sustainability

MDPI

Article

Using a Tablet Computer Application to Advance High School Students' Laboratory Learning Experiences: A Focus on Electrical Engineering Education

Pao-Nan Chou * and Shu-Tzu Feng

Department of Education, National University of Tainan, Tainan 70005, Taiwan; maker.nutn@gmail.com
* Correspondence: pnchou@gm2.nutn.edu.tw; Tel.: +886-6-2133111 (ext. 765)

Received: 29 November 2018; Accepted: 8 January 2019; Published: 13 January 2019

check for updates

Abstract: This study proposed an innovative instructional strategy for pre-college engineering education. Learning topics on electrical engineering education in a laboratory setting were selected for further exploration. Specifically, the study investigated how tablet computers with one adopted application influenced student engineering learning. The study adopted a quasi-experimental pretest and posttest research design. The educational experiment lasted for 6 weeks. The research participants comprised 57 ninth-grade students from a public high school in Taiwan. The students employed either a tablet computer or laptop computer to engage in weekly 3-h laboratory studies. A criterion test was developed to measure student knowledge of electrical engineering. The results revealed that the instructional effectiveness was identical for all the students, regardless of whether they used a tablet or laptop computer. However, those using the tablet computers achieved greater learning improvement. In addition, the qualitative data indicated that the tablet computers facilitated student learning in various engineering learning activities. The results of the study suggested that engineering educators in different educational levels might consider similar instructional methods to inspire students' engineering learning.

Keywords: laboratory mobile learning; tablet computer application; electrical engineering education; pre-college engineering education; industry 4.0

1. Introduction

To embrace the concept of industry 4.0, Dallasega [1] stated that "the entailing increased degree of digitization and automation requires a dramatic change for engineering education." From a radical change perspective, Ricardo et al. [2] even proposed the idea of engineering education 4.0, in which a curriculum renovation for engineering education is necessary. However, within this trend, the current research practice of innovation in engineering education (e.g., Jeganathan et al. [3]) tends to emphasize higher education. Theoretical discussions regarding pre-college (or K–12) engineering education remain uncommon. Since pre-college engineering education is closely related to students' choices for college engineering majors [4], advancing students' engineering learning experiences though a new pedagogical approach may develop their competence preparation for pre-service engineers [5].

To verify theoretical knowledge received in traditional classrooms, laboratories in high school settings provide students with valuable opportunities to use scientific machines and technological gadgets for science and engineering experiments [6]. In some instructional cases, students in laboratories might be provided with desktop or laptop computers to summarize their findings after determining experimental results [7]. However, according to Huang et al.'s [8] scientific report, current teaching practices in laboratories tend to focus on paper-based documentation after students have completed experiments. In other words, after using gadgets to observe specific scientific phenomenon, students are often instructed to summarize their findings in written laboratory reports.

According to Huang and Tsai's [9] analytic report, the integration of mobile technologies into classrooms has confirmed instructional benefits for supporting student learning, particularly for active learning behaviors and better learning performances. For this reason, Rogado et al. [10] proposed that mobile learning has the potential to advance students' engineering learning experiences in a laboratory setting. In the current study, diverging from the traditional teaching approach (i.e., writing paper-based reports), the concept of mobile learning was adopted in a laboratory at a high school in which students used one application on tablet computers to record their observations and findings in an electrical engineering experiment.

In the present study, the proposal of mobile learning integration in the science laboratory can fit well into the role of engineering education in the industry 4.0 Era, which emphasizes digitization and automation [1]. Regarding digitization, the tablet computers with one adopted application empowered students to digitally document their experimental findings in a manner other than relying on written reports, and enabled the teacher to simultaneously digitally observe students' progress. As for automation, after students completed their digital scientific reports, their work would be automatically saved to a cloud computing server. Subsequently, the teacher provided instant feedback by accessing the students' works. Overall, the digitization and automation process in the science laboratory might advance and facilitate students' engineering learning.

The purpose of this study was to investigate how using tablet computers with one adopted application influenced students' engineering learning. The tablet computers employed in the study were iOS-based mini tablets (i.e., iPad Minis). A 6-week educational experiment was conducted at a public high school in Taiwan. Electrical engineering knowledge was selected as the main instructional theme. Fifty-seven high school students voluntarily engaged in engineering learning activities in a laboratory. The main research question was as follows:

- Do significant differences exist between engineering learning achievements of students using tablet computers or laptop computers to facilitate their laboratory learning process?

2. Literature Review

2.1. Mobile Learning in Classrooms

Mobile learning is often defined as "using mobile technologies to facilitate learning" [9]. Mobile technologies refer to smart-phones or tablet computers that can connect wirelessly to the Internet. Depending on the teaching strategy, mobile learning can occur in outdoor fields or indoor classrooms [9]. Ferreira et al. [11] proposed that a critical concept in mobile learning is mobility; students can roam freely in most practical physical settings while using mobile technologies to obtain information. According to the Horizon Report [12], mobile learning is regarded as a crucial educational trend that could completely change current teaching practices and influence learning styles in K–12 educational environments.

App adoption is a critical step in implementing mobile learning. Generally, app selection strategies may affect the educational quality of mobile learning in classrooms [13]. Apps installed on smart-phones or tablet computers are similar to desktop computer software, and likewise can be used for various purposes. Depending on the mobile device operating system (e.g., Android or iOS), mobile learning users can download free or paid apps from unique app stores through a wireless communication. In the literature, some empirical studies have reported the benefits of apps in student engineering learning. For example, Boticki et al. [14] used an Android-based app to teach computer engineering concepts, reporting that app adoption efficiently facilitated student learning of sorting algorithms.

2.2. Tablet Computers in Engineering Education

Tablet computers are mobile computers with more compact features than laptop computers. The most popular type of tablet computers are A4 sized and without physical keyboards. Users can employ a stylus or directly use their fingers to create handwritten notes and drawings. For engineering pedagogy purposes, Walker et al. [15] argued that tablet computers combine several multimedia functions that could replace other instructional aids such as electronic white boards and digital slides. Amelink et al. [16] considered that tablet computers have the potential to facilitate various learning activities for student–instructor interaction. Casas et al. [17] proposed that tablet computers are suitable for three specific class learning activities: note taking, slide annotation and group discussion. However, regarding the use of tablet computers in teaching practice, previous studies have tended to focus on traditional classroom settings rather than science laboratories.

From an empirical perspective, previous studies have evidenced the educational benefits of tablet computers in various engineering courses. Fang [18] used a tablet computer to facilitate student learning in engineering dynamics, reporting that it increased learning interactions. Chegenizadeh and Nikra [19] adopted a tablet computer for a geotechnical engineering class, finding that it increased student engagement, productivity, and satisfaction. In a study by Johri and Lohani [20], students appreciated the tablet computer's visual representations, which aided knowledge construction and management in an engineering exploration course. However, although previous related studies have revealed several positive learning outcomes, a lack of an experimental research design is a potential problem for verifying the effect of tablet computers in classrooms.

2.3. Advancing the Laboratory Learning Experience

Because of increasing emphasis on K–12 engineering education, science education curricula in schools worldwide have begun incorporating engineering knowledge [5,21]. For example, a new K–12 science education framework, outlining engineering design as a feature of crucial science learning tasks, has been proposed in the United States to promote engineering learning [22]. Under such an educational reform, the science laboratory in K–12 learning environments becomes critical in learning engineering concepts. Therefore, designing an innovative instructional strategy for advancing laboratory learning experiences is necessary [7].

Because of the advantage of mobility, Markey et al. [23] and Rogado et al. [10] have proposed that mobile technologies might be suitable for laboratory learning. For field observation purposes, Benson et al. [24] suggested that tablet computers represent a superior instructional solution for replacing traditional teaching practices (e.g., paperwork) in science laboratories. However, the number of studies investigating mobile learning in laboratory settings is still limited.

3. Research Method

3.1. Research Design

This study adopted a quasi-experimental pretest and posttest research design to investigate the research question. The research focus was the effect of different instructional tools on the engineering learning achievements of students. The independent variable was the type of educational technology (tablet computer or laptop computer) that students used to facilitate engineering learning in the science laboratory. The dependent variable was student learning outcomes in electrical engineering. The rationale for not assigning a traditional control group (i.e., only without the technology intervention) was that students in such a group would not gain the same potential learning advantages as students who were provided with technological tools would [25], resulting in a meaningless comparison. In addition, because engineering pedagogy involves complex abstract knowledge, one research assumption was that the technological tools used in both groups were more effective for engineering learning. Table 1 presents the research design of the study.

Table 1. Quasi-experimental study design.

Group	Pretest	Experiment *	Posttest
Experimental group (Class A)	O_1	X_1	O_3
Control group (Class B)	O_2	X_2	O_4

X_1: Students using tablet computers with adopted apps in the science laboratory. X_2: Students using laptop computers with PowerPoint in the science laboratory. O_1~Q_4: Criterion test on electrical engineering. * The educational experiment lasted for 6 weeks.

Students in both the experimental and control groups engaged in a teamwork-learning scenario. The study teams comprised four or five students; each team member collaboratively used the given technological tool to complete engineering learning assignments. To improve learning results in a science laboratory setting, Chou et al. [26] suggested the heterogeneous group principle as an appropriate teamwork strategy for high school students. Therefore, according to the mean scores of three sectional science and technology examinations, the students in the present study were assigned to different heterogeneous groups in which individual abilities were divergent. The students received a pretest one week before the experiment, and a posttest one week after the completion of the experiment, which was completed in 30 min. Figure 1 shows a photograph of a team working in the experimental group.

Figure 1. Students in a team using a mini tablet computer in the laboratory.

3.2. Experimental Control

To prevent extraneous factors from influencing the validity of the experiment, strategies for experimental control were adopted [27]. Table 2 summarizes the strategies applied in the study.

Table 2. Strategies for experimental control in the study.

Control Factor	Description
1. Class instructor	The same instructor taught the course, which was entitled Science and Technology.
2. Class time	Both the experimental and control groups received the same class time (60 min per class).
3. Learning contents	The same learning material and textbook were employed for imparting engineering knowledge.

Table 2. *Cont.*

Control Factor	Description
4. Class setting	All learning activities occurred in the same science laboratory.
5. Test implementation	The pretest and posttest were administered on the same day of the week. The same concepts were measured in both tests.
6. Learning activity	Students completed the same learning tasks in the laboratory. Taking the task outside the classroom was not permitted.
7. Initial behavior	The pretest employed a covariance variable to control student initial learning behaviors.
8. Assignment rule	The same rubrics for assignments were created for both the experimental and control groups.

3.3. Research Instruments

3.3.1. GoodNote (Experimental Group)

GoodNote is an iOS-based app that allows users to create digital notes by using a tablet computer. The main functions of this app include picture taking, word processing, and drawing. Furthermore, the advanced function of synchronic editing enables users to co-edit the same document simultaneously. For teaching purposes, the instructor was able to observe students' document-editing process by accessing the students' notes. Overall, the students had no problems using the app to create colorful multimedia-based notes. In the experimental group, each student team was given two small tablet computers to engage in the app-based learning activity. Figure 2 shows a screenshot of GoodNote.

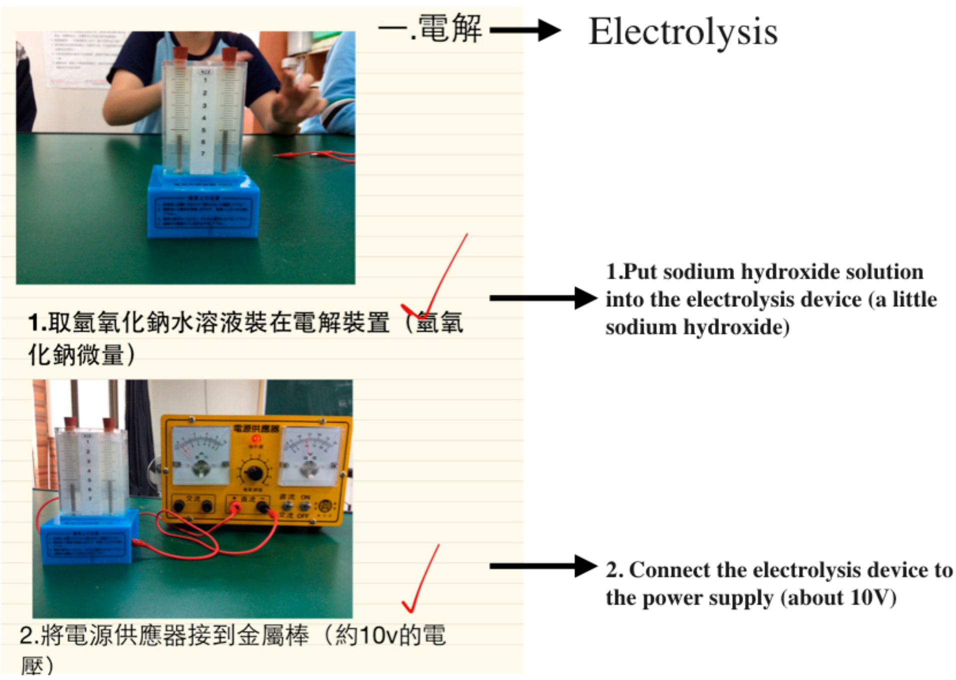

Figure 2. A page with teacher annotation in GoodNote. (The teacher read over the students' assignments with marks).

3.3.2. PowerPoint (Control Group)

In contrast to the experimental group, each student team in the control group was given two laptop computers with a digital camera to complete the laboratory assignments. The purpose of the digital camera was to compensate for the picture-taking function of GoodNote. Students employed PowerPoint to document their group project. The assignment requirements for the multimedia content of the PowerPoint presentation were the same as those for GoodNote. Because the students could not co-edit PowerPoint files simultaneously, they had to organize each of their files to compose a final project. To maintain progress, the instructor moved around the laboratory to examine the group projects. Figure 3 is a screenshot of a PowerPoint project completed by a student group.

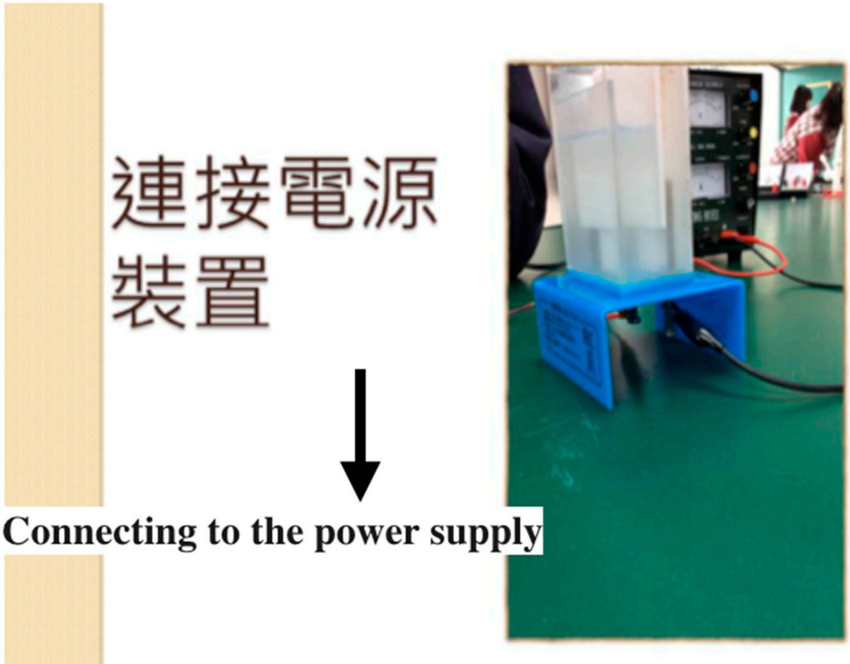

Figure 3. Screenshot of a PowerPoint project documenting student findings. (Students used PowerPoint to document their laboratory findings: connecting to the power supply).

3.3.3. Criterion Test

In the study, a criterion test on electrical engineering was developed. The test covered six learning domains: (a) battery introduction, (b) chemical reaction of circuit, (c) the relationship between magnetic field and magnetic line of force, (d) magnetic effect of circuit, (e) interaction between circuit and magnetic field, and (f) electromagnet effect. The test contained 20 short-answer question items. The score range of the test was between 0 and 100. Higher test scores represented higher student learning achievement in electrical engineering.

This study adopted a three-stage process to ensure the validity and reliability of the test. First, two high school teachers of science and technology and one university professor of engineering examined a draft of the test. Next, a revised version of the test was distributed to 10 high school students to verify the item description. Finally, the final version of the test was administered to 37 high school students who did not participate in the educational experiment. The results of the item analysis indicated that all the test items met the basic requirement of the discrimination index (higher than 0.33). In addition, the results of the reliability test showed that the reliability coefficient was 0.86. Therefore, according to basic evaluation standards suggested by Aiken and Groth-Marnat [28], the test demonstrated high validity and reliability. Figure 4 shows a representative test item on electromagnet effect.

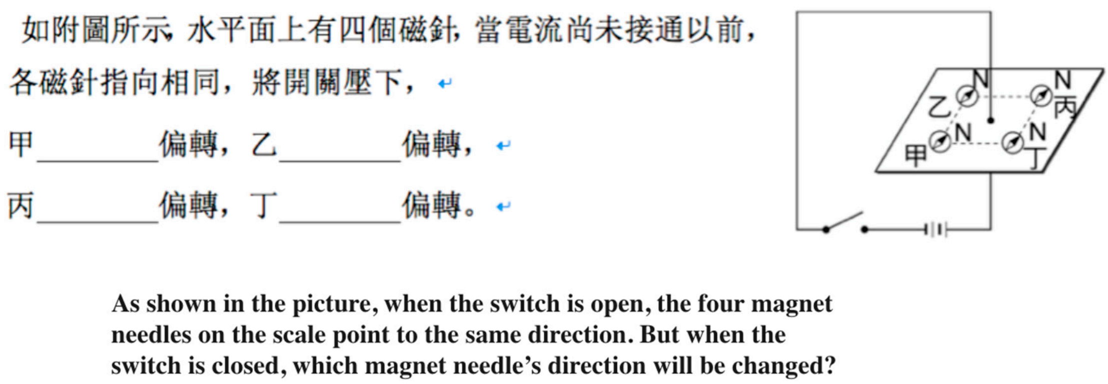

Figure 4. Test item from the criterion test on electromagnet effect. (Students should choose which item correctly describes the electromagnet effect).

3.3.4. Qualitative Data

The qualitative data played a minor role in supporting the quantitative information. This study collected qualitative data from: the teacher's observation report and through informal interviews between the teacher and students. The observation report comprised weekly class observation; the interviews were conducted within 30 min through informal conversations (without a specific interview guide) between the teacher and some of the students privately outside the classroom. Two students in each team in the experimental group were randomly selected for the interviews. The conversations in each interview were digitally recorded. Subsequently, the interview contents were transcribed for further analysis and comparison with the teacher's observation report.

3.4. Research Participants

In the study, the research participants comprised 57 ninth-grade students (Class A: 30, Class B: 27) from a public high school in Taiwan (See Table 3). Because the students had taken several computer courses in the first and second years of high school, they already possessed basic knowledge of computer application functions such as document editing in Word and slide creation in PowerPoint. All students had experience using desktop or laptop computers to facilitate their learning in the science laboratory. Prior to the educational experiment, the students in the experimental group also received instructions for using GoodNote. In both study groups, the students in each team took turns using the learning technologies (i.e., tablet or laptop computers) to assume different group roles. For instance, after the students used the scientific instruments in the laboratory, they took turns using the tablet computer to document their findings.

Table 3. Research participant profiles.

Group	Class	*n* *	Number of Teams	Team Size
Experimental	Class A	30	6	5
Control	Class B	27	6	4 or 5

* The sample size meets the basic requirement of GPower.

3.5. Research Procedure

In the study, the major learning activity in the science laboratory was a report on engineering learning. Regardless of which team the students were assigned to, upon entering the laboratory, each team received a document outlining the report requirements and was given several scientific instruments for engineering learning. Subsequently, the instructor held a class related to a specific unit to impart laboratory knowledge. Upon completing the class, each group began manipulating the scientific instruments and brainstorming on using the given technological tool (i.e., tablet or laptop computer) to summarize their findings. Once their reports were completed, each student team alternately used their learning devices to share their report results through a projector at the front of the laboratory. Subsequently, the instructor provided feedback to each group. A task requirement was that the content in the scientific reports had to contain multimedia elements (i.e., static images and textual descriptions of the laboratory learning process) to serve as components of student responses to open-ended questions devised by the instructor. Table 4 presents a summary of the learning schedule for the weekly engineering learning unit. Figure 5 shows the detailed research procedure.

Table 4. Summary of the learning schedule for the weekly engineering learning unit.

Learning Step	Content *	Time Allocation
1. Preparation	The students received an instructional document and obtained scientific instruments	10 min
2. Orientation	The instructor imparted basic concepts of laboratory learning	40 min
3. Observation and exploration	The students manipulated the instruments and used varied technological learning devices to document their findings	100 min
4. Presentation	Students used their learning devices to share their report results	30 min

* Students engaged in 3 h laboratory learning per week during a 6-week experiment.

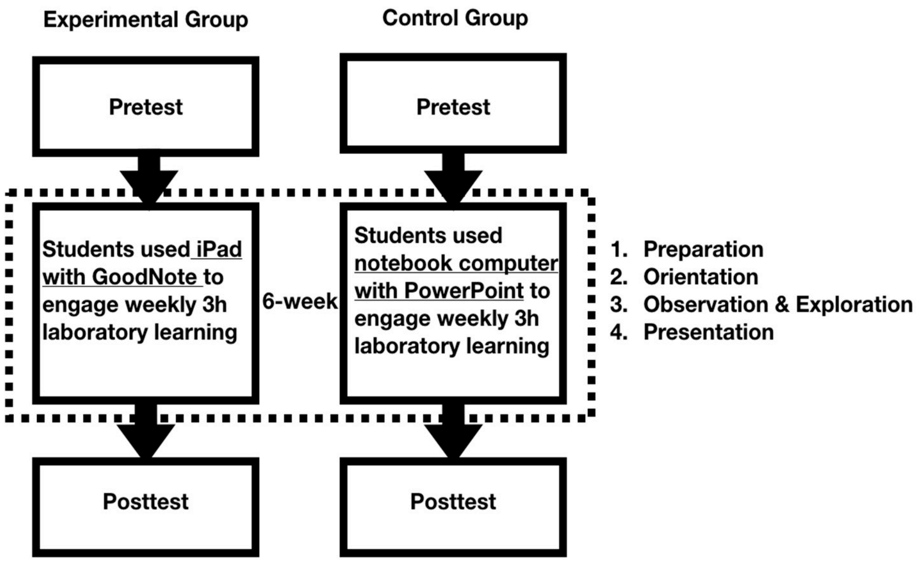

Figure 5. Research procedure of the study.

3.6. Data Analysis

In the study, both descriptive and inferential statistics were used to analyze the collected data. The descriptive statistics were the mean and standard deviation of student learning outcomes. For the inferential statistics, a one-way analysis of covariance (ANCOVA) was employed to observe the effect of the independent variables (i.e., varied learning technologies) on the student learning achievements. A t-test was used to measure the learning improvement between the pretest and posttest.

4. Research Result and Discussion

4.1. Quantitative Findings

Tables 5 and 6 summarize the results of the t-test with descriptive statistics and one-way ANCOVA, respectively. The results in Table 5 reveal significant within-groups differences between the posttest and pretest for the experimental ($t = -9.58$, $p < 0.01$) and control groups ($t = -7.39$, $p < 0.01$). In other words, student learning improved in both groups. Regarding the mean difference between the posttest and pretest scores, the students in experimental group (47.67) exhibited superior learning improvement compared with those in the control group (44.81). When considering the role of the pretest, the results in Table 6 reveal no significant between-groups difference for the posttest ($F = 0.55$, $p > 0.05$). Therefore, when the effect of the pretest was controlled, the learning outcomes in both study groups were identical.

Table 5. Results of the *t*-test.

	n	Posttest–Pretest	Pretest		Posttest		*t*	*df*
			M	SD	M	SD		
Experimental	30	47.67	9.17	10.43	56.83	22.15	−9.58 **	55
Control	27	44.81	8.15	6.39	52.96	28.60	−7.39 **	55

** $p < 0.01$.

Table 6. Results of the one-way ANCOVA.

Source	SS	*df*	MS	F	*p*
Covariance: Pretest	3484.85	1	3484.85	5.88	0.02 *
Class	325.84	1	325.84	0.55	0.46
Errors	32,002.28	54	592.64		

* $p < 0.05$.

To ensure the similar learning behaviors between two groups of students prior to the study, Table 7 reports the results of the *t*-test for pretest. The findings confirmed that students' learning performances were identical before the implementation of the educational experiment ($t = 0.44$, $p > 0.05$).

Table 7. Results of the *t*-test for pretest.

	Experiment Pretest		Control Pretest		*t*	*df*	*p*
	M	SD	M	SD			
Pretest	9.17	10.43	8.15	6.39	0.44	55	0.66

4.2. Qualitative Findings

Regarding various aspects of tablet computer use with the adopted app, Table 8 lists representative quotes from the interview results and observation report. This qualitative information indicated that despite the few negative comments on technical problems, both the instructor and the students in the experimental group expressed positive attitudes toward integrating the tablet computer into their laboratory learning.

Table 8. Aspects of tablet computer use with the adopted app.

Aspects	Representative Quotes
1. Note annotation	1. "The tablet computer allows me to easily grade students' submitted reports through the annotation function." (Instructor) 2. "We can annotate some information on the pictures we took. It was very easy to add descriptions for the images." (Student)
2. Learning facilitation	1. "I accessed the students' notes to observe their performance. It saved me a lot of time." (Instructor) 2. "My partner and I moved the tablet computer around the laboratory. It was very convenient for group discussion." (Student)

Table 8. *Cont.*

Aspects	Representative Quotes
3. Learning motivation	1. "Students were interested in using the tablet computer in their laboratory learning. Their active engagement created a different learning atmosphere." (Instructor) 2. "The app was very user friendly. We enjoyed using it to document our findings. It was very fun!" (Student)
4. Technical problems	1. "Wireless communication was a major potential problem. Sometimes, the wireless signal from the router was not strong enough for the tablet computer, which affected the learning process." (Instructor) 2. "The difficult part of operating the tablet computer was typing. The lack of a physical keyboard for typing was a challenge. We had to adjust to a new learning style." (Student)

4.3. Discussion

Before the experiment, the results of the pretest indicated that all students exhibited similar learning behaviors. After the 6-week experiment, the students in both the experimental group (i.e., tablet computer users) and control group (i.e., laptop computer users) exhibited a significant improvement in their engineering learning in the science laboratory. However, from a learning progress perspective, the students using the tablet computers outperformed their counterparts using the laptop computers. In other words, the tablet computers enabled the students to develop their learning potential, resulting in higher learning outcomes [18–20]. Therefore, in this study, the tablet computers with adopted app were effective instructional tools that may facilitate student engineering learning in the science laboratory [10,24].

Although the ANCOVA analysis results indicate that the students using both the tablet or laptop computers demonstrated the same instructional effectiveness, the qualitative information reveal several indirect learning benefits of using a tablet computer. In the experimental group, the students perceived that the annotation function in the app benefited their report writing; the instructor expressed the same opinion. In addition, because of their mobility, the tablet computer markedly facilitated the student learning process and group discussions. Although minor technical problems appeared in the educational setting, integrating the tablet computers into the students' science laboratory learning motivated them to actively engage in the learning activities. Thus, the results were consistent with previous studies that have showed the potential educational benefits of implementing tablet computer-based instruction [15–17,29].

In the present study, the use of laptop computers served as an established teaching model to determine the learning effect of tablet computers. After the effect of the pretest was controlled, the results of the inferential statistics revealed no significant difference between the experimental group (i.e., tablet computer users) and control group (i.e., laptop computer users). In other words, the learning value remained for the students using the laptop computers to document their scientific reports in the laboratory. This phenomenon can be attributed to the size of the computer device and the multimedia capabilities of PowerPoint. Compared with the miniature size of the tablet computer (i.e., iPad Mini), the laptop computer provided a wider screen for editing reports, which in turn influenced the students' knowledge acquisition. Additionally, elements of multimedia presentations, such as visual objects in PowerPoint, still exhibited technological effects on the students' learning outcomes [30]. Table 9 summarizes the pros and cons of two technological tools used in the present study.

Table 9. Pros and cons of tablet and laptop computers used in the science laboratory.

Type	Pros	Cons
Tablet computer with one application	1. Provides note annotation functionality [17] 2. Easy to use for group discussion [16–18] 3. Provides simultaneous document co-editing functionality 4. Easy to use for instructor supervision of the project progress 5. Provides picture-taking function (built-in camera)	1. Difficult to type 2. Small computer screen
Laptop computer with one piece of packaged software	1. Large computer screen 2. Easy to type 3. Provides a lot of multimedia elements [30]	1. Difficult to use for group discussion 2. Lack of note annotation functionality 3. Lack of picture-taking functionality 4. Lack of simultaneous document co-editing functionality 5. Difficult to use for instructor supervision

Regardless of the types of instructional tools, the findings confirmed our earlier research assumption, showing that information technologies (tablet and laptop computer) used in both experimental groups were effective for engineering learning in the science laboratory. However, since the instructional method for two learning groups in the study tended to focus on student-centered mechanisms, such constructive learning environments [31] might also facilitate students' knowledge acquisition for engineering learning. In other words, hands-on learning activities adopted in the science laboratory might be a potential variable influencing the results of the study.

In Sánchez-Martín et al.'s study [32], the survey results reported that high school students did not emotionally respond to technology learning modules in the same way. Sánchez-Martín et al. further suggested that promoting positive learning emotions might raise high school students' interests in learning engineering knowledge. In the present study, although the purpose was to evaluate the instructional effectiveness of two educational technologies on electrical engineering learning, the qualitative data from the instructor and students still indicated one additional finding: a tablet computer with one adopted application motivated student learning. In other words, the instructional strategy used in the study might arouse high school students' positive emotional responses, which indirectly affected their learning interests in the field of engineering and technology.

Because of the nature of the experimental research design, the findings in this study cannot be fully generalized for other research scenarios. Several research limitations that were encountered are discussed as follows. First, the app employed in this study was suitable only for teaching practice in the science laboratory. Alternative app selection strategies may influence overall instruction to a certain extent. Future studies should investigate the effect of other apps on student learning performance. Second, the research participants in this study engaged in a team-based learning activity. Whether differences among participant abilities may affect teamwork outcomes remains unknown. Future studies should consider emphasizing individual abilities in laboratory learning. Third, the mobile device adopted in this study was a miniature tablet computer. Other mobile technologies may create different learning atmospheres. Smart-phones with large screens may provide an alternative approach for future studies. Fourth, this study only focused on the combination effect of the tablet computers with one application or the laptop computers with PowerPoint. Future studies may investigate the single effect of hardware (tablet or laptop computer) or software (application or package software) on students' learning outcomes. Fifth, the learning theme in this study was electrical engineering knowledge. Observation of the manipulation of scientific instruments related to different engineering fields may influence the content of laboratory report. Future studies may verify the role of other engineering learning themes. Finally, the focus of the present study was students' overall knowledge acquisition about electrical engineering rather than detailed learning tasks in the science laboratory. Breaking down some learning tasks into smaller pieces of fundamental learning constructs may yield different learning outcomes. Future studies may analyze how the tablet computers with one adopted application influence students' analytical skills, scientific writing and knowledge retention in the science laboratory.

5. Conclusions and Implication

This study investigated the effect of the tablet computers with one adopted application on students' electrical engineering learning in a laboratory setting. No significant difference in engineering learning achievements was identified between the two experimental groups. The students in both the tablet computer group and the laptop computer group achieved the same learning outcomes. However, from a learning improvement perspective, the students using the tablet computers outperformed those using the laptop computers. In addition, the qualitative data collected in the study show that the tablet computers facilitated the students' learning process and motivated them to actively engage in engineering learning activities. Thus, the tablet computers provided a superior instructional solution for engineering learning in a laboratory setting.

The findings from the proposed instructional strategy (i.e., the integration of mobile learning) might contribute to existing knowledge base regarding engineering learning in the science laboratory. First, mobile learning might allow students easily construct their scientific understanding through the mobility of the tablet computers. Second, the application in the tablet computer might facilitate student collaborative learning by providing a document co-editing function. Third, from a teaching perspective, mobile learning might strengthen the interaction model between the teacher and students by providing instant feedbacks. Finally, the learning cycle (preparation, orientation, observation and exploration, and presentation) equipped with the use of the tablet computers might create a robust laboratory learning environment.

Although the research setting in the study was a K–12 learning environment, the findings may still provide some instructional implications for engineering educators who wish to enhance college student laboratory learning experiences. A major task for the integration of tablet computers into laboratory learning is the wireless communication setup. A strong wireless connection enables students to use tablet computers to smoothly record their observation. Another instructional concern in adopting tablet computers for engineering learning is app selection. Free and paid apps have unique features that can be applied in teaching practices. According to the instructional goals of a course, determining advantages and disadvantages of apps is a necessary task for engineering instructors.

Author Contributions: P.-N.C. is responsible of designing the study and writing the manuscript. S.-T.F. author is responsible of implementing the study.

Funding: This research was funded by Ministry of Science and Technology in Taiwan [grant number: MOST 105-2511-S-024 -001 -MY3].

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Dallasega, P. The Role of Engineering Education in Industry 4.0 Era. Available online: https://www.mdpi.com/journal/sustainability/special_issues/sus_engineering_edu (accessed on 10 October 2018).
2. Ricardo, A.R.; Ruben, M.M.; Hafiz, I.; Roberto, P.S. Engineering education 4.0: Proposal for a New Curricula. Available online: https://ieeexplore.ieee.org/document/8363376/authors (accessed on 12 October 2018).
3. Jeganathan, L.; Khan, A.N.; Raju, J.K.; Narayanasamy, S. On a Framework of Curriculum for Engineering Education 4.0. Available online: https://weef-gedc2018.org/wp-content/uploads/2018/11/76_on-a-frame-work-o-curriculum-for-engineering-education-4.0.pdf (accessed on 19 October 2018).
4. Chen, W.F.; Chou, P.N. Guest editorial: Current trends of K-12 engineering education. *Int. J. Eng. Educ.* **2017**, *33*, 285–286.
5. Katehi, L.; Pearson, G.; Feder, M. *Engineering in K-12 Education*; The National Academies Press: Washington, WA, USA, 2009.
6. Sorrentio, J. Science Laboratory in Elementary School. Available online: http://www.education.com/magazine/article/Science_Labs_Elementary_School (accessed on 2 February 2016).
7. Singer, S.R.; Hilton, M.L.; Schweingruber, H.A. *America' Lab Report, Investigations in High School Science*; The National Academies Press: Washington, WA, USA, 2005.
8. Huang, B.C.; Chang, Y.T.; Cheng, S.W. Manuals for Training Biological Experimental Skills of Students in Elementary and Middle Schools at National Taiwan Science Education Center. Available online: https://www.ntsec.gov.tw/User/Article.aspx?a=476 (accessed on 13 October 2018).
9. Huang, G.J.; Tsai, C.C. Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010. *Br. J. Educ. Technol.* **2011**, *42*, E65–E70.
10. Rogado, A.B.G.; Quintana, A.M.V.; Elorza, I.U. Mobile technology in academic laboratories in engineering. *Int. J. Eng. Educ.* **2015**, *31*, 694–701.
11. Ferreira, J.B.; Klein, A.Z.; Freitas, A.; Schlemmer, E. Mobile learning: Definition, uses and challenges. In *Increasing Student Engagement Andretention Using Mobile Applications: Smartphones Skype and Texting Technologies*; Wanket, L.A., Blessinger, P., Eds.; Emerald Group Publishing Limited: Bingley, UK, 2013; pp. 47–82.
12. The New Media Consortium. The Horizon Report. Available online: http://www.nmc.org/pdf/2013-horizon-report-k12.pdf (accessed on 21 February 2016).
13. Nortcliffe, A.; Middleton, A. The innovative use of personal smart devices by students to support their learning. In *Increasing Student Engagement and Retention Using Mobile Applications: Smartphones, Skype and Texting Technologie*; Wanket, L.A., Blessinger, P., Eds.; Emerald Group Publishing Limited: Bingley, UK, 2013; pp. 175–208.
14. Boticki, I.; Barisic, A.; Martin, S.; Drljevic, N. Teaching and learning computer since sorting algorithms with mobile devices: A. case study. *Comput. Appl. Eng. Educ.* **2013**, *21*, E41–E50. [CrossRef]
15. Walker, D.G.; Streamler, M.A.; Johnston, J.; Bruff, D.; Brophy, S.P. Case study on the perception of learning when tablet PCs are used as a presentation medium in engineering classrooms. *Int. J. Eng. Educ.* **2008**, *24*, 606–615.
16. Amelink, C.T.; Scales, G.; Tront, J.G. Student use of the tablet PC: Impact on student learning behaviors. *Adv. Eng. Educ.* **2017**, *3*, 1–17.
17. Casas, I.; Ochoa, S.F.; Puente, J. Using tablet PCs and pen-based technologies to support engineering education. In *Human-Computer Interaction*; Jacko, J.A., Ed.; Springer: Berlin, Germany, 2009; pp. 31–38.
18. Fang, N. Using tablet PCs to quickly assess students' problem-solving performance in an engineering dynamics classroom. *World Trans. Eng. Technol. Educ.* **2012**, *10*, 247–252.
19. Chegenizadeh, A.; Nikraz, H. Tablet PC application in geotechnical engineering. *Int. Proc. Econ. Dev. Res.* **2012**, *47*, 124–127.
20. Johri, A.; Lohani, V.K. Framework for improving engineering representational literacy by using pen-based computing. *Int. J. Eng. Educ.* **2011**, *27*, 958–967.
21. Miaoulis, I. K-12 engineering-the missing core discipline. In *Holistic Engineering Education: Beyond Technology*; Grasso, D., Burkins, M.B., Eds.; Springer: New York, NY, USA, 2010; pp. 37–51.
22. Quinn, H.; Schweingruber, H.; Keller, T. *A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Ore Deas*; The National Academies Press: Washington, WA, USA, 2012.

23. Markey, M.K.; Holmes, A.J.; Edgar, T.F.; Schmidt, K.J. Student-driven learning in integrated lecture-lab classroom environments: The role of mobile computing. *Int. J. Eng. Educ.* **2007**, *23*, 483–490.
24. Benson, E.R.; Krawczyk, C.; Figueiredo, G.F. Evaluation of tablet and laptopcomputers in field and laboratory settings. *Int. J. Eng. Educ.* **2006**, *22*, 1189–1196.
25. Clark, R.C.; Mayer, R.E. *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*; Pfeiffer: San Francisco, CA, USA, 2007.
26. Chou, P.-N.; Chen, W.-F.; Lin, H.-L. An investigation of using wiki to facilitate group composition in learning engineering knowledge: A quasi-experimental study. *Int. J. Eng. Educ.* **2015**, *31*, 619–626.
27. Creswell, J.W. *Research design: Qualitative, Quantitative and Mixed Methods Approaches*; Sage Publications Inc.: Thousand Oaks, CA, USA, 2009.
28. Aiken, L.R.; Groth-Marnat, G. *Psychological Testing and Assessment*, 12th ed.; Allyn & Bacon: Boston, MA, USA, 2006.
29. Tront, J.G. Using tablet PCs in engineering education. In Proceedings of the American Society for Engineering Education Annual Conference & Exposition, Honolulu, Hawaii, 24–27 June 2007.
30. Chou, P.-N.; Chang, C.-C.; Lu, P.-F. Prezi versus PowerPoint: The effects of varied digital presentation tools on students' learning performance. *Comput. Educ.* **2015**, *91*, 73–82. [CrossRef]
31. Smith, P.L.; Ragan, T.J. *Instructional Design*, 3rd ed.; Wiley: Hoboken, NJ, USA, 2005.
32. Sánchez-Martín, J.; Álvarez-Gragera, G.J.; Dávila-Acedo, M.A.; Mellado, V. What do K-12 students feel when dealing with technology and engineering issues? Gardner's multiple intelligence theory implications in technology lessons for motivating engineering vocations at Spanish Secondary School. *Eur. J. Eng. Educ.* **2017**, *42*, 1330–1343. [CrossRef]