understanding graphs that represent physics phenomena, such as those in kinematics (e.g., uniform motion) and thermodynamics (cf. Donnelly-Hermosillo et al., 2020; Glazer, 2011). For example, the report by Purba and Hwang (2017) of schoolgirls studying pendulum problems showed correlations between understanding the graphs and learning this physics topic. However, both making and analyzing graphics, when attempted manually by high school students, are skills prone to several errors (e.g., Pols et al., 2021; see Glazer, 2011). For example, understanding a graph is difficult because it requires the integration of perceptual surface structures and deep semantic structures (e.g., Schnotz & Baadte, 2015).

Instructional mobile technologies that include tools for graphs can help circumvent some of these difficulties (see Donnelly-Hermosillo et al., 2020). For instance, these tools facilitate making physics graphs by reducing the time students spend on details when drawing these visualizations (see Glazer, 2011). Also, mobile technologies can help students analyze or understand graphics by providing different representations that can be compared on the same screen (Becker et al., 2020) and by allowing instant feedback when data is changed, so students link visual and semantic relationships (Glazer, 2011).

Potential Problems

As described above, females may present lower interest (e.g., Potvin & Hasni, 2014) and achievement (e.g., Hoogerheide et al., 2018) in physics. A similar scenario can be observed for technology topics (cf. Mauk et al., 2020), in which females tend to show lower confidence (see a meta-analysis by Cai et al., 2017), although this does not necessarily mean that girls perform any worse with technological tools than boys do (e.g., Gnambs, 2021; Vonkova et al., 2021).

Concerning mobile technologies, Reychav and McHaney (2017) investigated a large sample of secondary school students (1,111 participants; 48% females) learning from mobile tablet materials. Results revealed that, although males showed higher self-perceived understanding or satisfaction learning with these technologies, the actual performance scores were higher in females. In all, these studies help support the premise that females are less confident than boys with technologies, including mobile devices, although their proficiency with these tools is not necessarily impacted. However, this evidence suggests that using mobile devices could be potentially problematic for sparking girls' interest in physics.

Another potential drawback of using mobile phones for physics instructional purposes is that using mobile phones can be challenging for teachers not accustomed to these relatively novel technologies. For example, Sung et al. (2016) conducted a meta-analysis about mobile education that included 110 articles (18,749 participants; 419 effect sizes). Results showed that learning with mobile devices was more effective than educational interventions with computers or pen-and-paper. Despite these encouraging findings about mobile instructional interventions, it was also observed that many approaches were not as effective because teachers were underprepared to deal with the mobile technologies or their educational application.

As described next, to manage these potential problems with female students and teachers, with our approach we provided paper-based lab reports to guide learners and teachers using mobile devices. Also, the mobile application incorporated help guides on-screen to assist and direct the users.

The Instructional Approach in Lab4Physics

Laboratory tasks and experimental activities that promote inquiry, critical thinking, and high levels of learning, such as analysis and evaluation of data, are desirable for science education (e.g., Holmes et al., 2015; Vorholzer et al., 2020). Mobile learning literature also promotes high over low levels of learning (see Crompton et al., 2019). However, engaging in this high cognitive activity can be difficult for high school students, so the evidence generally supports guided inquiry over unguided pure discovery learning (see Kirschner et al., 2006; Mayer, 2004; see also Ashman et al., 2020; Liou, 2021). Guided inquiry has also proven to be more effective than unguided instruction when students deal with technology (e.g., Cheung et al., 2017) or laboratory tasks (e.g., Vorholzer et al., 2020).

In other words, instructional approaches should strive for a balance where inquiry activities are aided by sufficient teacher guidance or similar feedback mechanisms (e.g., Jerrim et al., 2019; Vorholzer et al., 2020). This is particularly important for instructional approaches based on mobile devices, as these tools could be problematic for female students and teachers (Cai et al., 2017; Sung et al., 2016).

Following this rationale, Lab4Physics was designed to provide a balance between: (a) inquiry activity, as collaborative inquiry (see Liu et al., 2021) that is completed in groups of 3–4 students who write a laboratory report based on the experimental activity, data, and graphics from the mobile application; and (b) instructional guidance, provided by the instructional report materials for the students and the teachers, and by the mobile application that can display the data in multiple on-screen graphics, helping students create and understand the information in these displays and recognize the variables associated with changes in the graphics (see Glazer, 2011).

Hypotheses of the Present Study

In this study, we tested the following hypotheses:

- After using Lab4Physics, participants will show increased interest in physics (Hypothesis 1a).
- The effects of change in interest will be larger for females than for males (Hypothesis 1b).
- After using Lab4Physics, participants will show a higher level of understanding graphics (Hypothesis 2).

Hypothesis 1a was based on evidence (e.g., Hochberg et al., 2018; Nikou & Economides, 2016) indicating that physics activities undertaken on mobile devices can increase school students' interest in physics. Hypothesis 1b assumed a potential ceiling effect of interest in physics in male students, but not female students. In other words, based on the studies that show lower interest in physics in girls than boys (e.g., Baram-Tsabari & Yarden, 2011; Potvin & Hasni, 2014), ceiling effects in boys could leave more room for girls to raise their interest in physics. Hypothesis 2 was based on the positive findings of using mobile applications to help making and understanding graphics (e.g., Becker et al., 2020; Glazer, 2011).

Method

Participants

The high school students that completed both the pretest and the posttest were 268 (57% females). Dividing per level (equated to the US school system), there were 90 students (50% females) from Grade 9 (approximately 15 years-old), 138 participants (63% females) from Grade 10 (approximately 16 years-old), and 40 students (50% females) from Grade 11 (approximately 17 years old). The students were distributed among eight schools located in six different regions of Chile.

Physics Laboratory Mobile Application

The Lab4Physics mobile laboratory application includes several high-quality experiments for the students to test physics phenomena by themselves. For this study, the most employed experiments were Pirate Ship, Moon Walk, Skydiving, and Skatepark. For example, as shown in Figure 1, in the experimental activity called Pirate Ship, the accelerometer of the mobile device is used. In this activity, the mobile device must be inserted into a transparent bag that is hooked to a piece of string. After activating the accelerometer tool, the device is released from a certain height while another person holds the other end of the string firmly. The application records the data made from the movements of the device and then it graphs this phenomenon.

Figure 1. Screenshots of the Pirate Ship activity, showing how to set up the experiment (left), the procedure (center), and the graph that is obtained after conducting the activity (right).

The Lab4Physics application incorporates the following design features reviewed by Zydney and Warner (2016): (a) *technology-based scaffolding* to guide teachers and students in their activities, (b) *visual/audio representation* that allows students to create visual information (e.g., the graph of acceleration as a function of time) from the data produced, and (c) *digital knowledge-sharing mechanisms* to allow students to share the information produced on their mobile devices.

As a pivotal supplement for the physics application, we included printed laboratory reports. These reports were not only necessary to guide the students' learning and work (as suggested by Hofstein & Lunetta, 2004), but they were also used by the classroom instructors to optimize their teaching time and to avoid becoming discouraged or overwhelmed by the mobile technology (see Sung et al., 2016).

Paper-Based Materials

As part of a bigger project (CORFO 16PES-66152MASKED), a questionnaire was given to the students to obtain their gender, school level, and interest in (a) natural sciences, (b) technology, and (c) physics. Some of the questions were based on the *Physics Motivation Questionnaire* used by Nikou and Economides (2016). The questionnaire also included seven multiple choice items to assess students' understanding of graphs. For this study, we report the results regarding interest in physics (seven Likert scale items) and understanding graphics (seven multiple choice questions). The original instrument was delivered in the native tongue of the participants (Spanish), but we present it here in English.

Interest in Physics

In the instrument with seven questions, the first item assessed students' interest in science classes. It asked the question: *Do you like going to your science classes?* The second item assessed participants enjoyment of physics. It was worded as: *How much do you enjoy your physics classes?* Both items were answered by rating from 1 (very little) to 10 (very much).

Items 3–7 included only five points, which is common in instruments asking about interest in science (e.g., Glynn et al., 2009; Tuan et al., 2005). As such, Item 3 assessed students' familiarity with physics with the wording: *Can you link physics concepts to your real life?* The scores in this item ranged from 1 (never) to 5 (always). Item 4 assessed their frequency of experimentation in physics. It was written as: *How often do you conduct experiments in your physics classes?* The ratings were: 1 (never), 2 (once per year), 3 (once per semester), 4 (once per month), 5 (once per week).

Item 5, which assessed students' participation in physics classes, was worded as: *How much do you participate in your physics classes?* It ranged from 1 (never) to 5 (always). Item 6 assessed students' frequency of looking for alternative solutions to physics problems shown in classes. It asked the question: *Do you think of alternative solutions when attempting physics scientific problems?* Answers potentially ranged from 1 (never) to 5 (always). Item 7 was the last question, also a 5-point Likert scale. It assessed their understanding of physics. It was worded as: *How much do you understand about your physics classes?* The ratings were: 1 (0%), 2 (25%), 3 (50%), 4 (75%), and 5 (100%). The reliability indices for this instrument with seven questions was Cronbach's $\alpha = .74$ (pretest) and .77 (posttest).

Understanding Graphics

Seven multiple choice questions, with four alternative answers each, were given to the students. The questions assessed accuracy in understanding line graphs. Each question had only one correct option, which, if chosen, awarded 1 Point to the student. Incorrect and blank answers were given 0 Points. A total score for understanding graphics was calculated by adding the seven questions. Hence, the total score ranged from 0 to 7 Points. The reliability for these seven-item tests of the pre- and posttest was Cronbach's $\alpha = .62$ and .59, respectively.

Procedure

After a short period of training given to the participant teachers, the pretest was given to the students attending eight schools in six different regions in Chile. For the following seven months, teachers and students had access to the Lab4Physics mobile application and lab reports, so the participating students could conduct physics experiments, including collecting and analyzing the data. These activities were executed in groups of 3–4 students who discussed the information and completed laboratory reports on paper. Most of the data analysis, including graph interpretation, involved data of acceleration versus time that was measured with the accelerometer of the mobile devices. At the end of the seven months of free experimental sessions assisted by the mobile application and reports, the posttest was given and collected.

Independent and Dependent Variables

The independent variables were gender and testing time (pretest and posttest). Scores between males (N = 116, 43%) and females (N = 152, 57%) were compared both at pretest and posttest for the following eight ~~dependent variables~~measures: (a) interest in science classes, (b) enjoyment of physics, (c) familiarity with physics, (d) experimentation in physics, (e) participation in physics, (f) alternative solutions, (g) understanding physics, and (h) understanding graphics. The first two ~~variables~~ items were measured with 10-point Likert scales. All other variables, except for the last, were assessed with 5-point Likert scales. The last variable, understanding graphics, was measured by adding the participants' scores on the seven multiple choice questions about line graphs.

Results

For all statistical tests, a significance level of .05 was applied. Also, 95% confidence intervals (CI) are reported. For each of the eight dependent variables, we conducted a mixed design analysis of variance (ANOVA) with pretest and posttest scores in the independent variables as the within-subjects factor, and gender as the between-subjects factor. For all ANOVAs, effect sizes were expressed as partial eta squared (η_p^2), with .01 indicating a small, .06 a medium, and .14 a large effect (Cohen, 1988). Descriptive statistics for the results are shown in Table 2.

Table 2

Means (and SD) for the Results

Gender	Pretest	Posttest	Pretest	Posttest
	Interest in Science Classes[a]		Participation in Physics[b]	
Male	6.31 (2.24)	7.10 (2.29)	2.50 (1.39)	3.02 (1.12)
Female	6.09 (2.01)	7.09 (2.24)	2.18 (1.21)	2.91 (0.99)
Total	6.19 (2.11)	7.09 (2.26)	2.32 (1.30)	2.96 (1.05)
	Enjoyment of Physics[a]		Alternative Solutions[b]	
Male	6.20 (2.32)	6.78 (2.56)	2.94 (0.94)	3.20 (0.96)
Female	5.92 (2.25)	6.97 (2.46)	2.55 (0.94)	2.95 (1.01)
Total	6.04 (2.28)	6.89 (2.50)	2.72 (0.96)	3.06 (1.00)
	Familiarity with Physics[b]		Understanding Physics[b]	
Male	3.22 (1.19)	3.44 (1.02)	3.64 (0.94)	3.64 (1.12)
Female	3.04 (1.07)	3.39 (1.00)	3.47 (0.93)	3.85 (0.93)
Total	3.12 (1.12)	3.41 (1.01)	3.54 (0.93)	3.76 (1.02)
	Experimentation in Physics[b]		Understanding Graphics[c]	
Male	3.27 (1.20)	3.47 (1.13)	4.78 (1.75)	5.01 (1.60)
Female	3.09 (1.42)	3.62 (1.10)	4.68 (1.58)	4.76 (1.57)
Total	3.17 (1.33)	3.56 (1.11)	4.72 (1.66)	4.87 (1.59)

Note. For all data, $n = 268$ (57% females).
[a]Potential range = 1–10. [b]Potential range = 1–5. [c]Potential range = 0–7.

Interest in Physics

Regarding the first item, Interest in Science Classes, the mixed design ANOVA showed a significant main effect of this dependent variable between pretest and posttest, $F(1, 266) = 26.70$, $MSE = 3.93$, $p < .000$, $\eta_P^2 = .09$. A follow-up analysis revealed that females and males overall scored higher on the posttest ($M = 7.09$ [CI = 6.82–7.37], $SE = 0.14$) than on the pretest ($M = 6.20$ [CI = 5.95–6.46], $SE = 0.13$). The mixed analysis showed no significant main effect of gender nor a significant Interest in Science x Gender interaction, both $Fs < 1$, *ns*.

For the item Enjoyment of Physics, the mixed design ANOVA showed a significant main effect of this dependent variable between pretest and posttest, $F(1, 266) = 19.88$, $MSE = 4.40$, $p < .000$, $\eta_P^2 = .07$. A follow-up analysis revealed that participants overall scored higher on the posttest ($M = 6.88$ [CI = 6.57–7.18], $SE = 0.15$), compared to the pretest ($M = 6.06$ [CI = 5.78–6.34], $SE = 0.14$). The mixed analysis showed no significant main effect of gender ($F < 1$, *ns*) nor a significant Enjoyment of Physics x Gender interaction, $F(1, 266) = 1.69$, $MSE = 4.40$, $p = .195$, $\eta_P^2 = .01$.

For Familiarity with Physics, the mixed ANOVA showed a significant main effect between pretest and posttest, $F(1, 266) = 9.84$, $MSE = 1.12$, $p = .002$, $\eta_P^2 = .04$. A follow-up analysis showed that students overall self-rated higher on the posttest ($M = 3.42$ [CI = 3.30–3.54], $SE = 0.06$), compared to the pretest ($M = 3.13$ [CI = 2.99–3.26], $SE = 0.07$). The mixed ANOVA did not show a significant main effect of gender, $F(1, 266) = 1.39$, $MSE = 1.16$, $p = .240$, $\eta_P^2 = .01$, nor a significant Familiarity with Physics x Gender interaction, $F < 1$, *ns*.

For Experimentation in Physics, the mixed ANOVA showed a significant main effect between pretest and posttest, $F(1, 266) = 13.40$, $MSE = 1.31$, $p < .000$, $\eta_P^2 = .05$. A follow-up analysis showed that students overall self-rated higher on the posttest ($M = 3.55$ [CI = 3.41–3.68], $SE = 0.07$), as compared to the pretest ($M = 3.18$ [CI = 3.02–3.34], $SE = 0.08$). The mixed ANOVA did not show a main effect of gender ($F < 1$, *ns*) nor an interaction of Experimentation in Physics x Gender, $F(1, 266) = 2.81$, $MSE = 1.31$, $p = .095$, $\eta_P^2 = .01$.

For Participation in Physics, the mixed ANOVA showed a significant main effect between the tests, $F(1, 266) = 42.76$, $MSE = 1.20$, $p < .000$, $\eta_P^2 = .14$. A follow-up analysis revealed that participants overall self-rated higher on the posttest ($M = 2.96$ [CI = 2.84–3.09], $SE = 0.06$) than on the pretest ($M = 2.34$ [CI = 2.18–2.50], $SE = 0.08$). Also, the mixed analysis showed a significant main effect of gender, $F(1, 266) = 3.93$, $MSE = 1.56$, $p = .049$, $\eta_P^2 = .02$. A follow-up analysis revealed that males, overall in both pretest and posttest, self-rated higher ($M = 2.76$ [CI = 2.60–2.92], $SE = 0.08$), as compared to females in both tests ($M = 2.54$ [CI = 2.40–2.68], $SE = 0.07$), as shown in Fig.2. Last, the mixed ANOVA showed no significant Participation in Physics x Gender interaction, $F(1, 266) = 1.25$, $MSE = 1.20$, $p = .265$, $\eta_P^2 = .01$.

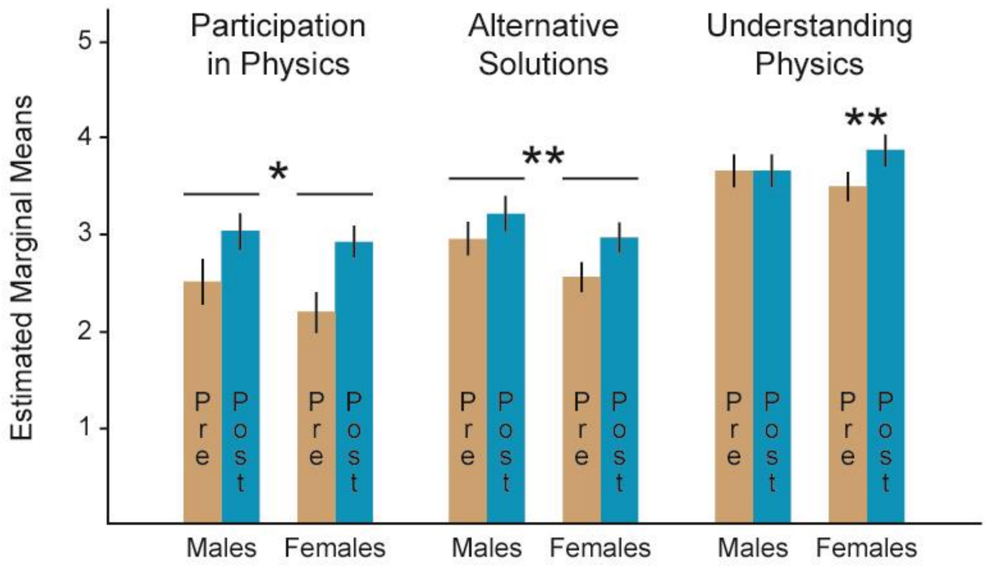

Figure 2. Estimated marginal means of Participation in Physics, Alternative Solutions, and Understanding Physics, as a function of gender and pretest vs. posttest. Error bars represent 95% CI. * $p < .050$. ** $p < .010$.

For Alternative Solutions, the mixed ANOVA showed a significant main effect between pretest and posttest, $F(1, 266) = 16.87$, $MSE = 0.87$, $p < .000$, $\eta_P^2 = .06$. A follow-up analysis showed that students overall self-rated higher on the posttest ($M = 3.08$ [CI = 2.96–3.20], $SE = 0.06$), compared to the pretest ($M = 2.74$ [CI = 2.63–2.86], $SE = 0.06$). The mixed ANOVA also showed a significant main effect of gender, $F(1, 266) = 13.44$, $MSE = 1.00$, $p < .000$, $\eta_P^2 = .05$. A follow-up analysis (see Fig.2) revealed that males, overall in both pretest and posttest, self-rated higher ($M = 3.07$ [CI = 2.94–3.20], $SE = 0.07$), as compared to females in both tests ($M = 2.75$ [CI = 2.64–2.86], $SE = 0.06$). The mixed ANOVA showed no significant Alternative Solutions x Gender interaction, $F < 1$, *ns*.

For Understanding Physics, the mixed ANOVA showed a significant main effect between pretest and posttest, $F(1, 266) = 6.01$, $MSE = 0.77$, $p = .015$, $\eta_P^2 = .02$. The mixed

ANOVA did not show a main effect of gender ($F < 1$, *ns*). As shown in Fig. 2, there was a significant Understanding Physics x Gender interaction, $F(1, 266) = 6.01$, $MSE = 0.77$, $p = .015$, $\eta_P^2 = .02$. A follow-up analysis of the interaction showed that male students self-rated similarly on the posttest ($M = 3.64$ [CI = 3.45–3.82], $SE = 0.09$) than on the pretest ($M = 3.64$ [CI = 3.47–3.81], $SE = 0.09$), $F < 1$, *ns*. In contrast, female participants self-rated higher on the posttest ($M = 3.85$ [CI = 3.69–4.01], $SE = 0.08$), compared to the pretest ($M = 3.47$ [CI = 3.33–3.62], $SE = 0.08$), $F(1, 266) = 13.88$, $p < .000$, $\eta_P^2 = .05$.

Understanding Graphics

The mixed ANOVA did not show a significant main difference of graph scores between pretest and posttest, $F(1, 266) = 1.59$, $MSE = 1.90$, $p = .208$, $\eta_P^2 = .01$. Similarly, there was no significant main effect of gender, $F(1, 266) = 1.26$, $MSE = 3.36$, $p = .262$, $\eta_P^2 = .01$, nor a significant interaction between the factors, $F < 1$, *ns*.

Discussion

We conducted a study to investigate potential changes in interest in physics and understanding graphics in high school students attempting physics experimentation activities with a novel mobile application and printed reports that allowed guided inquiry. We also investigated probable gender differences.

Interest in physics was measured with seven Likert scale items that assessed: (a) interest in science classes, (b) enjoyment of physics, (c) familiarity with physics, (d) experimentation in physics, (e) participation in physics, (f) alternative solutions, and (g) understanding physics. We observed that all seven variables showed significant self-rating increases from pretest to posttest. These findings, which support Hypothesis 1a, endorse the premise that the mobile activities under consideration can increase student's interest in school physics. This is consistent with previous research supporting mobile device applications for raising interest in physics topics (e.g., Hochberg et al., 2018; Nikou & Economides, 2016).

In addition, for two of the variables (i.e., participation in physics and alternative solutions) males showed higher ratings than females, in both pretest and posttest. This greater interest in physics observed for males, both before and after using Lab4Physics mobile activities, is coherent with findings in which boys prefer physics and girls prefer other science areas (Baram-Tsabari & Yarden, 2011; Potvin & Hasni, 2014).

The results concerning changes in understanding physics indicated there was an interaction with gender. As such, using the mobile activities raised the self-ratings on this variable only in females, but it was not associated with significant changes in males. This result partially supports Hypothesis 1b, as there was a change in interest in physics that was greater for females, but this was only observed in one out of seven variables.

In addition to assessing self-ratings of interest in physics, we also measured understanding graphics. This variable was measured with a test of seven multiple choice questions with four alternative answers each. The scores on this test did not indicate differences between pretest and posttest, nor gender differences or an interaction. This finding, which failed to show a significant effect in understanding graphs associated with using the mobile application and lab reports, does not support Hypothesis 2.

In all, the results of the present study showed that our mobile application activities in Lab4Physics were associated with a higher interest in physics, for both boys and girls. Also, understanding physics showed greater effects for females than males. However, these changes in self-rated interest were not linked to higher learning achievement in understanding graphics. Previous studies have also shown changes in interest in science or physics that are not associated with changes in actual performance in these subjects (e.g., Hochberg et al., 2018; Potvin & Hasni, 2014; Wulff et al., 2018).

Despite these null effects on learning about an important physics topic (understanding graphics), the application and lab reports allowed for increases in ratings of interest in physics. Notably, females increased their self-ratings about understanding physics more substantially, which suggests that the intervention could be more helpful for women than for men. Future interventions with new experiments and tools in Lab4Physics could try to connect these gendered changes in interest to changes in physics performance.

Instructional Implications

The first implication of the present study for teachers and instructors of science is that they could attempt instructional tasks aided by mobile devices, for example concerning physics, as these interventions could increase students' interest in these science topics.

The second instructional implication is that, by being provided with challenging mobile inquiry activities aided by guided instruction, students could increase their interest in the topics covered in these activities. Also, this rise in interest could be more evident in female students.

The third instructional implication is that, although a mobile intervention ~~designed to promote interest in science~~ could be effective in promoting interest in science, this increased interest may not necessarily produce learning gains.

Limitations and Future Directions

One limitation of the current study is the lack of a control group that did not receive the mobile learning activities. Without this group, we cannot ascertain that it was the treatment, and not an uncontrolled "third" variable, the cause for an increased students' interest in physics from the pretest to the posttest (see Coolican, 2009). Future research could compare control versus experimental groups, once actions are taken so that the control students are not always lacking an effective learning activity.

A second limitation is the problematic use of self-reports about interest in physics rather than an actual behavioral measurement of interest in this science discipline (see Baumeister et al., 2007). This may explain why self-reported interest in physics was not related to understanding graphics in the current study. To measure actual interest in physics, future research could investigate choices that participants make when confronted with decisions between attempting tasks in physics or other science subjects. Also, it should be investigated whether a behavioral assessment of interest in physics could be related with learning about physics or understanding graphics.

A third limitation is that we did not assess various moderating variables in the literature about gender differences, such as visuospatial processing (see Castro-Alonso & Jansen, 2019; see also Castro-Alonso & Uttal, 2019), e-learning (e.g., Rodríguez-Ardura & Meseguer-Artola, 2021), multimedia learning (e.g., Castro-Alonso et al., 2019; Geerling et al., 2020; Wong et al., 2018), and math proficiency (e.g., Guiso et al., 2008). Future research could control or investigate the effects of these influential variables.

Conclusion

Investigating Lab4Physics, a novel mobile application with lab reports that allows guided inquiry learning in the classroom, we predicted that high school students could increase their interest in physics and their understanding about graphics. As anticipated, we observed an overall increase in self-ratings of interest in physics. In the variable that measured understanding physics, we observed a greater increase in females than in males. However, this overall increased interest and the gender difference were~~as~~ not linked to changes in actual learning, measured in a test of understanding graphics. Future investigations with similar mobile laboratory activities could reveal a relationship between interest in physics and learning performance. Similarly, future investigations that tackle the limitations of this study could more conclusively support Lab4Physics as a mobile application with lab reports that promote learning about physics topics.

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