Assessing the Effects of the Smartphone as a Learning Tool on the Academic Achievement of School-Based Agricultural Education Students in Louisiana

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Abstract

The purpose of this preexperimental study was to determine the effects of a blended learning environment on school-based agricultural education students' ability to identify 30 species of trees by leaves. Louisiana agriculture teachers were recruited based on district policy regarding whether students could use smartphones for learning in the classroom. The treatment group utilized smartphone technology to aid in the identification of tree species, while the comparison group utilized traditional, printed materials. All students were taught via guided inquiry and engaged in multiple formative assessments during the course of the research study. No statistically significant differences were found between the groups on the posttest tree leaf identification. It is recommended that future research be conducted over a longer duration of time to better measure long-term performance and learning gains. Further, more research should be conducted to determine if motivational differences exist based on utilizing smartphones for learning. Teachers who desire to incorporate the smartphone into blended learning environments can do so without diminishing student achievement.

Keywords: blended learning; smartphones; educational technology; mobile learning

Introduction and Literature Review

In 2009, United States Secretary of Education, Arne Duncan, addressed members of Congress and called for "applying the advanced technologies used in our daily personal and professional lives to the entire education system to improve student learning" (U.S. Department of Education, 2010, p. v). The device most often used in American personal and professional life is the smartphone. Smartphones have become the leading device for information and communication technology among American teenagers (Pew Research Center, 2017) because in one small device they can talk, text, email, record video, send pictures, check social media, play games, and watch movies (Smith, 2011). Smartphones are so intertwined in our culture that an overwhelming majority of Americans reported their smartphone as being indispensable (Chen & Katz, 2009). With this in

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mind, it is not surprising that the most current data show that 92% of Americans between the ages of 18 and 29 own a smartphone (Pew Research Center, 2017).

With the rapid development of the technology, some educators feel intimidated to incorporate applications they do not fully understand (Laskin & Avena, 2015). People born after 1980 are designated as digital natives because they have used technology their entire lives, while digital immigrants did not grow up immersed in technology (Laskin & Avena 2015; Prensky, 2001). Digital native college students drove the adoption of smartphones in higher education, convinced that technology improved learning (Gikas & Grant, 2013). Most high school students share the same argument; one exploratory study found 60% of students believed mobile devices influenced their academic success positively (Gikas & Grant, 2013). However, not all students used their phones for learning (McCoy, 2013). Despite the popularity of smartphones, there are often restrictions on their use in secondary education (Laskin & Avena, 2015).

Smartphones are often viewed as a classroom distraction, an opportunity for heinous behavior, or simply a mode of entertainment (Laskin & Avena, 2015). Approximately 69% of school districts in the U.S. ban mobile phones in the classroom (Commonsense Media, 2010), while university policies have typically allowed student use at the instructor's discretion (McCoy, 2013). Research has reported students spend between 20% and 40% of class time on their phones for purposes unrelated to the lesson (Laskin & Avena, 2015; McCoy, 2013). In secondary education, academic dishonesty has been a concern, as 35% of students reported using their phones for cheating (Commonsense, 2010; Thomas & Muñoz, 2016). Unsurprisingly, the typical secondary education administrations' response to mobile devices in the classroom is to ban them (Keengwe, Schnellert, & Jonas, 2014; Laskin& Avena, 2015). However, O'Bannon and Thomas (2014) found teachers' attitude towards smartphones in the classroom has shifted. As a growing number of digital natives become classroom teachers, the willingness to incorporate smartphones for learning on the rise (O'Bannon & Thomas, 2014). The goal of educators should be to use students' passion towards smartphones to improve learning (Laskin & Avena, 2015).

Despite the popularity of smartphones, studies measuring achievement gains when comparing teaching with smartphones to traditional methods vary (Liu & Huang, 2015; Liu, et al.,2015; Su & Cheng, 2015). Thomas and Muñoz (2016) conducted a study that identified which popular smartphone technologies were being most utilized by teachers and students. They reported basic applications such as accessing the internet, calculator, clock, and calendar were most often used within the classroom (Thomas & Muñoz, 2016) while only a very small portion of students used more advanced functions of their smartphones for developing 21st century skills such as creating content, posting content online, or recording audio/video (Bennett, Maton, & Kervin, 2008; Ertmer & Otterbein-Leftwich, 2010; Thomas & O'Bannon, 2015). However, research has indicated when more advanced applications of smartphones are applied in teaching and learning, achievement gains are significant (Liu et al., 2015; Su & Cheng, 2015).

The use of advanced technology in agricultural education programs is related to the development of 21st century skills (Ertmer & Otterbein-Leftwich, 2010). Several important studies have described how educational technology has been implemented into secondary agricultural education. One study sampled 203 Louisiana agriculture teachers using the Kotrlik-Redmann Technology Integration Model (Kotrlik, Redmann & Douglas, 2003). Results of the study indicated agriculture teachers in Louisiana were successfully employing basic technology such as email, but were not fully incorporating more advanced technology into their curriculum. Significant predictors of technology integration were (a) the teachers' belief in their teaching effectiveness, (b) computer anxiety, and (c) teachers' perceived barriers to technology integration. Five years later, a follow-up study by Kotrlik and Redmann (2009) reported that far more technology integration had taken

place in Louisiana agriscience programs. Computer anxiety scores among the agriculture teachers collectively had decreased, Internet availability had increased, and perceived barriers were reduced. Williams, Warner, Flowers, and Croom (2014) found that North Carolina secondary agriculture teachers used (a) projectors, (b) laptops, and (c) desktop computer hardware most frequently. The software used most frequently by agriscience teachers were (a) internet browsers, (b) word processors, (c) grading/attendance software, and (d) presentation software (Coley, Warner, Stair, Flowers, & Croom, 2015; Williams et al., 2014;). Notably, more advanced hardware like student response clickers and iPads for teaching and learning were reported as not readily available (Coley et al., 2015; Williams et al., 2014). Similarly, Williams et al. (2014) described student use of multimedia software and technology such as contributing to blogs, using social media, creating movies, art and webcasts were rarely used in the classroom.

Teachers who blend the use of smartphone technology into their classrooms may see gains in student achievement. Blended learning is a general term utilized to describe the simultaneous use of multiple instructional delivery methods to improve learning by satisfying multiple learning styles at once (Lothridge, Fox, & Fynan, 2013). Often blended learning environments are those infused with technology (Francis & Shannon, 2013; Olapiriyakul & Scher, 2006; Lothridge et al., 2013; Vacik, Wolfslehner, Spörk, & Kortschak, 2006; Wasoh, 2016). Blended learning environments can be particularly successful when teachers employ guided inquiry and formative assessment (Kuhlthau, Maniotes & Caspari, 2015; Moskal, Dzuban, & Hartman, 2013). Guided inquiry requires the learner to discover solutions for authentic problems and can help students develop deeper meaning of the content to be learned (Traxler, 2007; Kuhlthau et al., 2015).

Theoretical Framework

The focus on the interaction between learners and technology is often described as being a complex process. The Theory of Learning for the Mobile Age (TLMA) (Sharples, Taylor, & Vavoula, 2007) is based on the notion that learning is a process of acquiring knowledge through communication across continuously shifting contexts (Taylor, Sharples, O'Malley, Vavoula & Waycott, 2006). Further, Sharples et al. (2007) produced the Task Model for Mobile Learners (TMLL) that was modified from Engeström's (2009) expansive activity model. The TMLL divided learning into semiotic and technological activity (Sharples et al., 2007). The semiotic layer represents learner actions moderated by culture, environment, and meaningful signals. This layer represents an abstract domain inside the mind where personal language events such as previous conversations, lectures, and private thoughts are synthesized (Taylor et al., 2006). The technological layer represents a physical domain that has helped explain smartphones as a tool for "creating a human-technology system" that enables learning (Sharples et al., 2007, p. 11). Sharples et al. (2007) insisted that the semiotic and technological layers can be separated to provide a more semiotic or technological model or combined for a more holistic model. The purpose of the theory and model was to move research forward in the investigation of mobile learning (ML) (Sharples et al., 2007).

The TMLL can be used to illustrate cognition through smartphone technologies in a traditional classroom, distance education environment, or an informal learning context (Sharples et al., 2007; see Figure 1). In the triangular TMLL, all factors (i.e., Object, Tool, Subject, Control, Context and Communication) are interconnected, representing the complex relationship and dependency of the factors within the model (Taylor et al., 2007). The intertwined, yet flexible, structure of the model allows technologically enhanced learning experiences of many kinds to be examined (Sharples et al., 2007). An object is the material or problem which learning effected and has often been the dependent variable in experimental designs (Sharples et al., 2007). Tools are determined to be any device that serves the purpose of inquiry, and subjects are learners or

technological devices and may be considered one in the same (Sharples et al., 2007). Control of learning may depend on a teacher, be distributed to learners, or may pass between learners and smartphones (Sharples et al., 2007). Context embraced multiple formats including but not limited to (a) classrooms, (b) social media, (c) text messaging, and (d) interpersonal conversation (Sharples et al., 2007). Communication also embraced traditional and technological means of people sending and receiving messages (Sharples et al., 2007).
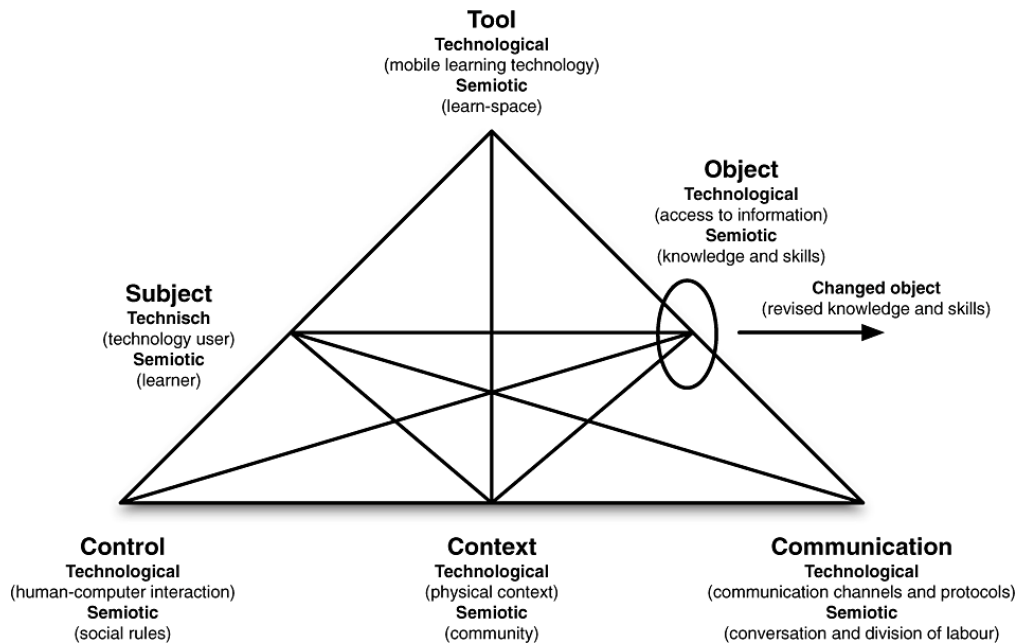
Tool
Technological
(mobile learning technology)
Semiotic
(learn-space)

Object
Technological
(access to information)
Semiotic
(knowledge and skills)

Changed object
(revised knowledge and skills)

Subject
Technisch
(technology user)
Semiotic
(learner)

Control
Technological
(human-computer interaction)
Semiotic
(social rules)

Context
Technological
(physical context)
Semiotic
(community)

Communication
Technological
(communication channels and protocols)
Semiotic
(conversation and division of labour)

Figure 1. Task model for mobile learners (Sharples et al., 2007).

There is little in the agricultural education literature pertaining to smartphone enhanced learning among secondary agriculture students. No research has focused on the use of smartphone applications in forestry education at the secondary level. Furthermore, little is known about how teaching a forestry curriculum with advanced smartphone tools would affect student achievement in leaf identification. Therefore, the principle question that arose from the literature was what effect does smartphone enhanced teaching have on Louisiana high school agriculture student achievement in a leaf identification unit? This research aligns with the American Association for Agricultural Education's National Research Agenda Research Priority 4: Meaningful, Engaged Learning in All Environments. Specifically, this study helps to provide answers to Research Priority Question One: "How do digital technologies impact learning in face-to-face and online learning environments?" (Edgar, Retallick, & Jones, 2016, p.39).

Purpose and Objectives

The purpose of this study was to compare the achievement of students in a forestry curriculum based on learning through smartphone technology or traditional, printed materials. The following research questions guided the study:

1. What are the personal and educational characteristics of students enrolled in agriculture courses offering a forestry curriculum in Louisiana?
2. What difference existed in posttest leaf ID scores between students learning through smartphone technology and students learning through printed materials?

3. The following null hypothesis guided the statistical analysis of the study:
4. There were no statistically significant differences in leaf ID posttest scores between students learning through smartphones and students learning through printed materials.

Methods and Procedures

Research Design

A preexperimental design utilizing nonequivalent comparison groups was employed for this study (Campbell & Stanley, 1963; Shadish, Cook, & Campbell, 2002). Agriculture teachers were recruited for this study based on whether or not their school district allowed smartphones to be utilized for learning in the classroom. In all, seven teachers were assigned to the treatment group and completed all parts of the study fully. A total of six teachers were in the comparison and completed all parts of the study. Overall, the treatment group was comprised of $n=128$ students and $n=135$ students were in the comparison group. These students were enrolled in either Agriscience I or Agriscience II, the two courses in Louisiana where introduction to forestry is commonly taught. Table 1 lists student personal characteristics. Overall, most students were male (73.4%), 15 or 16 years old (60.5%), and White/Caucasian (71.5%). Regarding high school classification, seniors (9.1%) made up the smallest portion of the sample.

Table 1

Personal Characteristics of Louisiana Students Enrolled in Secondary Agriculture Classes Offering a Forestry Curriculum in the Fall of 2016 ($n = 263$)

Variable		f	$\%$
Gender			
	Male	193	73.4
	Female	70	26.6
Age			
	13	10	3.8
	14	37	14.1
	15	77	29.3
	16	82	31.2
	17	44	16.7
	18	12	4.6
	19	1	0.4
Ethnicity			
	Caucasian	188	71.5
	African-American	51	19.5
	Asian	3	1.1
	American Indian	3	1.1
	Hispanic	9	3.4
	Other	9	3.4

Random sampling and random assignment were not feasible due to the small number of school districts that allowed smartphones for learning in the classroom. Smith, Stair, Blackburn, and Easley (2018) reported that roughly 30% of districts in Louisiana allowed smartphones for learning in the classroom. Due to the inability to employ randomization, pretreatment equivalence was not assumed. However, a pretest was administered to the students prior to any instruction in leaf identification and no statistically significant differences were found between the treatment (*M* = 16.48) and comparison (*M* = 17.01) groups on the 30-item pretest.

Participant Recruitment and Training

Agriculture teachers were invited to participate in the treatment group if they met the following criteria: (a) volunteer to participate; (b) taught high school level courses; (c) taught 50 minute periods, and (d) taught in a district that allowed the use of smartphones for learning. Teachers in the comparison group also met these criteria, minus the district permitting smartphones for learning. Initially, 16 teachers were identified for the treatment group and 14 for the comparisons group. These 30 teachers were invited to attend a professional development workshop during the 2016 Louisiana agriculture teachers' summer conference and 22 attended.

The focus of the workshop was basic leaf identification (i.e., leaf parts, leaf arrangements on a stem, leaf margins, and leaf types) for all teachers. The teachers were then separated by treatment group (*n*=10) and comparison group (*n*=12) to learn how to utilize leaf identification resources. The treatment group teachers were instructed on utilizing smartphone applications (e.g., LeafSnap and V-tree) to teach leaf identification and to identify the 30 tree species chosen for this study. This group was also taught how to utilize Quizlet® to formatively assess student learning. The comparison group teachers were taught how to utilize printed resources to teach leaf identification as well as to identify the 30 tree species utilized in the study. This group was provided paper-based flash cards to formatively assess student learning. The groups were then brought back together and taught how to employ Test Generator (TG) Web© to assess their students' leaf identification knowledge for the purposes of the pretest and post-test.

A second workshop was scheduled for the late summer of 2016 on the campus of Louisiana State University. However, this workshop was cancelled due to the Great Flood of 2016, which affected a large portion of Louisiana. To replace this workshop, small group and individual training sessions were scheduled at each teacher's convenience. The focus of this training session was (a) how to follow the study protocol, (b) use of the smartphone applications (treatment group) or printed materials (comparison group) to identify the 30 leaf samples utilized in the study, and (c) employing guided inquiry. In all, teachers received between two and three hours of professional development. At the end of the individual training sessions each teacher was provided a binder that outlined procedures for each day of the study. To ensure fidelity of the treatment, teachers completed daily logs located in the binder and returned them to the researcher.

Data Collection

Data collection for this study began on September 19, 2016 and was completed on September 27, 2016, encompassing seven instructional days. Table 2 outlines procedures utilized by both the treatment and comparison group teachers. Students in the treatment group utilized smartphone applications to identify tree species and engaged in formative assessments via Quizlet. Comparison group students utilized printed resources (i.e., field guides) to identify tree species and were formatively assessed using paper flash cards.

Table 2

Instructional Procedures Utilized by the Treatment and Comparison Groups

Instructional Day	Specific Tasks Completed
1	Pre-test of tree leaf identification; download applications
2	Lesson on the Importance of Forestry and Leaf Identification Terminology
3	Identification of tree leaf samples; formative assessment
4	Identification of tree leaf samples; formative assessment
5	Identification of tree leaf samples; formative assessment
6	Identification of tree leaf samples; formative assessment
7	Post-Test of tree leaf identification

Note. Treatment group utilized smartphone applications while comparison group utilized printed resources to aid in the identification of tree species

Instrumentation

The instrument used to collect leaf identification data for this study consisted of a criterion-referenced pretest and posttest delivered electronically with TG Web© testing software donated by Fain and Company®. Both the pretest and posttest consisted of 30 items–15 multiple choice questions, 10 fill in the blank questions, and five true/false questions. TG Web© provided the students with a picture of a leaf in a pop-up window. The student then closed the window and answered the identification question that followed. The student could recall the photo at any time during the question attempt as well as scroll back and forth through the questions. The 30 leaf samples resting on solid backgrounds were photographed by the researcher and uploaded into TG Web©. The authentic photos were chosen by the researcher based on experience in the subject of tree identification. Furthermore, the 30 species were chosen because they could be found in all of the learning materials given to each group of student participants in the study. A panel of three tree identification experts, consisting of two secondary agriculture instructors and an assistant professor of Forestry Extension and Natural Resources at Louisiana State University, reviewed the exam for content validity. All photos chosen for the instrument were deemed to be of (a) high quality, (c) distinguishable, and (c) correct in species identification.

There are eight reliability components that should be addressed by those who create criterion-referenced examinations (Wiersma & Jurs, 1990). These components include (a) homogenous items, (b) discriminating items, (c) quantity of items, (d) high quality test, (e) clear directions, (f) controlled environment, (g) participant motivation, and (h) scorer directions. These items were carefully considered when the researcher created the 30-item criterion referenced test. To ensure fidelity of the treatment, binders were created for both teacher groups that detailed step-by-step instructions for each instructional period. The binders contained a lesson plan and daily agenda that teachers were to check off as they progressed through the lessons. Also included in the agenda was a notes section where teachers could document any major changes or disruptions experienced during the instructional periods. These daily agendas and notes sections were mailed back to the researcher upon completion of the lessons. To ensure students received the same amount of instruction, there was a testing window created for the posttest that allowed students who missed instructional days due to illness, sports, or other excused absences to take the posttest upon completion of five days of instruction.

Data Analysis

The research question asked if differences existed in pretest and posttest leaf identification scores between students who learned with smartphones and students who learned with printed materials. The treatment and comparison groups comprised a nested data set, therefore could not be considered statistically independent (Raudenbush & Byrk, 1986; 2002). Therefore, a two-level hierarchical linear model (HLM) with fixed effects was employed. This statistical method has advantages over tests that assume independence of groups because it accounts for variance in the dependent variable (DV) by students across the school level. However, not all nested data sets warrant HLM (Peugh, 2010). An intraclass correlation coefficient (ICC) was calculated to ensure HLM was the proper statistical procedure. Essentially, ICC is an effect size calculation similar to R^2 for regression and eta-squared for ANOVA (Peugh, 2010) that helped determine if sufficient variance existed across students within schools to warrant HLM (McGraw & Wong, 1996). ICC calculated for this data was 9.4%, indicating sufficient variance existed to warrant the use of HLM (Muthén, 1994; Raudenbush & Bryk, 2002; Peugh, 2010). The independent variable (IV) in the model that predicted achievement was group (i.e., treatment or comparison). The DV was posttest score on the leaf identification test. The covariate was the pretest (centered). Grand mean centering is most often preferred when models will involve level one and level two predictors (Peugh, 2010; Wu & Wooldridge, 2005). Centering scores means rescaling them in a way that a researcher can determine if a relationship existed between the predictor and the outcome based on school level factors (Peugh, 2010; Wu, & Wooldridge, 2005). Therefore, grand mean centering was performed on the covariate in SPSS by subtracting the individual students pretest score from the sample mean.

An ICC calculation that equals zero implies no variation in posttest scores exists across schools, and that all variation exists between students. If this were the case, then traditional techniques like ANOVA are warranted. However, as ICC increased, statistical evidence supported the variation of scores occur across schools and the assumption of independence is violated. In order to determine the ICC for the DV, an unconditional model (i.e., one-way random effects ANOVA) was utilized (Castro, 2002). An unconditional model for posttest by school was calculated using the mixed model command in SPSS (Peugh & Enders, 2005). Schools accounted for 9.4% of the variance in posttest scores. After calculating the ICC from the unconditional model, the HLM technique had three steps. The first step produced the level one model that measured student differences in achievement between groups as a function of school. The second step produced the full model that measured group level outcomes on achievement as a function of school while controlling for prior knowledge. The third step utilized likelihood ratio testing to determine if adding a school level variable improved the model. This model building process was necessary to determine if adding school level effects improved the model. Most importantly, step two (full model) specifically addressed research question number two.

Findings

The research question of this study sought to determine if differences existed in achievement between students who learned with smartphones and those who learned with printed materials. A 30-item pretest was employed to assess prior knowledge and used as a covariate (centered) in the HLM analysis. The same 30 items constituted the posttest and were used to measure achievement differences. The final analysis conducted consisted of a treatment group and a comparison group that completed the pretest, the learning interventions, and the posttest. The pretest and posttest consisted of 30 items and scores ranged from 0–100%. Pretest mean for the treatment group was 16.5% ($SD = 8.29$). Pretest mean for the comparison group was 17.0% ($SD = 6.05$). Therefore, groups had equivalent prior knowledge before the intervention. The posttest mean

for the treatment group ($n = 128$) was 46.0% ($SD = 19.6$) and the posttest mean for the comparison ($n = 135$) was 42.8% ($SD = 20.7$).

Achievement Level One Model

The level one predictor for Achievement was the grouping variable (i.e. treatment or comparison). The intercept in this model is based on fixed effects and is the treatment group mean ($M = 46.0$). No statistically significant difference ($p > .05$) was found in Achievement between the treatment and comparison group at level one ($\gamma_{00} = -3.26$, $SE = 2.48$, $t = -1.31$, $df = 263$, $F = 1.73$ and $p = .190$) (see Table 3).

Table 3

Level One Model for Achievement Between Treatment and Comparison Group After Accounting for Individual Student Differences as a Function of School

Fixed effects	Coefficient (*SE*)	*t* (*df*)	*F* (*p*)
Level one model			
Intercept ($_{1j}$ mean)	46.0 (1.78)	25.9 (263)	1281.3 (.000)
Group ($_{0j}$) variance nested in school (γ_{00})	–3.26 (2.48)	(–1.31) (263)	1.73 (.190)

Note: Deviance (maximum likelihood) $X^2 = 2325.1$; 3 estimated parameters.

Achievement Full Model

The full model analyzed achievement between groups as a function of school while controlling for prior knowledge. Prior knowledge is controlled for in the full model by adding a centered covariate (i.e., pretest). The new intercept estimate (45.8) is the mean for the treatment group adjusted for individual differences by school. There was no statistically significant difference ($p > .05$) in Achievement ($\gamma_{00} = .56$, $SE = .35$, $t = 1.62$, $df = 262$, $F = 2.63$ and $p = .106$) between the treatment and comparison groups nested in schools. Therefore, the null hypothesis was not rejected (see Table 4). The critical value for X^2 ($df = 3$) was 11.34 ($p < .01$). The -2LL ratio test between the level 1 and full models yielded a statistically significant difference ($p < .01$) when the variance due to group is confounded with the variance due to school ($X^2 = 22.1$, $df = 3$ $p < .01$). This result revealed the full model improved accuracy for the level 1 model to detect effects. The full model accounted for school level and individual student level differences in all posttest scores while controlling for prior knowledge.

Table 4

Full model for Achievement Between Treatment and Comparison Group as a Function of School While Controlling for Prior Knowledge

Fixed effects	Coefficient (*SE*)	*t* (*df*)	*F* (*p*)
Full model			
Intercept (adjusted β_{1j} mean)[a]	45.8 (2.89)	15.8 (14.3)	446.9 (.000)
Grouping ($_{0j}$) variance nested in school (γ_{00})	–3.68 (4.16)	–.844 (13.2)	.782 (.392)
Group * Pretest (β_{0j})	.56 (.35)	1.62 (262)	2.63 (.106)

Note: Deviance (maximum likelihood) X^2 = 2303.0; six estimated parameters.

fixed effects = group (IV) and random effects = school (subject)

Conclusions and Implications

There were no statistically significant differences in leaf identification ability between students who utilized smartphones and those who learned through the use of printed materials. As such, the researchers failed to reject the null hypothesis. This finding refutes research that suggests when students use more advanced functions on their phones for learning, achievement gains are noticeable (Bennett et al., 2008; Liu & Huang, 2015; Liu et al., 2015; Su & Cheng, 2015; Thomas & Muñoz, 2016). Furthermore, this finding is inconsistent with research that suggests formative assessment executed on mobile platforms increases knowledge gains (Aldon & Dempsey, 2016; Buchanon, 2000; Lu, 2008; Sly, 1999; Wang, 2007). However, results from this study did support the notion that smartphones are not superior to traditional materials for learning in a student-centered approach (Traxler, 2007; Vacik et al., 2006; Yuping, Xibin, & Juan, 2015). This study supports the Theory of Learning for the Mobile Age (TLMA) which suggested that all cognitive factors are interconnected (Sharples et al., 2007), and consequently neglecting some factors (i.e. Communication, & Control) may have negative effects on other factors.

The results of this study indicate using smartphones in the context of tree identification does not affect achievement. However, posttest scores for the treatment group were nearly four points higher than the comparison group. It may be that the short nature of this study's intervention (e.g., one week) was not long enough to produce statistically significant differences. Perhaps more time spent utilizing technology to identify tree species would have increased the score difference between groups. It could also be possible that instructional time was lost due to the treatment group spending the first day of the study downloading and becoming familiar with the applications. Treatment group students were able to take formative tests 24 hours a day on their phones while the comparison group was limited to formative quizzes during class. It was not clear if the treatment group accessed the tests outside of class time, but this could have been a factor in student achievement. It is also possible that while the treatment group employed advanced smartphone functions (Liu et al., 2015; Thomas & Muñoz, 2016) the problems and tasks were not meaningful enough to spark student interest and inspire them to inquire deeper understanding (Kuhlthau et al., 2015; Leslie, 2014; Padeste et al., 2015;). Perhaps, as in previous research, the students needed

more interaction and communication with one another through their mobile devices to solidify learning (Thomas & Muñoz, 2016; Su & Cheng 2015).

Students in both groups engaged in formative assessments that were designed to provide as many repetitions of identifying the leaf samples as possible. The only difference in the assessment was paper index cards with names printed on them for the comparison group versus the touch screen of a smartphone for the treatment group. Increased student interaction thought the development of their own electronic study materials could possibly have lead to higher achievement in the experimental group (Hwang & Chang, 2011; Jiao, 2015). Lastly, the teachers were facilitators of the groups but were not tree identification experts. The recruitment process for this study eliminated teachers who were experts at teaching tree identification. It is possible, that the previous educational experiences of the treatment group students had not adequately prepared them for a student-centered classroom approach that focused on self-directed learning more than teaching (Kuhlthau et al., 2015).

Recommendations

Through this research, several questions emerged regarding the methods of teaching and if the time spent on learning tree identification could have possibly contributed to smaller learning gains. It is recommended that future research should utilize a longer duration of smartphone use spread across multiple technical agriculture fields to determine if the utilization of smartphones can enhance learning in long-term studies. A delayed posttest should also be administered to determine if one group retained leaf identification knowledge better than the other. Further, this study only focused on educational post-test gains. Future studies should determine if student motivation differs between groups who utilize instructional technology versus traditional materials. This research study, as analyzed through the Theory of Learning for the Mobile Age (TLMA), focused more abundantly on the interaction between Objects, Tools, Subjects, and Technology and less on the factors Communication, Context, and Control (Sharples et al. 2007). The framework suggested that all of the factors are interconnected. This study however, operated in the technology layer, not the more abstract domain of the semiotic layer that attempts to understand metacognition in mobile learning research. Therefore, future studies in agricultural education that employ mobile learning should investigate the interconnected factors and the more abstract constructs of the semiotic layer offered by TLMA.

Additional research should focus on the ubiquitous nature of smartphones in the context of agricultural education to determine if students spent time outside of class learning on their own and how this affects achievement. The foremost challenge in information age schools is to prepare students to thrive in a technologically saturated environment (Kuhlthau et al., 2015). Future research in agricultural education should go beyond foundational knowledge achievement and incorporate smartphone applications used for 21st century skills such as creating electronic portfolios or posting demonstration videos online. Student collaboration was encouraged by the researcher, but was not required nor measured in this study. In the future, a mobile collaborative element needs to be added to the research design that encourages students to discuss what is being taught outside of the formal classroom and how that collaboration may result in other educational gains.

This research indicated that the use of smartphones for learning did not diminish student achievement. Therefore, agricultural educators can implement smartphones in their teaching (as policy permits) with confidence that learning should not be impeded. Teacher educators should consider adding student-centered smartphone applications into methods coursework. Modern students in America are digital natives who prefer a student-centered approach to self-directed

learning that incorporates current technology. Though millennial students may be perceived as superior to some of their teachers in terms of technological savvy, they still adopt their teachers' attitudes and mimic their actions (Thomas & Muñoz, 2016). Most teachers prefer to learn from others who have already mastered the nuances of an innovation (Rogers, 2003). The same holds true for agricultural educators and smartphone applications. Educational leaders should be strategic in creating opportunities for agricultural educators to learn about smartphone applications from one another. Communities of best practices for agricultural teachers in Louisiana could be implemented at events that provide large gatherings of agricultural teachers. These events include FFA Career Development Events, leadership camps, Louisiana Agriscience Teachers Association summer conference, State FFA Convention, and National FFA Convention.

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