Investigating the Effects of Teacher-Student Led Functions of Mobile Technology on Students' Achievement and Learning Interest in High School Physics

Siwei Chen

A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Education

University of Washington

2017

Committee:

Min Li

Elizabeth Sanders

Program Authorized to Offer Degree:

Education

University of Washington

Abstract

Investigating the Effects of Teacher-Student Led Functions of Mobile Technology on Students' Achievement and Learning Interest in High School Physics

Siwei Chen

Chair of the Supervisory Committee:

Min Li

College of Education

The present study investigates the effects of using teacher-led, student-led, and collaborative mobile device functions on high school students' physics learning and interest. Participants included 439 high school freshman students from 16 classrooms at one large province in China. Descriptively, we found that students reported using the collaborative functions on their mobile devices more than student-led or teacher-led functions. Hierarchical multilevel linear model results showed that the frequency with which students used student-led, teacher-led, and collaborative mobile technology functions each had a significant direct and unique effect on students' 10th grade physics interest, but not their achievement. Implications for research and practice are discussed.

Keywords: mobile learning, student-led, teacher-led, collaborative, high school physics

Investigating the Effects of Teacher-Student Led Functions of Mobile Technology on Students' Achievement and Learning Interest in High School Physics

Mobile devices are becoming popular in people's daily lives. Students have opportunities to access different mobile devices such as smartphones, iPads, Tablets, and PDAs. These devices have the potential to transform how students learn and to change the traditional classroom into a more interactive one (Shen, Wang, & Pan, 2008). It is important for teachers and practitioners to consider how mobile devices can be used to assist students' learning.

Determining what constitutes mobile learning is a necessary first step in mobile device research. Romrell, Kidder, and Wood (2014) define it as "learning that is personalized, situated, and connected through the use of a mobile device" (p. 80). The personalized nature of mobile learning reflects not only different devices that students choose, but also various way students learn from different devices, software, and so on. Mobile learning is situated because students can take them to school as well as use them for field trip due to the small size of the devices. Mobile learning is connected because students can access a variety of information through the Internet. Cheon, Lee, Crooks, and Song (2012) state that mobile learning should have at least three characteristics: portability, instant connectivity, and context sensitivity. The first two characteristics are similar to those in Romrell et al.'s (2014) definition. Portability means the mobile device can be taken to different places. Connectivity means students can access a variety of information anytime and anywhere. In addition, Cheon et al. add one more characteristic to mobile learning, which is context sensitivity. By context sensitivity, Cheon et al. underscore that the data the mobile device can access is real or simulated depending on the situation.

Together, the above definitions capture the core of mobile learning – by using mobile devices, students can overcome the limitations of time and space, as well as access information instantly. In class, students can not only listen to a teacher's lecture, but also review materials as well as share information with their classmates. They can bring their devices home for field study, and search for information online. Teachers can also benefit from mobile learning. They can answer students' questions anywhere and anytime, which will immediately assist students' learning.

Many studies have been conducted to detect the overall effects of mobile devices on student learning. Results from a number of these studies suggest that mobile learning devices may improve student learning. For example, Hsiao, Lin, Feng, and Li (2010) studied fifth-grade students in life science in Taiwan. The results showed that the experimental group using mobile devices performed better than the traditional class group on the ecological knowledge test. Shen et al. (2008) designed a mobile learning system to be used by 1,000 students (average age 25-35) in an English class. The mobile learning system increased students' learning effectiveness. The researchers also found that students' perception of mobile learning gradually changed, and by the end of the study, the students used the mobile learning to create a community in which they could obtain feedback from teachers and share materials. Ahmed and Parsons (2013) designed a mobile learning application, *ThinkLearn*, to assist high school students in generating hypotheses during abductive inquiry investigations in physics. The results showed that the experimental group performed better compared to the traditional class group.

However, there are some limitations in this body of literature. Firstly, few studies of any kind have been conducted in science education, especially at the level of high school. Zydney and Warner (2016) carried out a literature review of articles from 2000 to 2014 in science education about mobile learning. The results showed that only 37 articles published were in the science domain, mostly in the domain of life science. Only four of these studies focused on physics, including three in elementary school and one in high school (Ahmed & Parsons, 2013). Another recent literature review (Crompton, Burke, Gregory, & Gräbe, 2016) draws similar conclusions. Only forty-nine out of 1,532 articles researching mobile devices in education focused on science education. Only three of them focused on physics. Also, twenty-six were done on elementary school students. All this suggests more research needs to be conducted in high school physics classrooms.

Secondly, the long-term effects of mobile learning have yet to be adequately investigated. A literature review revealed that the durations of the tests of the effectiveness of mobile learning ranged from 40 minutes to 8 hours (Zydney & Warner, 2016). Several studies have tested the long-term effects of mobile learning in the sciences. Song (2014) did a one-year study of 28 middle school students in life science. The findings showed that students developed positive attitudes toward seamless science inquiry in the “bring your own device” environment. Looi, Zhang, Chen, Seow, Chia, Norris, and Soloway (2011) did a 21-week 1:1 mobile inquiry study and found that students using a mobile-designed curriculum perform better in science subjects than those who did not. However, the long-term effects in high school physics classrooms, especially with large sample sizes, remain largely unknown.

Thirdly, in the 49 articles in Crompton et al.’s (2016) review that took place in the science classroom, mobile phones and PDAs were the most studied mobile devices, with 30% of the studies employing PDAs and 30% using mobile phones. Only two of the 49 articles investigated tablets as their research device. It is possible that tablets affect learning in significantly different ways in comparison to other mobile devices, given differences such as tablets' comparatively larger screen size, compatibility with external keyboards, greater range of programs, and more flexible capabilities. Thus, studies of one type of mobile device may not be generalizable across all platforms and additional research is warranted.

Another limitation of the previous studies is that among all those that address mobile learning in science, most test whether mobile learning can increase students' achievement. Few have investigated the relationship between mobile learning and students' learning interests. Similar studies have been done in other academic subjects, however. Hwang and Chang (2011) conducted a study in a local culture course and found that mobile learning environments have positive relationship with the students' interest in learning the topic. Tan and Liu (2004) also found that mobile learning environments have positive relationship with students' interest in an elementary English class. It follows that additional research should be conducted to test the effects of mobile learning on interest among students in high school science classrooms, such as physics.

Teacher-Student Led Models

Most important, both Zydney and Warner (2016) and Crompton et al. (2016) found that most of these studies only test student interaction with mobile learning. The researchers either design either a mobile learning system or an app and test its effectiveness for student use (51%), or test the effects of mobile devices on students' learning achievement, learning interest, attitude toward mobile learning, and so on (45%). Few have investigated the role of teacher or student and how they collaborate with each other in a mobile learning context (Holme & Sharples, 2002; Looi et al., 2011; Dunleavy, Dede & Mitchell, 2009; Ruiz, Mintzer & Leipzig, 2006), and none have done so in the context of the physics classroom

Different researchers take various approaches to theorizing the role of teachers and students in mobile learning. Some claim mobile technology shifts learning from being teacher-led to student-led (Miangah & Nezarat, 2012). Others think mobile technology can offer opportunities for learning that extend the teacher-led classroom, both within the classroom and beyond (Sharples, Arnedillo-Sánchez, Milrad, & Vavoula, 2009).

Perhaps because of this focus on the student-centered nature of mobile learning, most studies consider only the role of students and student-led functions in mobile learning. Traxler (2010) asserts that mobile devices allow students to produce, store, and transmit information, and that this allows students to have greater ownership through self-learning. Pintrich (2003) suggests mobile learning will increase students' motivation in a learning and teaching context. Holme and Sharples (2002) conducted one of the few studies to specifically consider the role of teacher-led functions in mobile learning. The researchers designed a learning organizer for both university teachers and students on Pocket PC computers. In their system, teachers can publish homework and provide lecture resources. Students can check the timeline of the syllabus, download resources, and submit their homework online. However, these findings only demonstrated that students provided positive feedback regarding the mobile learning system.

They do not address the effects of teacher-led functions. Similarly, Looi et al. (2011) designed a student-centered mobilized lesson on science that allowed students to access resources and bring mobile devices on field trips to support their learning. The mobilized lesson also supported teachers in developing a good curriculum and accessing student learning. They reported that mobile learning increased students' achievement in science. Students reported finding the learning more personal, deep, and engaging. This study did not report on teacher-led functions.

Students' roles in mobile learning require much support from teachers and the curriculum. Shen et al. (2008) think mobile learning systems can increase teaching effectiveness. They state that by using a mobile learning system, instructors can monitor students' mobile phone screens instantly. They found that the system also helped instructor supervise students' learning activities and provide guidance when necessary. Naismith, Lonsdale, Vavoula, and Sharples (2004) proposed that teachers could use mobile devices for many functions, for example attendance reporting or providing materials to students electronically. In such ways, mobile devices could be used both for learning as well as instructional support.

Although few studies have investigated teacher-led, student-led, and collaborative functions, it is important to understand the effects of these functions in students' learning processes. Kukulska-Hulme (2009) suggests that in this age of technology, teachers and students must find a way to understand how mobile devices can best be used for learning. Educators must rethink the ways in which mobile devices can be used to create a more integrated, collaborative pedagogical experience that bridges formal and informal learning both in and out of the classroom. To fill this gap, the present study investigates teacher-led, student-led, and collaborative functions in mobile learning, and their relationship to student achievement and interest in the physics classroom.

Research Questions

Research Questions

To fill the aforementioned research gaps, this study addresses two research questions:

1. How often do high school students use different categories of physics learning functions on their mobile devices in and out of class?
2. Is there any relationship between frequency of using different categories of mobile learning functions and high school students' achievement and interest in physics?

Method

Setting

This study took place in a high school in Shandong province, China. The education ministry in China launched a smart classroom system project in 2014. In this project, each student was equipped with a tablet (1:1). The government sponsored all the tablets so that every student had the ability to use mobile technology regardless of his or her family's income.

The smart classroom system also fits Looi et al.'s (2011) "seamless learning" paradigm, in which mobile devices bridge formal and informal learning. Teachers could control the pace of the class activities, manage resources, and respond to students in class. They also received statistics on how students used the different functions of the mobile devices after class in order to monitor students' learning progress. Students could access resources, take their own learning notes, and share their ideas with classmates both in and after class. An E-cloud platform was built to store all the resources. The teachers as well as their students were trained to use the system. In this study, teachers controlled most of the tablet resources and the mobile learning system. Thus, the mobile learning system is a more controlled environment than students' self-situated mobile devices.

Apart from passively receiving materials and homework from the E-cloud platform, students can also learn actively. They can use the tablets to take notes, use mind-maps to structure knowledge, and so on. The mobile devices and platform used in this study captured the characteristics of mobile learning described by Romrell et al. (2014) and Cheon et al. (2012).

Participants

We launched the present study one year after designing the mobile learning system. (Each student received his or her own tablet installed with a mobile learning system. Students were allowed to use the tablets in class and bring them home.) Students were measured on achievement the year prior to the study as well as after the study was completed (end of grade 10). In addition, they completed two online surveys (to be described next). In total, we collected 454 surveys; however, after deleting surveys in which students filled in all the questions with only 5s or 1s, data from 439 students from 16 classrooms was available for analysis. Of these, 231 were male and 208 were female.

Measures

Mobile Technology Survey (Mobile Function Predictors). Zhai, Zhang, and Li (in press) developed the survey used in the present study. We selected 15 typical functions used in this mobile learning system, eight of which were used in class, and seven of which were used after class. We asked students to indicate, using a 5-point self-report rating scale, how frequently they used each of the functions. The in-class use question stem was: "How frequently did you use the following functions in the physics classroom?" with response options that included: A. in every class, B. in most classes, C. in about half of the classes, D. in less than half of the classes, or E. seldom." The after-class use question stem was: "How frequently did you use the following functions in after-class physics learning?" with response options that included: A. every day, B. 2-3 times a week, C. once a week, D. once a month, or E. seldom. Specific survey item functions for each stem are provided in Appendix A, Tables A1 and A2.

To investigate the ways in which students and teachers deployed mobile technology-supported instruction functions in and out of the classroom, we categorized each of the 15 available functions (again, see Appendix A) as either a **teacher-led function**, a **student-led function**, or a **collaborative function**. A high school teacher and a researcher completed categorizations with sufficient inter-rater reliability ($r = 0.88$, $p < 0.001$). Functions categorized as student-led were those in which teachers were thought to have no influence on use; there were 5 student-led items. An example of a student-led function includes the *build incorrect items set* function in which students add items to the incorrect sets and add tags or notes to them, all without input from teachers. Teacher-led functions were those in which students were thought to have no input; there were 5 teacher-led items. *Screen display* is an example of a teacher-led function. Using *screen display*, a teacher can display a student's screen on the whiteboard to show the student's work or drawing. Students cannot control whether the teacher decides to display their work or not. Finally, collaborative functions were defined as those in which the teacher provides resources that students are then able to use. In turn, teachers can respond to student progress reports, thereby enhancing teaching. There were 5 items categorized as collaborative functions. *Use learning guide* is an example of a collaborative function. For this function, students can watch the guide that the teacher provides, and then teachers can check the statistical report of student use and adjust their instruction accordingly. Because of the reciprocal nature of the process, this function is considered collaborative. Cronbach's alpha (internal consistency) was computed for each of the sets of items, and was found to be 0.96, 0.95, and 0.86 for student-led, teacher-led, and collaborative functions, respectively.

A confirmatory factor analysis (CFA) was also carried out on the mobile technology function items to determine whether the teacher-student model categorization of the items fit the data well. The CFA results, presented in the first row of Table 1, showed that the three-factor model had a good fit to the data.

Physics Achievement (Outcome 1). An achievement test was administered to students by their teacher at the beginning of their 9th grade academic year as well as the end of their 10th-grade year. The two tests were not identical, but measured the same content.

Physics Interest (Outcome 2). Zhai, Zhang, and Li (in press) developed a 4-item survey, which is a revised version of a survey used in Lamb's (2012) study to measure high school students' interest in physics. The survey was administered at the end of 10th grade, at the same time that the mobile functioning survey was conducted. All items are self-reported 5-point rating scales. An example of an item stem includes: I found learning physics is interesting, with responses of 1 = Very Disagree and 5 = Very Agree. For this sample, Cronbach's alpha was 0.89.

A one-factor CFA was conducted on the items. The results, which are presented in the second row of Table 1, showed good model fit.

Data Analysis

We analyzed all data using the open-source software *R*. Specifically, the **lmer** package was used to model the data. Because students within one classroom may have more in common with each other than with students in another classroom (i.e., different classroom cultures, teaching styles, etc.[1]) and therefore induce dependencies in the data, we used multilevel hierarchical linear models (HLM) with random[1] intercepts (Raudenbush & Bryk, 2002) to analyze the data. For ease of interpreting the magnitude of the effects, we standardized all variables into *z*-scores prior to analysis ($M = 0$, $SD = 1$).

Baseline ICC Estimates. Our first model was a baseline intercept-only model (i.e., with no predictors) that served to determine the intraclass correlation (ICC) among students within classes (i.e., the magnitude of the classroom membership effect on the outcome) (Raudenbush & Bryk, 2002). This model can be written as follows.

$$Y_{sc} = \gamma_{00} + a_c + e_{sc},$$

where $a_c \sim$ i.i.d. normal $(0, \tau^2)$, and

where $e_{sc} \sim$ i.i.d. normal $(0, \sigma^2)$.

In the model above, Y_{sc} is the score of the sth student in the cth classroom on the outcome variable (10th grade physics achievement or physics interest) which is a function of γ_{00}, the grand mean among all classes, and the deviation between an the student's classroom mean and the

---

[1] Students in China are fixed in class rather than school, so we only take their class membership into account.

grand mean. a_c, and the deviation between a student's score and their classroom's mean. e_{sc}.

Predictor Models. Because we had no strong a priori hypotheses regarding the relationships between the teacher, student, and collaborative functions with student achievement or learning interests, we conducted two sets of model analyses. In the first set of models, we tested student-led, teacher-led, and collaborative functions each separately after controlling for 9th grade achievement. For our second set of models, we entered each function into the model sequentially.

Exploratory Models (Model Set 1a-c). In this model set, we entered each function predictor into the model separately, after controlling for students' prior 9th grade achievement. Additionally, because Jansen, Lüdtke, and Schroeders (2016) found that learning interest can significantly increase students' academic achievement in physics, 10th grade physics interest was also controlled for in the achievement model.

Models 1a-1c were specifically as follows.

Model 1a: $Y_{sc} = \gamma_{00} + \gamma_{01}*9^{th}\text{ Grade Achievement}_{sc} + \gamma_{02}*10^{th}\text{ Grade Interest}_{sc} + \gamma_{03}*\text{Student-led Function}_{sc} + a_c + e_{sc}$

Model 1b: $Y_{sc} = \gamma_{00} + \gamma_{01}*9^{th}\text{ Grade Achievement}_{sc} + \gamma_{02}*10^{th}\text{ Grade Interest}_{sc} + \gamma_{03}*\text{Teacher-led Function}_{sc} + a_c + e_{sc}$

Model 1c: $Y_{sc} = \gamma_{00} + \gamma_{01}*9^{th}\text{ Grade Acheivement}_{sc} + \gamma_{02}*10^{th}\text{ Grade Interest}_{sc} + \gamma_{03}*\text{Collaborative Function}_{sc} + a_c + e_{sc}$

Formal Models (Model Set 2a-g). For this set of models, we entered each set of function predictors in different combinations to evaluate their *unique* effect on each of the two outcomes after controlling for each other. We did this specifically because the function variables were so highly correlated with each other (forthcoming in results). The model for 10th Grade Achievement was as follows (for 10th Grade Physics Interest, there was no Interest predictor; otherwise the model was identical).

Model 2a: $Y_{sc} = \gamma_{00} + a_c + e_{sc}$

Model 2b: $Y_{sc} = \gamma_{00} + \gamma_{01}$*9th Grade Achievement$_{sc} + a_c + e_{sc}$

Model 2c: $Y_{sc} = \gamma_{00} + \gamma_{01}$*9th Grade Achievement$_{sc} + \gamma_{02}$*10th Grade Interest$_{sc} + a_c + e_{sc}$

Model 2d: $Y_{sc} = \gamma_{00} + \gamma_{01}$*9th Grade Achievement$_{sc} + \gamma_{02}$*10th Grade Interest$_{sc} + \gamma_{03}$*Student-led Function$_{sc} + a_c + e_{sc}$

Model 2e: $Y_{sc} = \gamma_{00} + \gamma_{01}$*9th Grade Achievement$_{sc} + \gamma_{02}$*10th Grade Interest$_{sc}$ + γ_{03}*Student-led Function$_{sc} + \gamma_{04}$*Teacher-led Function$_{sc} + a_c + e_{sc}$

Model 2f: $Y_{sc} = \gamma_{00} + \gamma_{01}$*9th Grade Achievement$_{sc} + \gamma_{02}$*10th Grade Interest$_{sc}$ $+\gamma_{03}$*Teacher-led Function$_{sc} + \gamma_{04}$*Collaborative Function$_{sc} + e_{sc} + a_c + e_{sc}$

Model 2g: $Y_{sc} = \gamma_{00} + \gamma_{01}$*9th Grade Achievement$_{sc} + \gamma_{02}$*10th Grade Interest$_{sc} + \gamma_{03}$*Student-led Function$_{sc} + \gamma_{04}$*Teacher-led Function$_{sc} + \gamma_{05}$*Collaborative Function$_{sc} + a_c + e_{sc}$

To determine the best of the above models, we used several methods commonly employed for model selection. In this study, AIC, BIC, and LRT were used for model selection. Aikake's information criterion (AIC) and the Bayesian information criterion (BIC) are two criteria often used for model selection (Burnham & Anderson, 2004). The lower the values of AIC and BIC, the better the model. The likelihood ratio test (LRT) is another statistical method used to compare models (Anisimova & Gascuel, 2006). In LRT, the χ^2 test is conducted based on the degree of freedom of different parameters among the models. A smaller p-value suggests more a complex model. LRT favors simpler models.

Results

RQ1: How Frequently do Students Use Mobile Device Learning Functions?

The frequency of student use of the different types of functions can be seen in Table 2. Sixteen percent of the students reported using teacher-led mobile device functions in most in physics classes, while 36% reported seldom using these functions. Fourteen percent of the students reported using student-led functions several times a week, while 60% of students reported that they seldom use them. Results indicated no significant difference among in-class collaborative and after-class collaborative functions. Twenty percent of students stated that they used collaborative functions in every class, and 17% reported using collaborative functions every day. Ten percent and 12% of students reported using collaborative function seldom both in-class and after-class, respectively.

As shown from the means given in Table 3, collaborative functions were used the most in physics classrooms. Results indicate that frequency of use of collaborative functions ($M = 3.40$, $SD = 1.11$) was significantly higher than teacher-led functions ($M = 2.20$, $SD = 1.21$), $t(1314) = 1.89$, $p < 0.001$, and was also significantly higher than student-led functions ($M = 1.88$, $SD = 1.25$), $t(1314) = 1.45$, $p < 0.001$.

RQ2: What are the Relationships among Mobile Functions and Student Outcomes?

Zero-order correlations, without adjusting for classroom membership, are provided in

Table 3. As can be seen, the 10th-grade physics achievement test was not significantly correlated with any mobile learning functions ($p > 0.05$). Tenth grade interest in physics was significantly correlated with all independent variables. Interest in physics was also significantly positively correlated with student-led functions ($r = 0.34$, $p < 0.001$), teacher-led functions ($r = 0.38$, $p < 0.001$), and collaborative functions ($r = 0.44$, $p < 0.001$).

Student 10th Grade Physics Achievement. We conducted an analysis of variance on achievement scores using class as a fixed independent variable and found that there was a significant main effect of class on 10th grade student achievement, $\chi^2 = 3.28$, $df = 15$, $p < 0.001$. Additionally, the baseline multilevel intercept-only model showed that there was a substantial intraclass correlation (ICC) = 0.14, which means 14% of the variance in student achievement can be explained by which 10th grade class the student was in.

The results of Model Set 1 are provided in Table 4. After controlling for classroom (as a random effect in multilevel modeling), 9th grade achievement, and 10th grade physics learning interest, student-led functions did not significantly predict students' physics achievement. Teacher-led and collaborative functions yielded the same results.

The results for Model Set 2 are provided in Table 5. Regardless of the model used, 9th grade physics achievement ($\gamma = 0.64$, $p < 0.001$) and physics interest ($\gamma = 0.09$, $p < 0.05$) significantly predicted 10th grade achievement. Again, none of the mobile device functions uniquely predicted students' physics achievement.

The results of AIC and BIC can be seen in Table 5. Model 3 has the lowest AIC and BIC, which suggests that the model with 9th grade achievement and physics interest best explains the data.

Student 10th Grade Physics Interest. With respect to 10th grade physics interest as the dependent variable, the results of the ANOVA showed unsurprisingly that classroom membership had a significant effect on student physics interest, $\chi^2 = 2.22$, $df = 15$, $p < 0.01$. The ICC = 0.05, indicating that 5% of the variance in 10th grade student physics interest can be explained by which 10th grade classroom the student was in. The results of Model Set 1 for physics interest can be seen in Table 4. After controlling 9th grade achievement, frequency of using student-led functions ($\gamma = 0.37$, $p < 0.001$), teacher-led functions ($\gamma = 0.40$, $p < 0.001$), and collaborative functions ($\gamma = 0.45$, $p < 0.001$) all had a significant positive relationship with students' physics learning interest. The results suggest that with one standard deviation increase in frequency of using student-led functions, students' learning interest increases by 0.37 standard deviations. When teacher-led function use increases by 1 standard deviation, students' learning interest increases by 0.40 standard deviations. Collaborative functions have a similar explanation: with a 1 standard deviation increase in frequency of collaborative function use, students' learning interest increases by 0.45 standard deviations.

Aside from understanding the individual relationships among the three functions and the outcome, another aim was to determine what would the relationship between the different functions and students' physics learning interest be if all the variables were controlled at the same time. As shown in Table 6 (Models 2a-f), Model 2c results are the same as those found in Model Set 1. Student-led functions ($\gamma = 0.37$, $p < 0.001$) had a significant positive relationship with learning interest. In Model 2d, both student-led and teacher-led functions were controlled. Both student-led ($\gamma = 0.16$, $p < 0.05$) and teacher-led ($\gamma = 0.27$, $p < 0.001$) functions had significant positive associations with physics interest. However, the coefficient of student-led functions decreased. Model 2e takes teacher-led and collaborative functions into consideration, and the results showed that after controlling for both variables, teacher-led ($\gamma = 0.17$, $p < 0.001$) and collaborative ($\gamma = 0.33$, $p < 0.001$) functions had significant positive relationships with students' physics learning interest. Finally, Model 2f includes all three function use variables. After controlling for collaborative functions, student-led and teacher-led functions no longer significantly predicted learning interest; only collaborative functions had a significant positive link with students' physics learning interest ($\gamma = 0.32$, $p < 0.001$).

The BIC for Model 2e was lower than that for Model 2f, but Model 2e's AIC was higher than that for Model 2f. To decide between the two models, we used the LRT. The LRT results showed no significant difference between the two models ($p > 0.05$), and as such, the simpler Model 2e should be retained.

Discussion

This study contributes to several important aspects of mobile learning research. Firstly, previous research seldom investigated the role of teachers and students and how they collaborate with each other in mobile learning, especially in science subjects. Little is known about the status quo of teacher- and student-led function usage. Several previous studies attended to the role of teachers and students in mobile learning when developing mobile learning system, but did not report function usage. For example, Holme and Sharples (2002) designed a mobile learning system using pocket PC computers both for teachers and students. They reported only that the teacher and student feedback regarding the mobile learning system was positive, but did not discuss the frequency of use. Other studies haven't differentiated the roles of teachers or students, and therefore their studies report only usage of student-led functions. For example, Thornton and Houser (2005) addressed the usage of different functions in mobile learning in an English class in Japan. However, they reported on the frequency of student-led functions, not teacher-led functions. The present study provides an overview of the frequency of usage of teacher-led, student-led, and collaborative functions. The results of this study reveal that the frequency of collaborative function use is significantly higher than either teacher-led or student-led function use. Teacher-led function use is also significantly higher than student-led function use. For frequency of use, 29% of the students reported using teacher-led functions more than half of the time in classes, while 36% reported using them seldom. Twenty-five percent of the students reported using student-led functions at least once per week, but 60% reported seldom using them. These results demonstrate that student-led functions are not highly used. In contrast, students reported using collaborative functions much more frequently than the other two functions. Seventy-seven percent of the students reported using collaborative functions more than half of the time in classes, and 73% reported using collaborative functions at least once per week.

That collaborative functions were used the most often suggests that when teachers and students can engage with mobile learning together, their frequency of use is high. Blending the roles of teachers and students using mobile learning may ultimately make learning more effective and efficient. For example, in the function *use learning guide*, students can learn from teachers' selected material, which they may believe is more trustworthy than their own materials (e.g., student notes). Teachers can also receive feedback from the *use learning guide* function, which may encourage teachers to use such functions. The results of this study also showed that teacher use of teacher-led functions is high. Teachers treated the mobile learning system as a support for their teaching in this study. If teachers were adequately trained, they would be more involved with mobile learning.

However, student-led functions remained the least used in this study, which suggests that students may still favor traditional teacher-led, classroom-based instruction. It is possible that when not in a highly structured classroom environment led by the teacher, students may lack the motivation to use mobile devices. Thus, a way to engage students in using mobile devices outside the classroom is needed. One such solution is to find ways to make the learning system more interesting to students. For example, Schmitz, Klemke, and Specht (2012) found that mobile learning games can enhance students' motivation. The mobile learning system investigated in the present study could be similarly modified by installing teacher-selected educational gaming on the tablet in conjunction with the learning materials the teacher provides, possibly resulting in greater student use.

Secondly, this study also helps fill the gap in previous research by using the teacher-student led model to detect the effects of mobile learning in student learning achievement in physics classes. Neither student-led, nor teacher-led, nor collaborative functions significantly predicted students' learning achievement in the present study, even though students heavily used the first two functions, suggesting that more frequent use of mobile devices may not lead to greater students' achievement. One explanation for these results may be that we assessed only the frequency with which students used the various functions, but not the quality of that use. For example, *class note* is categorized as a student-led function in which students can review class notes after class; these notes can be easily modified, tagged, and searched. However, in the present study, we did not evaluate whether the notes they took in class were reliable, reasonable, and consistent with the teaching. Such evaluation of the quality of student use might better explain the link between use and achievement. *Class test,* which is categorized as a teacher-led function, is another example of the way in which evaluating the quality of use might lead to more instructive results. Teachers use the *class test* function to retrieve statistical results immediately, unlike the traditional, slower process, in which teachers need to read and grade each student's answers to obtain the results. This function does offer assessment information of the students' learning in a convenient manner, but it is unknown how teachers choose to use such information. Teachers may or may not change their instructional moves after obtaining the statistical results to address students' learning needs revealed by the *class test*. Better teacher training in effective use of such statistical information might lead to a stronger correlation between more frequent use of mobile devices and increased student achievement.

Most of the previous research reported positive outcomes on student achievement from mobile learning. However, as Crompton et al. (2016) point out, it is important to report negative findings so that researchers and practitioners will not repeat the same failures. Results of the present study strongly suggest that in addition to studying the frequency with which mobile learning technology is used, researchers need to find ways to effectively evaluate the quality of mobile learning interactions. Such qualitative evaluations in conjunction with data on frequency of use may provide more insight into effective deployment of mobile learning in the classroom.

Thirdly, few studies have investigated the effect of mobile learning on interest in physics, not to mention which functions may increase students' physics interest. The present study demonstrated that the frequency of teacher-led and collaborative function use had a positive link with students' physics learning interest. Ruiz, Mintzer, and Leipzig (2006) assert that collaborative functions offer a strong learning stimulus to learners. Our findings support this assertion. One explanation may be that collaborative resources can be more closely tied to class content than student-led functions. In the *preview learning guide* function, for example, students can access resources to review knowledge that their teacher has provided. Because these resources are directly linked to class content, students may see the relevance and utility of the resources, which will in turn trigger their interest to learn. Teacher-led functions also have the potential to significantly increase students' learning interest. For example, teachers were able to use the *clicker* function to pose questions or votes in class and ask students to respond via their tablets. In a traditional classroom, a teacher could only ask one or two students to answer a question, but now, students can all be involved, thereby keeping them engaged. In the past, some students may have felt sleepy or not paid enough attention in the classroom, but now they are, in a way, "forced" to be engaged in class activities. Hannafin and Land (1997) found that technology enables students to become immersed, which increases students' interest. The present study results similarly suggested that when teachers use more teacher-led and collaborative functions, this enhances students' interest.

However, results of the present study indicate that student-led functions do not have a significant relationship to learning interest. This may be due to students considering student-led functions as mundane or routine. In the function *build incorrect items set*, for example, students may treat the material as a daily routine, like doing homework every day, leading to lack of engagement with the material. More research should be conducted to discover why this is.

Limitations and Future Research

Firstly, this study took place in only one high school in China, so results may not be generalizable. More research could be carried out in various schools, cities, or even countries. Secondly, better measures should be developed to capture the quality of mobile device use. As stated before, this study only captures the frequency of use of the different functions, but not the quality of use. Thirdly, more research should be done on the effects of student-led mobile learning functions on learning interest. This study did not find significant results, but this may be due to students' lack of interest in student-led functions due to their potentially routine nature. A fourth and related concern is that taking notes on paper is still prevalent in Chinese high school classrooms; thus, more study is need as to how to increase student's interest in using mobile devices for note taking. Finally, this study only addresses the student's perspective; more research investigating the teacher's perspective (Zhai, Zhang, & Li, in press) would help to determine how teachers use and view the effectiveness of different functions.

References

Ahmed, S., & Parsons, D. (2013). Abductive science inquiry using mobile devices in the classroom. *Computers & Education*, *63*, 62-72.

Anisimova, M., & Gascuel, O. (2006). Approximate likelihood-ratio test for branches: A fast, accurate, and powerful alternative. *Systematic biology*, *55*(4), 539-552.

Burnham, K. P., & Anderson, D. R. (2004). Multimodel inference understanding AIC and BIC in model selection. *Sociological methods & research*, *33*(2), 261-304.

Chang, C. B., Wall, D., Tare, M., Golonka, E., & Vatz, K. (2014). Relationships of attitudes toward homework and time spent on homework to course outcomes: The case of foreign language learning. *Journal of Educational Psychology*, *106*(4), 1049.

Cheon, J., Lee, S., Crooks, S. M., & Song, J. (2012). An investigation of mobile learning readiness in higher education based on the theory of planned behavior. *Computers & Education*, *59*(3), 1054-1064.

Crompton, H., Burke, D., Gregory, K. H., & Gräbe, C. (2016). The use of mobile learning in science: A systematic review. *Journal of Science Education and Technology, 25*(2), 1–12.

Dunleavy, M., Dede, C., & Mitchell, R. (2009). Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning. *Journal of Science Education and Technology*, *18*(1), 7-22.

Godwin-Jones, R. (2011). Emerging technologies: Mobile apps for language learning. *Language Learning & Technology*, *15*(2), 2-11.

Hannafin, M. J., & Land, S. M. (1997). The foundations and assumptions of technology-enhanced student-centered learning environments. *Instructional science*, *25*(3), 167-202.

Hofmann, D. A. (1997). An overview of the logic and rationale of hierarchica linear models. *Journal of Management, 23,* 723–744.

Holme, O., & Sharples, M. (2002). Implementing a student learning organiser on the pocket pc platform. In *Proceedings of the European Workshop on Mobile and Contextual Learning* (pp. 40-43).

Hsiao, H. S., Lin, C. C., Feng, R. T., & Li, K. J. (2010). Location Based Services for Outdoor Ecological Learning System: Design and Implementation. *Educational Technology & Society*, *13*(4), 98-111.

Hwang, G. J., & Chang, H. F. (2011). A formative assessment-based mobile learning approach to improving the learning attitudes and achievements of students. *Computers & Education*, *56*(4), 1023-1031.

Jansen, M., Lüdtke, O., & Schroeders, U. (2016). Evidence for a positive relation between interest and achievement: Examining between-person and within-person variation in five domains. *Contemporary Educational Psychology*, *46*, 116-127.

Kolk, K., Hartog, R., Beldman, G., & Gruppen, H. (2013). Exploring the potential of smartphones and tablets for performance support in food chemistry laboratory classes. *Journal of Science Education and Technology*,*22*(6), 984-992.

Kukulska-Hulme, A. (2009). Will mobile learning change language learning? *ReCALL*, *21*(02), 157-165.

Lamb, R., Annetta, L., Meldrum, J., & Vallett, D. (2012). Measuring science interest: Rasch validation of the science interest survey. *International Journal of Science and Mathematics Education*, 10(3), 643–668.

Looi, C. K., Zhang, B., Chen, W., Seow, P., Chia, G., Norris, C., & Soloway, E. (2011). 1: 1 mobile inquiry learning experience for primary science students: A study of learning effectiveness. *Journal of Computer Assisted Learning*, *27*(3), 269-287.

Miangah, T. M., & Nezarat, A. (2012). Mobile-assisted language learning.*International Journal of Distributed and Parallel Systems*, *3*(1), 309.

Naismith, L., Lonsdale, P., Vavoula, G. N., & Sharples, M. (2004). Mobile technologies and learning.

Pintrich, P. R. (2003). A motivational science perspective on the role of student motivation in learning and teaching contexts. *Journal of educational Psychology*, *95*(4), 667.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods.* Thousand Oaks, CA: Sage Publications.

Romrell, D., Kidder, L. C., & Wood, E. (2014). The SAMR Model as a Framework for Evaluating mLearning. *Journal of Asynchronous Learning Networks*, *18*(2), n2.

Ruiz, J. G., Mintzer, M. J., & Leipzig, R. M. (2006). The impact of e-learning in medical education. *Academic medicine*, *81*(3), 207-212.

Schmitz, B., Klemke, R., & Specht, M. (2012). Effects of mobile gaming patterns on learning outcomes: a literature review. *International Journal of Technology Enhanced Learning*, *4*(5-6), 345-358.

Sharples, M., Arnedillo-Sánchez, I., Milrad, M., & Vavoula, G. (2009). Mobile learning. In *Technology-enhanced learning* (pp. 233-249). Springer Netherlands.

Shen, R., Wang, M., & Pan, X. (2008). Increasing interactivity in blended classrooms through a cutting-edge mobile learning system. *British Journal of Educational Technology*, *39*(6), 1073-1086.

Song, Y. (2014). “Bring Your Own Device (BYOD)” for seamless science inquiry in a primary school. *Computers & Education*, *74*, 50-60.

Tan, T. H., & Liu, T. Y. (2004). The mobile-based interactive learning environment (MOBILE) and a case study for assisting elementary school English learning. In *Advanced Learning Technologies, 2004. Proceedings. IEEE International Conference on* (pp. 530-534). IEEE.

Thornton, P., & Houser, C. (2005). Using mobile phones in English education in Japan. *Journal of computer assisted learning*, *21*(3), 217-228.

Traxler, J. (2010). Students and mobile devices. *Research in Learning Technology*, *18*(2).

Zhai, X., Zhang, M., & Li, M. (in press) One-to-one mobile technology in high school physics classrooms: Understanding its use and outcome. To appear in *British Journal of Educational Technology*.

Zydney, J. M., & Warner, Z. (2016). Mobile apps for science learning: Review of research. *Computers & Education, 94*, 1–17.

Table 1.

Results of Confirmatory Factor Analyses

Scale	χ^2	*df*	χ^2/df	RMSEA	CFI	TLI
Mobile Technology Function Items	280.18	85	3.29	0.072	0.974	0.968
Physics Interest Items	1.38	1	1.38	0.029	1.000	0.998

Note. RMSEA = root mean square error of approximation; CFI = comparative fit index; TLI = Tucker Lewis index.

Table 2.

Frequency and Duration of Mobile Technology Use Functions

	In Class	%		After School	%
Teacher-led	Used in every class	8	Student-led	Everyday	8
	Used in most classes	8		2-3 times a week	6
	Used in about half classes	13		Once a week	11
	Used in less than half classes	34		Once a month	15
	Seldom use	36		Seldom use	60
Collaborative	Used in every class	20	Collaborative	Everyday	17
	Used in most classes	34		2-3 times a week	31
	Used in about half classes	23		Once a week	25
	Used in less than half classes	13		Once a month	16
	Seldom use	10		Seldom use	12

Table 3.

Descriptive Statistics and Zero-Order Correlations among Variables

Measure	*M*	*(SD)*	1.	2.	3.	4.	5.	6.
Outcomes								
1.10th Grade Physics Achievement	54.09	(20.97)	--					
2. 10th Grade Physics Interest	4.04	(0.83)	**.26**	--				
Predictors								
3. 9th Grade Achievement	79.54	(15.30)	**.69**	**.22**	--			
4. Student-Led Function	1.88	(1.25)	-.19	**.34**	-.17	--		
5. Teacher-Led Function	2.20	(1.21)	.03	**.38**	.01	**.78**	--	
6. Collaborative Function	3.40	(1.11)	.02	**.44**	.01	**.57**	**.69**	--

Note. *N* = 439 students from 16 classrooms. Pearson's *r* reported; correlations in boldface are significant at the .05 level.

Table 4.

Multilevel Model Results for Exploratory Model Set 1

	10th Grade Outcomes	
	Achievement	Physics Interest
Predictor Sets	*Coeff*	*Coeff*
Set 1a		
9th Grade Physics Achievement	0.64***	0.20***
10th Grade Physics Interest	0.10**	--
Student-led Function	-0.02	0.37***
Set 1b		
9th Grade Physics Achievement	0.64***	0.19***
10th Grade Physics Interest	0.09**	--
Teacher-led Function	-0.01	0.40***
Set 1c		
9th Grade Physics Achievement	0.64***	0.20***
10th Grade Physics Interest	0.11**	--
Collaborative Function	-0.04	0.45***

Note. $N = 439$ students from 16 classrooms. All variables were standardized into z-scores prior to analysis ($M = 0$, $SD = 1$).

* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 5.

Multilevel Model Results for Predicting 10th Grade Physics Achievement

	Model 2a	Model 2b	Model 2c	Model 2d	Model 2e	Model 2f	Model 2g
Fixed Effects	*Coeff*	*Coeff*	*Coeff*	*Coeff*	*Coeff*	*Coeff*	*Coeff*
γ_{00} (Intercept: 10th Physics Grade Achievement)	-0.03	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
γ_{01} (9th Grade Achievement)		0.67***	0.64***	0.64***	0.64***	0.64***	0.64***
γ_{02} (10th Grade Physics Interest)			0.09**	0.10**	0.10**	0.11**	0.11**
γ_{03} (Student-led Function)				-0.02	-0.04	--	-0.04
γ_{04} (Teacher-led Function)					0.03	0.03	0.05
γ_{05} (Collaborative Function)						-0.01	-0.05
Random Effects	*Var*	*Var*	*Var*	*Var*	*Var*	*Var*	*Var*
Between-Class	0.14	0.04	0.03	0.04	0.03	0.03	0.03
Within-Class, Residual	0.88	0.49	0.48	0.49	0.48	0.48	0.48
Model Fit Indices	*Value*	*Value*	*Value*	*Value*	*Value*	*Value*	*Value*
AIC	1222	958	952	954	956	955	957
BIC	1235	974	973	979	984	984	989

Note. N = 439 students from 16 classrooms. All variables were standardized into z-scores prior to analysis (M = 0, SD = 1).

Table 6.

Multilevel Model Results for Predicting 10th Grade Physics Interest

	Model 2a	Model 2b	Model 2c	Model 2d	Model 2e	Model 2f
Fixed Effects	*Coeff*	*Coeff*	*Coeff*	*Coeff*	*Coeff*	*Coeff*
γ_{00} (Intercept: 10th Grade Interest)	-0.02	-0.01	-0.01	-0.02	-0.02	-0.02
γ_{01} (9th Grade Achievement)		0.20***	0.20***	0.19***	0.20***	0.20***
γ_{02} (Student-led Function)			0.37***	0.16*		0.11
γ_{03} (Teacher-led Function)				0.27***	0.17***	0.09
γ_{04} (Collaborative Function)					0.33***	0.32***
Random Effects	*Var*	*Var*	*Var*	*Var*	*Var*	*Var*
Between-Class	0.06	0.04	0.05	0.05	0.03	0.03
Within-Class, Residual	0.94	0.91	0.78	0.75	0.72	0.71
Model Fit Indices	*Value*	*Value*	*Value*	*Value*	*Value*	*Value*
AIC	1241	1225	1163	1150	1125	1124
BIC	1253	1240	1184	1175	1150	1153

Note. *N* = 439 students from 16 classrooms. All variables were standardized into *z*-scores prior to analysis (*M* = 0, *SD* = 1).

Appendix A

Table A1. Student-Teacher Categories for In-Class Functions (Zhai, Zhang, & Li, in press)

Functions	Mobile Technology-Supported Instruction	S-T
Screen Broadcast	Students watch slides or other material offered by teachers from mobile-device screens. They can take screenshots and store the content in their own files.	C
Picture Uploading	When teachers assign subjective work to students, they can upload pictures that are taken of their work, test or drawing to teachers immediately during class.	T
Doodling	When teachers broadcast screens or assign subjective work, students write or draw directly on the screen and store or submit.	T
Clicker	When teachers have formative questions, quick tests, or votes for students to monitor or adjust the instruction, they will ask students to respond by using clickers.	T
Class Test	When teachers want to monitor students' learning outcome during class or at the end of class, they will issue a class test to students. Teachers can retrieve statistical results immediately.	T
Screen Display	Teachers display a student's screen onto the whiteboard to show the student's work or drawing. Students can explain their work at the same time.	T
Use Learning Guide	Students can watch the guide resources (pictures, videos, simulation experiments, etc.) that accompany the teacher's explanation. Teachers can check the statistical report and adjust their instruction.	C

Note. S = student-led function; T = teacher-led function; C = collaborative function.

Table A2. Student-Teacher Categories for After-School Functions

Functions	Mobile Technology-Supported Instruction	S-T
Preview Learning Guide	Use of resources in learning guide (texts, pictures, videos, simulation experiments, etc., provided by teachers for class usage) to prepare for class.	C
Review Learning Guide	Use of resources in learning guide (texts, pictures, videos, simulation experiments, etc. which may be used in class) to review the learned content.	C
My Homework	If the homework consists of objective multiple-choice items, student answers can be statistically summarized for teachers automatically. If the homework consists of subjective items, students can complete them on paper and upload them by taking pictures. Teachers correct or give comments on them directly. They can also add items to the incorrect items set or check homework guide.	C
My Textbook	Students use the textbook for preparation, review, and searching, or as a tool for learning. It is easy to insert tags, highlight, etc.	S
Mindmap	Students use this function especially at the end of a chapter for building knowledge structure. It can also be used to make notes	S
Class Notes	Students review class notes after class, which can be easily modified, reorganized, tagged, and searched, etc.	S
Build Incorrect Items Set	Students add items to the incorrect items set and add tags or notes to it.	S
Use Incorrect Items Set	Review or management of the incorrect items set in the device, such as highlighting, marking, searching, indexing, etc.	S

Note. S = student-led function; T = teacher-led function; C = collaborative function.