GPS and Geocaching Integration in Agriscience: The Impact on Critical Thinking

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Abstract

Global Positioning System (GPS) technology has an important role in both agriculture and in everyday life. However, the effects of GPS integration into agricultural classrooms has never been fully explored. This study evaluated the potential for critical thinking skill development as a result of student participation in a GPS lesson and the GPS-based treasure hunting game of Geocaching. The GPS lesson for both groups combined, the treatment (integrated Geocaching) and control (no geocaching integration), yielded statistically significant improvements on student engagement, cognitive maturity, innovation, and total critical thinking disposition. However, there were no statistically significant improvements resulting from the Geocaching integration. The authors recommend additional research on the influence of Geocaching on other variables of student achievement (i.e., knowledge gained, mathematical processing skills, science processing). Geocaching can be designed to be educational and the authors contend it is a novel way to promote student engagement and reinforce academic content into the Agriscience classroom.

Introduction

Treasure hunting is often imagined to be the sport of pirates and adventurers looking to strike it rich. Now, thanks to the concept of Geocaching, anyone with a Global Positioning System (GPS) receiver and Internet access can explore for hidden objects. Geocaching can serve as an enjoyable hobby, but can also be beneficial within various learning environments (Christie, 2007; Hendrix et al., 2011). This study introduced GPS technology and a modern-day treasure hunting activity, Geocaching, into the agriscience classroom.

GPS technology is a “navigation and precise-positioning tool” that was developed by the U.S. Department of Defense in 1973 (Glasscoe, 1998, para. 1; “What is GPS?,” 2011). Global Positioning System technology allows users to create accurate maps of their surroundings by receiving geographic information beamed down from satellites orbiting the Earth (Shaunessy & Page, 2006). One way to introduce GPS technology to students is through the game of Geocaching (Groundspeak, 2011). Geocaching is a high-tech treasure hunt experience in which participants use GPS units to discover hidden objects known as Geocaches. Any member of the Geocaching community can hide a Geocache, although they must follow certain rules pertaining to safety and legal issues (Groundspeak, 2011).

The impact of technology integration in education has been studied widely, and results indicate that access to technology in education improved student motivation, self-esteem, technical knowledge, and interpersonal skills compared to students without access (U.S. Department of Education, 1998). Teachers who frequently use technology can aid in developing their students’ understanding of essential 21st Century Skills – skills regarding knowledge of technology, the developing world, communication, creativity, teamwork, and self-discipline (Grunwald & Associates, 2010).

Teaching with GPS "is an ideal context in which to develop critical thinking" (Schwartz, 2016, p. 13). "Students use critical thinking skills [when learning through GPS] to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources" (Schwartz, 2016, p. 13). According to Siegel (1988), critical thinking skills are an important component of life, and should be included in educational systems because young people deserve the chance to learn to think critically. Additionally, critical thinking has been included in frameworks to illustrate the skills students need to succeed in work and life (Crawford & Fink, 2020). A student's mastery of critical thinking also helps them to improve control over their own lives and increase the quality of their life experiences (Paul, 1995). In a 1991 report, the U.S. Department of Labor identified critical thinking skills as one of the foundational skills in which students should gain competency (Secretary's Commission on Achieving Necessary Skills).

In addition to critical thinking, GPS requires a working knowledge of geography, math, and physical science. Therefore, GPS systems and tools are often utilized in classrooms in these subject areas. Geocaching adds to the teacher toolbox, allowing them to cover almost any topic in a fun and engaging manner (Dixon, 2011; Thorpe, 2006;). Related technology experiences have had significant impacts on the development of critical thinking in students (Duran & Sendag, 2012). Therefore, we tested the impact of integrating a GPS and geocaching lesson and activity in an agriscience course to determine if similar, positive critical thinking outcomes would be realized.

Conceptual Framework

Critical thinking has been defined as "a reasoned, purposive, and introspective approach to solving problems or addressing questions with incomplete evidence and information and for which an incontrovertible solution is unlikely" (Rudd et al., 2000, p. 5). Angelo (1995) notes critical thinking involves "the intentional application of rational, higher order thinking skills" including "analysis, synthesis, problem recognition and problem solving, inference, and evaluation" (p. 6). Although these definitions are complex, when simplified, they reveal that critical thinking is the ability of a person to make a difficult decision after considering all people, situations, and options – a trait agricultural education students ought to reflect (Facione et al., 1997).

Effective critical thinking has positive effects across the aspects of one's life. Murawski (2014) says that critical thinkers produce more ideas of higher quality than non-critical thinkers, and are more likely to set goals and overcome obstacles such as failure, distraction, and limitations. Ruggiero (2012) notes critical thinkers are better at demonstrating effective listening skills, identifying extreme views, avoiding emotionalism and stereotyping, seeing multiple perspectives, acknowledging limitations, and thinking before acting. Butler (2012) and Butler et al. (2015) found that critical thinking was more effective than intelligence at predicting life decisions. In their study, individuals possessing higher critical thinking scores reported experiencing fewer negative life events than those with lower critical thinking scores.

Critical thinking has benefits in the workplace (Ennis, 1987; Murawski, 2014; Willsen, 1995). Casner-Lotto et al. (2006) found that 92.1% of surveyed employers identified critical thinking and problem solving skills as “very important” to successful job performance for four-year college graduates (p. 20). Research shows that people who score well on critical thinking assessments are rated by their supervisors as possessing “good analysis and problem-solving skills,” “good judgment and decision making” skills, “good overall job performance,” “the ability to evaluate the quality of information,” “creativity,” “job knowledge,” and “the potential to move up” in the workplace (Harris, 2015, para. 9).

Leaders who exercise quality critical thinking on the job are better able to evaluate and mitigate risk, weigh options, and recognize the effect that consequences have on not only themselves, but on coworkers and stakeholders (Anderson, 2013; Murawaski, 2014). Unfit or hasty decisions result in real issues for businesses, which illustrates the need for employees who can gather information, consider outcomes, and make informed decisions. Thus, critical thinking - alongside related behavioral skills such as leadership, communication, collaboration, and innovation – are highly sought by employers when making hiring decisions (AACU, 2010; Casner-Lotto et al., 2006; Hendrix & Morrison, 2018; Landrum & Harrold, 2003).

While effective critical thinking is beneficial to students, it is a difficult skill to teach (Angelo, 1995). It does not often arise “simply as a result of maturation,” but rather through guided learning experiences that overtly highlight “active engagement” and “personal investment” in the learning activity, “comprehensible and timely feedback,” and cooperative work “with peers and teachers” (Angelo, 1995, p. 6). Yet students cannot simply be passive receivers of knowledge. Critical thinking is purposeful, and it requires the active use of information to make effective decisions – a process that includes application of knowledge in real-world circumstances, experimentation through trial and error, and reflection upon successess and failures (Murawski, 2014; Paul, 1995).

When measuring the critical thinking abilities of agricultural education students, Cano (1995) stated they were able to “think critically at various levels,” and that they tend to “score at higher percentages at the higher levels of cognition” (p. 29). These findings supported the earlier work of Rollins et al. (1988), who found agricultural education students able to successfully employ critical thinking skills when addressing problem-based situations. Akins et al. (2019) noted the use of case studies in agricultural communications courses increased students’ critical thinking, information-seeking, and interpersonal engagement behaviors.

Ricketts and Rudd (2004) found the National FFA Organization – a co-curricular organization for agricultural education students – to be fertile ground for critical thinking development. Student leaders in the National FFA Organization showed “high” levels of critical thinking, with scores in the “upper end of the range” for the sub-skills of analysis, inference, and evaluation (Ricketts & Rudd, 2004, p. 15). In contrast, Latham et al. (2014) found that critical thinking was occuring at a lower level among senior Texas FFA members than their counterparts. Latham et al. called for an improvement for critical thinking instruction within agricultural education throughout the curriculum.

The conceptual framework for this study is supported by a National Delphi study conducted by Facione (1990), who defined critical thinking as "purposeful, self-regulatory judgment, which results in interpretation, analysis, evaluation, and inference, as well as explanation of the evidential, conceptual, methodological, criteriological, or contextual considerations upon which that judgment is based" (p. 2). The Delphi study revealed a set of critical thinking dispositions that are inherent in critical thinking. Facione (2011) referred to the dispositions as approaches to life that characterize critical thinking. He developed an assessment of the following critical thinking dispositions: Truth-Seeking, Open-mindedness, Analyticity, Systematicity, Self-confidence, Inquisitiveness, and Maturity.

This study utlized a model of critical thinking developed by agricultural educators at the University of Florida (UF). Researchers at UF developed an instrument that measured dispositions as Facione (2011) did, but in a more effective and efficient way (Irani et al., 2007). Because of the length and amount of time Facione's assessment took to complete and the suspect reliability of the scales on Facione's California Critical Thinking Disposition Inventory (CCTDI) (Moore et al., 2002), researchers developed the UF-EMI (Irani et al., 2007). For this study, changes in these dispositions were assessed utilzing a retrospective/post version of the UF-EMI (University of Florida – Engagement, Maturity, and Innovativeness) assessment (Ricketts et al., 2007) described in the methods section below.

The UF-EMI model of critical thinking assessment used to reach this study's objectives contains three scales (Engagement, Cognitive Maturity, and Innovativeness). The Engagement construct measures a person's ability to anticipate and seek out situations requiring logical reasoning, use existing critical thinking skills to confidently solve problems, and to be an effective group leader. The Maturity construct assesses a person's awareness of their own biases, their environment, their opinions, and their influences on both their own lives and the lives of others. The Innovation construct assess a person's desire to learn new information and to explore the world around them while continually seeking truth through research and questioning (Irani et al., 2007; Ricketts, 2003).

Purpose and Objectives

Despite existing literature illuminating how effective Geocaching can be as an educational activity (Christie, 2007; Dixon, 2011; Schwartz, 2016), its use has rarely been documented as a method of teaching agriculture. While this does not exclude the possibility that agriculture teachers have used Geocaching before, it does show a lack of knowledge about either the educational possibilities or the existence of the game in general.

Therefore, it is important that if GPS technology and Geocaching are to be used as an educational tool in agriculture classes, the possibilities are fully explored. Geocaching makes learning an active experience that requires the evaluation of ideas alongside problem-solving, decision-making. Therefore it is possible that students' critical thinking will be impacted by the introduction of GPS in the agriscience education curriculum.

The purpose of this study was to determine the effects of Geocaching integration in an agriscience lesson plan. The primary objectives of this study were to:

1. Describe the change in critical thinking dispositions as a result of the GPS lesson for both the treatment (Geocaching integration) and control (no Geocaching integration) groups in the agriscience courses.
2. Compare the critical thinking dispositions of students of the treatment group who participated in the GPS lesson with integrated Geocaching activity against those the control group who participated in a GPS lesson void of Geocaching integration.

Procedures

The first step undertaken in this study was the development of an introductory level GPS lesson which fit into a 50-minute class period. This lesson opened with a 20-minute lecture discussing GPS history, reading coordinates, usage in agriculture, and the game of Geocaching.Materials including an accompanying PowerPoint a coordinate worksheet, and a Geocaching worksheet were created as well.

Eight Garmin eTrex 10 GPS receivers and carrying cases were purchased for use in the study. These specific receivers were chosen due to their low cost, durability, and ease of use. Other purchased materials included Geocache container materials such as a plastic hide-a-key containter and a PVC pipe with one cap attached to the bottom. All materials were clearly labeled as Geocaches using official stickers purchased from Groundspeak (2021).

Five schools were contacted through email about participating in the study. On the day of each visit, the researcher arrived at the selected school approximately forty-five minutes early and proceeded to hide the Geocaches. When the selected classes began, the researcher allowed the teacher to perform any necessary duties before beginning the GPS lesson.

After the end of the introductory lecture, the students were introduced to their first activity. This activity was developed to introduce basic GPS ability and to reinforce the concepts of latitude and longitude. In this activity, students were placed into groups of two to five students, with each group given a GPS unit, a GPS Instructions page, and a Coordinate Worksheet. Each group was then led outside and asked to turn on their GPS unit. The teacher visited each group to ensure that everyone understood the directions and to minimize potential problems. After each unit had a successful lock on three or more satellites, the teacher asked students to write their current coordinates down on the Coordinate Worksheet. The students then moved to a new location not far away, and wrote down a new pair of coordinates. Again, the teacher visited each group, this time to discuss the results with the students. Discussion topics included uncovering which coordinate numbers changed, why certain numbers changed the way they did, and how the numbers indicated the students' direction of travel. Then each group would compare their results with other groups before the Coordinate Worksheets were collected.

The next part of the GPS unit varied between classes. For those classes randomly chosen to be the control group, the GPS units were collected, the class returned to their classroom, and the paper-and-pencil based GPS Review Worksheet provided.

The treatment groups were instead allowed to keep their GPS units for a second activity in which they would experience the game of Geocaching. The Geocaching activity began by dividing up students into three groups. Each group was given a different set of coordinates that were designed to lead them a Geocache. Although both their teacher and the researcher monitored the groups, the students were allowed to follow their GPS and search for the Geocaches on their own. If problems arose, students were given clues or hints to help them discover the final location of the cache. When the caches were discovered, students were instructed to sign the contained log sheet, take a few stickers as a prize, and then re-hide the cache back in its original location before returning to the classroom.

When either the Review Worksheet or Geocaching activity was complete, the students were given the GPS Test and survey instrument. The test was written with the specific intent of testing what knowledge was gained during both the lecture and activity portions of the lesson. It consisted of seventeen multiple choice questions that covered basic concepts regarding the history of GPS, the usage of GPS in agriculture, the workings of GPS technology, and also latitude and longitude. Students were not allowed to use notes during the test, and would be given as much time as needed to answer the questions and survey instruments.

Following the end of the lesson, GPS units, tests and surveys were collected, and the remaining five to ten minutes left in each class period would be spent debriefing students about what they had learned and experienced. This was to help the students further retain what they had learned, and to give them a chance to offer their thoughts on the GPS unit as a whole.

Methods

This study utilized survey research and took place at [university] and in five different high schools in three counties in the [state]. These schools were chosen to participate in the study due to their proximity to [university], because they all had successful agricultural education programs, and because they offered agriculture courses that fit study criterion. In order to be selected, a school had to offer two of the same agriculture classes that were taught by the same teacher. This was done to minimize error and decrease the number of potential variables. Due to budgetary and time restraints, the selected classes were not the same in every school. A total of four different types of agricultural classes were visited overall – two agriscience classes, two agricultural mechanics classes, two floral design classes, and four small animal care classes.

Each class had a different number of students ranging between 13 and 21 students, with an average of 16.8 students per class. One hundred and fifty-five usable responses were collected, for a response rate of 92%. Of these usable responses, 79 were from female students and 76 were from males. Students ages ranged from 14 to 19 with an average age of 16.1 years. One of the two classes at each school was randomly selected by a coin toss to serve as the test group that would receive the treatment Geocaching activity. The other class served as the control group and received a paper assignment in place of the Geocaching activity. Seventy-eight students who provided usable responses were members of the treatment group/classes, while seventy-seven were members of the control group/classes.

The survey instrument used to collect data was the EMI Critical Thinking Disposition Retrospective Post Instrument (Ricketts et al., 2007) as adapted from the original UF-EMI (Irani et al., 2007; Ricketts, 2003). This version was used for convienience since it has been found to be just as reliable as the original instrument. Reliability of the original UF-EMI ranges from (α = 0.79 to 0.94) (Irani et al.), and reliability of the retrospective post version, as used in this study, ranges from (α = 0.79 to 0.93) (Ricketts et al., 2007).

This instrument asks students to state on a six-point scale their agreement or disagreement with 26 statements in order to evaluate their level of critical thinking disposition. Because it was a retrospective post instrument, it asks students to first rate how they thought their critical thinking disposition was before participating in the study, and then to rate their disposition following the lesson. Retrospective post research designs are frequently used in Agricultural Education and Extension research and evaluation, specifically in regards to the effectiveness of educational programs (Klatt & Taylor-Powell, 2005). A retrospective post design was chosen for use in this study for two reasons.

First, it was selected to minimize the effects of response shift bias. Response shift bias occurs when a participant's understanding of the construct being measured changes in response to the content of an educational program (Drennan & Hyde, 2008; Klatt & Taylor-Powell, 2005). In this study, the educational program was the introductory lecture and the Geocaching activity. Since students knew little about critical thinking or GPS technology prior to the introductory lecture and Geocaching activity, it is likely that students would have not possessed enough information to give an accurate picture of their understanding of these subjects on a true pre-test. By presenting students with the information and then asking them to compare their new knowledge with their prior state, the researchers were better able to compare the changes in critical thinking that occurred as a result of the educational program.

Second, the retrospective post was chosen due to convenience and time constraints. Retrospective post studies are versatile and can be used "to evaluate many types of programs for different audiences in varied settings" (Klatt & Taylor-Powell, 2005, p. 2). They are also "less burdensome and intrusive" for participants and take less time to administer, as all data are collected at the same time instead of at two different points (Klatt & Taylor-Powell, 2005, p. 2). This type of research design fit the needs of the study, since all participating schools used schedules that offered class lengths of only 45 to 60 minutes. Including a separate pre-test and post-test, alongside the introductory lecture and Geocaching activity, would not have fit into this single-class time frame. Separating the experience into two days was a possibility, but the researchers rejected this idea for being intrusive on participating agricultural educators, and to manage the potential for incomplete data due to student absences.

The standards for reliability for Cronbach's alpha by Robinson et al.(1991) were utilized to assess the quality of the scales in the instrument: .80 - 1.00 - exemplary reliability, .70 - .79 - extensive reliability, .60 - .69 - moderate reliability, and <.60 - minimal reliability. Using these standards, all scales possessed exemplary or extensive reliability. Internal consistency coefficients for the subscales for the EMI Critical Thinking Disposition Retrospective Post Instrument were 0.89 for Engagement, 0.75 for Maturity, and 0.79 for Innovativeness. Engagment was measured by 13 items on the instrument, Maturity by six, and

Innovativeness by 11 (Irani et al., 2007; Ricketts, 2003). The total possible score for Engagement ranged from 13 to 78, Maturity from 6 to 36, and Innovativeness from 11 to 66. The total survey score ranged from 30 to 180.

Data were recorded in Microsoft Excel spreadsheets, which were later transferred to SPSS statistical software (SPSS, IBM Corporation, 2010) for further analysis. An alpha level of 0.05 was used, providing a 95% level of confidence. Inferences (t-tests) were drawn by comparing critical thinking and leadership development mean scores of the different groups.

Findings/Results

Objective One

The GPS lesson for both groups combined yielded statistically significant improvements in the critical thinking dispositions of student engagement, cognitive maturity, innovation, and total critical thinking disposition, albeit with a small effect size according to Cohen (1988). The study participants as a whole scored a total Critical Thinking Disposition (CTD) mean of 90.88 (*SD* = 13.58) for the retrospective assessment, and a mean of 94.03 (*SD* =14.59) for the post-lesson assessment. The Engagement retrospective mean was 38.65 (*SD* = 6.80), and the post-lesson mean was 39.92 (*SD* = 7.10). The Cognitive Maturity retrospective mean was 28.45 (*SD* = 3.99) and the post-lesson mean was 29.23 (*SD* = 4.42). The retrospective Innovation mean score was 23.79 (*SD* = 4.10), and the post-lesson mean was 24.88 (*SD* = 4.34) (Table 1).

Table 1
Critical Thinking Change Resulting from the GPS Lesson

Item	*n*	*M*	*SD*	*SE*	*t*	*df*	*p*	*d*
Retro Total	155	90.88	13.58	1.09	-6.26	154	.00	0.23
Post Total	155	94.03	14.59	1.17				
Retro Engagement	155	38.65	6.80	0.55	-4.63	154	.00	0.19
Post Engagement	155	39.92	7.10	0.57				
Retro Maturity	155	28.45	3.99	0.32	-5.04	154	.00	0.20
Post Maturity	155	29.23	4.42	0.36				
Retro Innovation	155	23.79	4.10	0.33	-5.88	154	.00	0.27
Post Innovation	155	24.88	4.34	0.35				

Note. **p* < .05, 2-tailed
**Cohen's interpretation of effect size (*d*), 0.2 = Small, 0.5 = Medium, 0.8 = Large

Objective Two

To determine the influence of the integrated Geocaching activity, changes in critical thinking dispositions were measured by comparing the control group mean score and the treatment group mean score. The total mean score for the control group was 91.03 (*SD* = 12.80), and the total mean CTD score for the treatment group was 90.74 (*SD* = 14.40). The Engagement mean score was 38.86 (*SD* = 6.40) for the control group and 38.44 (*SD* = 7.21) for the group receiving the treatment. The Cognitive Maturity mean score was 28.42 (*SD* = 3.66) for the control group and 28.47 (*SD* = 4.32) for the treatment group. The Innovation mean score for the control group was 23.75 (*SD* = 4.19), and was 23.83 (*SD* = 4.02) for the treatment group (Table 2).

Table 2
Critical Thinking Change Resulting from Geocaching Integration

Item	*n*	*M*	*SD*	*SE*	*t*	*df*	*p*	*d*
Control Total	77	91.03	12.80	1.46	-0.13	153	0.89	0.02
Treatment Total	78	90.74	14.40	1.63				
Control Engagement	77	38.86	6.40	.73	-0.39	153	0.70	0.05
Treatment Engagement	78	38.44	7.21	.82				
Control Maturity	77	28.42	3.66	.47	-0.09	153	0.93	0.01
Treatment Maturity	78	28.47	4.32	.49				
Control Innovation	77	23.75	4.19	.48	-0.12	153	0.90	0.02
Treatment Innovation	78	23.83	4.02	.46				

There were no significant differences between the group with the integrated Geocaching activity and the control group who received the GPS lesson minus the activity.

Conclusions and Recommendations

Although research has already shown that technology in the classroom has benefits (Duran & Sendag, 2012; Grunwald & Associates, 2010; U.S. Department of Education, 1998), the use of GPS technology is hasdistinct benefits to students' critical thinking ability (Schwartz, 2006). Using GPS technology requires students to solve problems, overcome obstacles, make decisions, participate actively in the learning process, and apply new uses to technology – all factors that play a role in the development and exercise of critical thinking skills (Angelo, 1995; Harris, 2015; Murawski, 2014; Paul, 1995; Schwartz, 2006).

Study results imply the introduction of GPS technology into the agriscience classroom has potential to improve student critical thinking, especially regarding the quality of Innovativeness. Innovativeness involves one's desire to learn new information through exploration, truth-seeking, research, and questioning (Irani et al., 2007; Ricketts, 2003). Hands-on use of GPS systems required participants to exercise innovativeness as they experimented with unfamiliar tools and concepts and sought answers via trial and error. At first, student participants were unsure about their ability to navigate, but by the end of the lesson they could utilize concepts such as coordinate planes and latitute and longitude while connecting them to uses in the modern agricultural industry. This behavior demonstrates critical thinking as defined by Facione (1990) and Angelo (1995), who both included problem solving, analysis, evaluation, and inference as crucial parts of the critical thinking process. Students were able to quickly and correctly make use of new information and tools in order to gain new understanding.

The Engagement construct of critical thinking saw some development. Engagement concerns itself with a person's ability to identify and solve situations that require logical reasoning, leadership, and critical thinking. Students in the coordinate activity worked in groups, with each group assigned only one GPS receiver. This naturally led to some students adopting an unofficial leadership position with the group. These leaders often took responsibility for determining positions using the unit while delegating other tasks such as writing coordinates, marking locations, or reading instructions to other members. While there were overall gains in engagement, some students were able to take greater advantage of the situation than others, and perhaps see higher gains in critical thinking than others.

The Cognitive Maturity construct saw the least amount of gain among the three EMI constructs. This construct evaluates a person's awareness of their own biases, their environment, their opinions, and their influences on both their own lives and the lives of others (Irani et al., 2007). This study was not designed to focus on any of these aspects of the Maturity construct, which is most likely the reason that the gain in Maturity scores was the least of all critical thinking gains.

Integrating Geocaching into the lesson did not show any significant benefits to student critical thinking levels. This could potentially be because Geocaching is traditionally a recreational activity, and students saw it as such. Although there are some official Geocaches designed to be educational or to require complex research, inquiry, and puzzle-solving efforts (Groundspeak, 2020), the caches used in this activity were not of this type. Instead, they were representations of the simpler Geocaches that most typically populate the game. After using their GPS receiver to find the general location of a Geocache – a skill already demonstrated in the earlier portion of the lesson – students then physically searched for the hidden container. While this did require students to explore their school grounds and consider where objects could be hidden, usually only one student out of each group made the find while others were unsuccessful. It is possible that the finder alone saw some critical thinking development, or perhaps already possessed higher critical thinking abilities than the rest of their group.

The researchers recommend further study into the use of GPS technology in agricultural education. Global Positioning Systems play a large role in modern agriculture (GPS.gov, 2018), yet this technology not frequently addressed in agricultural education programs. The researchers recommend course developers in agricultural education consider including lessons and applications for GPS/GIS in agriculture. These lessons should focus on (a) developing critical thinking dispositions in students and (b) exposing students to career-relevant technology and content that will enhance those critical thinking dispositons.

The researchers recommend attempting to study GPS integration outcomes with the use of more GPS units. This was a limitation for the study, as not every student participant was able to personally interact with their assigned GPS receiver for the duration of the lesson. Possessing enough GPS receivers to allow students to work in pairs, or perhaps individually, might impact the level of critical thinking that occurs.

Researchers recommend further study to identify the effectivness of Geocaching and other game-based learning methods with the use of a true pre-post design rather than the retrospective-post design. While a retrospective-post design was chosen to minimize response shift bias bias and fit the needs of the study, the format had a downside. Klatt and Powell-Taylor (2008) report that reflecting upon and evaluating one's prior knowledge can be a difficult task, making a retrospective-post design "difficult or inappropriate for certain learners" (Klatt & Powell-Taylor, 2008, p. 2). A true pre-post design would eliminate this issue and measure student critical thinking growth in a more straightforward manner.

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