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THE EFFECTS OF A MOBILE APP-BASED SKY MAP IN TEACHING COLLEGE STUDENTS ABOUT CONSTELLATIONS

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by

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Dedication

I am dedicating this work to my father and brother! It was their dream for me!

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First, I would like to thank my wife, son, and daughter for their support for me to complete this doctoral program. They were enormously gracious with allowing me to take thousands of hours from their precious family time. This work wouldn't have come to this end if it had not been for their extreme patience with my absence while doing the program.

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Abstract

The purpose of this study was to investigate the effects of using a mobile app-based sky map to teach college students about constellations, stars, nebulae, and star clusters. The name of the app was Star Chart. The setting for the study was a community college in West Tennessee. Twenty out of 60 participants were males, with 83% of all being less than 25 years old. The first effect studied was concerning students' level of attitude toward astronomy after they used the mobile app to learn about sky constellations, stars, nebulae, and star clusters. The second effect investigated in the study was regarding the ability of participating college students to identify the above astronomical objects after using the mobile app. For comparison purposes, the same measurements were taken for a control group that used a conventional print-based sky map, commonly known as a planisphere. Multivariate Analysis of Variance (MANOVA) was used to compare the experimental or app-users group ($n = 30$) and control group ($n = 30$).

The results of the study showed that Star Chart app users developed significantly more positive attitude toward astronomy than the planisphere users (Hotelling's Trace = 0.132, F (2, 57) = 3.751, $p < .05$, multivariate effect size $\eta 2 = 0.12$). The multivariate effect size obtained showed that the difference was substantial. On the other hand, both Star Chart and planisphere groups learned comparable skills of identifying constellations, stars, nebulae, and star clusters.

Since app-based sky maps are available freely for various platforms of mobile devices, they can be added to the technology repertoire of teachers and other community members involved in astronomy education. Due to time constraints, the researcher used planetarium software to simulate the sky. Hence, future researchers are recommended to replicate this study in the context of real night sky observations.

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CHAPTER ONE: INTRODUCTION

Mobile devices have versatile features that make them attractive for educational purposes. Their use is stretched over a wide spectrum of practices and across all school levels including higher education (Sung, Chang, & Liu, 2016). Like other areas of study, mobile devices have also been introduced to astronomy education. Integration of new technology into instruction needs to be supported by research (Sung et al., 2016). This study was intended to contribute to such pool of research.

The focus of this study was on investigating the effects of a mobile app-based sky map to teach college students about constellations, stars, nebulae and star clusters. It used an experimental design to assess the students' learning (i.e., identification of astronomical objects) and their attitude toward astronomy. An experimental group used an app-based sky map, Star Chart, while a control group used a print-based sky map, known as a planisphere. Both sky maps help to learn how to identify constellations, stars, nebulae and star clusters. The results of this research are expected to support astronomy teachers' decisions about using app-based sky maps for instruction. The results can also benefit science museum guides or other community members who are interested in using mobile devices for public outreach that involve sky observations. Finally, the study is intended to contribute to the knowledge base of research about instructional efficacy of mobile devices.

Statement of the Problem

Over the last two decades, mobile devices such as smartphones, tablets, and laptops have been available in educational environments (Sung et al., 2016). With time, such devices have increasingly attained more computing power. Through their ability to wirelessly connect to the

Internet, they have enabled people to access enormous amount of information at any time and from any place.

Researchers have been studying the educational benefits of using mobile devices in higher education. In their study, Martin and Ertzberger (2013) compared undergraduate students who used iPads in art lessons versus students who used computer-based instruction. Students who used iPads had better attitudes toward learning than the other students. Noguera, Jiménez, and Osuna-Pérez (2013) conducted a study that was focused around development and evaluation of a mobile application on physical therapy. Their posttest results showed that the experimental group (students who used the mobile app) showed significantly higher learning than the control group (those who did not use the app).

Astronomy is a field of study that is taught across all school levels either as a separate course or integrated with other science fields. College students of introductory astronomy courses are required to learn the names and locations of constellations, bright stars, nebulae, and star clusters (Hintz, Hintz, & Lawler, 2015). Such learning is important during night-sky observations. Slater and Tatge (2017) indicated that developing positive attitude toward astronomy is as important as learning the content matter. Consequently, astronomy courses in colleges include both learning and attitudes in their intended course outcomes (Slater & Tatge, 2017).

The success of night-sky observations is, however, strongly affected by limiting factors such as cloudy skies, city lights, obstruction by tall buildings or trees, cold (winter) conditions, inconvenience of observation times, and so on. Due to the above setbacks for real observations, virtual alternatives have been sought. Among those alternatives was to use dome planetariums. Due to high prices of commercially manufactured dome planetariums, schools have been restricted to using computer planetariums shown on monitor screens (Reid et al., 2014). However, even when outside sky conditions are favorable, dome or computer planetariums cannot be taken outside to guide observations.

Mobile devices, especially smartphones and tablets, can marry the indoor use of planetariums with the real learning experiences of outside night-sky observations. There are many available mobile applications that show sky maps on the screens of the devices (Fraknoi, 2011). Since the devices house multiple sensors (like GPS, electronic compass, and 3-axes accelerometer), such apps can show the exact view of the sky above the location where the devices are. In such a way, mobile devices combine the potential of a computer planetarium with the technology of augmented reality (Tarng, Pan, & Lin, 2017).

Carefully designed research can benefit astronomy instructors in their effort to integrate innovative technologies. Zhang, Sung, Hou, and Chang (2014) points out that new technologies in astronomy education have not been tested systematically. Moreover, not many studies on the instructional efficacy of planetariums use experimental or quasi-experimental research designs (Brazell & Espinoza, 2009; Larsen & Bednarski, 2011). Similarly, Reid et al. (2014) stated that the literature in planetarium effectiveness as a teaching tool is focused on elementary school students. This study was intended to address those research gaps by investigating the learning and attitudinal effects of using app-based sky map in teaching college students how to identify bright constellations, stars, nebulae and star clusters.

Purpose Statement

The purpose of this study was to investigate the effects of using a mobile app-based sky map to teach college students about constellations, stars, nebulae, and star clusters. The independent variable for the study was the type of sky map that participants used. The independent variable had two levels: an app-based sky map called Star Chart and a print-based sky map, commonly called a planisphere. The first effect to be studied was students' attitudes toward astronomy. The attitude level of the experimental group was compared with a control group that used a planisphere.

The second effect investigated was learning achievement, which was defined as a student's ability to identify constellations, stars, nebulae, and star clusters. Both the experimental and control groups were compared based on their learning level.

Research Questions

The study was focused around two research questions which are described below. Each question was also followed by related null and alternative hypotheses. The descriptions of the independent and dependent variables follow each hypothesis.

Research Question 1

What, if any, are the differences in attitude toward astronomy for students who use the Star Chart mobile app and those who use the print-based sky map, called planisphere, for identifying constellations, stars, nebulae, and star clusters?

Null hypothesis 1. Students who use the Star Chart mobile app will have no significant difference in attitude toward astronomy as those using a print-based sky map, called planisphere.

Alternative hypothesis 1. Students who use the Star Chart mobile app will have significant differences in attitude toward astronomy as those using the print-based planisphere map.

In these hypotheses, the independent variable is the kind of sky map that the participants used. It is a nominal scale having two levels: app-based sky map (Star Chart) and print-based sky map (planisphere). The dependent variable is attitude toward astronomy. It was operationally defined as an interval scale and was measured by a validated instrument called Astronomy Attitude Scale (AAS; Türk & Kalkan, 2015).

Research Question 2

What difference exists between students who use the Star Chart mobile app and those who use the print-based sky map (planisphere) in their ability to correctly identify constellations, stars, nebulae, and star clusters?

Null hypothesis 2. There will be no significant difference in identifying constellations, stars, nebulae, and star clusters between students who use the print-based sky map and those who use the Star Chart mobile app.

Alternative hypothesis 2. There will be a significant difference in identifying constellations, stars, nebulae, and star clusters between students who use the print-based sky map and those who use the Star Chart mobile app.

The independent variable is the kind of sky map that the students used. It is nominal-scaled variable with two levels, which were app-based sky map (Star Chart) and print-based one (planisphere). The dependent variable was the learning level attained by the participants in their ability to identify bright constellations, stars, nebulae, and star clusters. It is a ratio scale and was measured using a validated instrument, the Astronomy Content Test (Mallon, 1980).

Significance of the Study

Parallel to the wide prevalence of mobile devices in educational settings, research should be conducted to assess the outcomes of instruction. This study will contribute to the body of knowledge in the field. Specifically, it was intended to generate information about the effects of mobile devices in teaching college students about constellations, stars, nebulae, and star clusters.

The results of the study will benefit astronomy teachers who want to integrate mobile devices in their instructions. The findings will provide them with data to make informed decisions when they consider making choices between mobile app- and print-based sky maps.

The outcomes of this study can also benefit school or community members involved in public education about astronomy. Some examples include astronomy club leaders, amateur astronomers, science museum guides and others. Astronomy public outreach often involves observation of the sky in evening events. Organizers of such events can use the results of this research to make informed decisions.

Definition of Terms

For this study, the following terms will be used:

Astronomical object. The term is used to refer to any naturally occurring object that is found in space. Some examples of such objects include stars, planets, moons, galaxies, clusters, black holes, and many others (Palen, Kay, & Blumenthal, 2018).

Augmented reality (AR). This type of technology comes with the use of mobile devices. It supplements learning objects with instructional content in the form of video, audio, graphics, or other representations (Majid, Mohammed, & Sulaiman, 2015). The learning objects could be real objects (such as specimens in museums), pictures, maps, and so on. In this study, one of the two student groups used mobile app-based sky map known as Star Chart. Among other uses of the app, the major one is its AR feature. When an observer holds the mobile device up towards the sky, the app shows an image of the real-life sky above the observer. The device uses its sensors (such as GPS, compass, accelerometer, and others) to load a dynamic sky image that depends on its location and orientation. The AR feature of the app overlays on the image an instructional content about any astronomical object that the observer taps on. For stars, for instance, the content includes properties such as brightness, distance from Earth, sky coordinates and so on (Star Chart, n.d.).

Constellations. Palen, Kay, and Blumenthal (2018) defined constellation as “any of 88 defined areas on celestial sphere used by astronomers to locate celestial objects” (p. G-3). They also stated that the term may refer to “an imaginary image formed by patterns of stars” (p. G-3). They used the term celestial sphere to refer to an imaginary dome-shape of the sky that we view from Earth.

Cyberbullying. Cyberbullying is an act of bullying somebody in an online environment (Dillon & Bushman, 2015).

Cybersecurity. Cybersecurity refers to protection from malicious use of resources in online learning environment (Chen & He, 2013).

Mobile devices. Sung, Chang, and Liu (2016) defined mobile devices to refer to technologies such as laptops, personal digital assistants (PDAs), tablets, cell phones, and e-book readers.

Mobile learning. El-Hussein and Cronje (2010) explored the status of mobile learning in higher education and developed a succinct definition that was applicable to higher education contexts. From their study, they identified three components of mobile learning and listed them as mobile devices or technology, mobility of learners and mobility of learning. The component of mobile technology included devices such as mobile phones, smartphones, tablets, personal digital assistant devices (PDAs), iPods, and similar devices. They used the component mobility of learners to refer to the potential of mobile devices to allow people to be engaged in learning without being bound to a particular location and time. They contrasted this with using personal computers that were connected by Internet cables in computer labs or classrooms. By mobility of learning, third component, El-Hussein and Cronje (2010) referred to the dynamics of flow of information in the learning environment of students. It addresses the immense connectivity, flow of information, and interaction that can happen in real time even between two people at the opposite sides of the globe.

Planetarium. Baxter and Preece (2000) explained, in a planetarium, night sky view is projected onto a hemispherical dome. It can be used to demonstrate motions of the sun, moon, or any astronomical object as seen from any point on Earth's surface.

Planisphere. Hughes and Stott (1995) defined a planisphere as consisting of

two circular discs of cardboard or plastic. The lower one shows a circular map of the sky and is free to spin about a small bolt placed through either the north or the south celestial pole. The upper disc contains an oval-shaped window that allows that portion of the heavens visible from a specific spot on Earth, at specific time to be segregated from the map (p. 35). They used the term celestial pole to refer to an imaginary axis around which the Earth spins within the 24-hour period of time. The axis is an extension or projection of the geographic North-South Earth axis on to the sky.

CHAPTER TWO: REVIEW OF THE LITERATURE

This review of literature addresses mobile learning in astronomy education broadly. Different studies are reviewed to demonstrate variations in the rich land of mobile learning. First, the review discusses the use of mobile devices in astronomy education. This is followed by a presentation of general educational uses of mobile devices. The review, then, continues to explain detailed examples of some of the current states of mobile learning in higher education. Finally, it presents the rationale to use mobile devices in higher education and the benefits and barriers that come with their use.

Astronomy Education

Astronomy is one of the science fields that is taught across all school levels either as a separate course or integrated with other science fields. It is also a science area that is appealing to the general public (Rees, 1998). In ancient times, people used astronomical knowledge to guide their agricultural activities, religious ceremonies, navigation, time telling, season tracking, aesthetic appreciations, and so forth (Palen et al., 2018).

Introductory astronomy courses are among the general education category of courses that are available to students enrolled in community colleges housed in the Tennessee Board of Regents (TBR, n.d.) system. Some of these courses focus on the solar system only, which mainly include the Sun, planets, moons, asteroids, and comets. Other courses have a larger scope that extends beyond our solar system. Such courses explore stars, galaxies, nebulae, and other celestial bodies.

Learning astronomy content and developing a positive attitude about the subject have had a significant place in astronomy education (Rees, 1998). Slater and Tatge (2017) explained that one of the foci of planetarium education has been on making differences in mastery of astronomical concepts and principles. They also stated that changing a person's interests and values toward astronomy is as important as learning the content. The goal of changing attitudes goes beyond astronomy education. A major concern in physical sciences is a continuous decrease in the number of college students pursuing science careers (Flohic, 2017). Bektasli (2013) argued that a decline might stem from poor attitudes and interests of students toward science. Astronomy is one of the areas under physical science and shares this problem (Slater & Tatge, 2017). Instead of expecting students to improve their attitude as a result of learning science content, Mason and Singh (2016) advised instructors to develop lessons that focus explicitly or primarily on student attitudes. Buxner, Impey, Romine, and Nieberding (2018) noted that since astronomy has relatively higher student enrollment than other physical sciences, it gives more opportunity to address this attitude problem toward science as a whole.

Making observations outside has been a major component in teaching astronomy. Watching the night sky not only has aesthetic value, but also gives students a real-life experience of astronomical phenomena such as motion of stars, phases of the moon and its motion, seasonal changes of stars that appear on the sky, and so on. Learning names and locations of constellations helps to guide the exploration of night sky. Traditionally, such learning activities are supported by use of a planisphere, which is general name used to refer to any form of paper-based sky map composed two circular shaped discs. Commonly, such maps show names of constellations, stars, nebulae, and star clusters. Observers use the maps to familiarize themselves with the locations of such astronomical objects, which help to guide any of their sky-observation activities.

Planetariums

The success of night-sky observations depends on many factors. Examples of limiting factors include cloudy skies, city lights, obstruction by tall buildings or trees, current location, cold (winter) conditions, and inconveniences of observation times for students. To address the problems that inhibit successful night-sky observations, planetariums were invented (Reid et. al., 2014). In a planetarium, a projector casts images of the sky up onto a dome-shaped screen. Such projections are meant to simulate how the outside sky looks from an observation location set by the operator of the planetarium. Using the software settings, different locations can be chosen to show viewers how the night sky would look like from those locations.

Brazell and Espinoza (2009) conducted a meta-analysis of 19 studies on the effectiveness of using planetariums in astronomy education. Using effect-size as scale of comparison for the studies, the authors concluded that a planetarium could be an effective tool for teaching astronomy, especially for grades K-12. They also reported that a planetarium has great potential to positively influence student learning when used with interactive observational-astronomy instruction. The generalizability of their results, however, is limited by a lack of common assessment instruments and by a variety of astronomy topics used in the analyzed research. As a consequence, the authors recommended the need for further research that compares planetarium-based instructions with astronomy instructions that use other tools. Moreover, the meta-analysis study did not address the effect of a planetarium on motivation of students in learning astronomy. The following paragraphs will discuss about factors that affect the practical adoption or use of planetariums by schools.

Due to the high price of commercially manufactured dome planetariums, schools have been limited to using computer planetariums shown on monitor screens (Baxter & Preece, 2000;

Reid et al., 2014). Such planetarium software can be installed to computers in science labs, giving students more opportunity for individual learning experience. The software can be used to demonstrate the motion of the Sun, Moon, planets, and stars as viewed from Earth (Reid et al., 2014).

Dome planetariums are solely made for indoor uses. Similarly, computer planetariums, even though they can be portable as in the case of laptops, are not useful for outside night sky observation. In other words, even if they can be downloaded onto a laptop, they still will not help night sky observers because laptops lack sensors such as a GPS, digital compass, and accelerometers. Due to their lack of having a GPS, laptops cannot identify the location of observers (using latitude and longitude) that determine what part of sky will be visible to the observer from their place at the time of observation. The lack of a digital compass in laptops also prevents them from identifying which direction (East, West, North, or South) an observer is facing, which is a factor that affects what part of sky is visible. Laptops cannot know how high (altitude) above the horizon an observer is looking. On the contrary, mobile devices are equipped with the above sensors, which make them very helpful for outside night sky observations.

Mobile Devices

Mobile app-based sky maps combine the potential of computer planetariums with the possibility of using them in outside night-sky observations. Currently, there are many mobile sky map applications (Fraknoi, 2011). Due to the availability of multiple sensors (GPS, electronic compass, and g-accelerometer) on mobile devices, such apps can show the exact view of the sky above the location where the device is. In such a way, mobile devices combine the potential of computer planetariums with the technology of augmented reality (Tarng et al., 2017).

Use of any technology for instructional purposes has to be supported by research-based evidence. In this regard, researchers have been studying many variations of mobile-device uses in astronomy education. In this current study, mobile learning is defined as a type of learning environment where learners use various mobile devices to access content while interacting with learners located anywhere in the world (El-Hussein & Cronje, 2010). The following paragraphs discuss some of the research.

Several studies report positive results on the use of mobile devices for astronomy education. The content of the studies cover different topics of astronomy. The results referring to student learning look particularly encouraging (Tarng et al., 2017; Zhang, Sun, Hou, & Chang, 2014). After comparing three classes of elementary schools in Taiwan, Tarng, Pan, and Lin (2017) reported that an app developed for the study helped the users to locate constellations quicker than a group that used a planisphere and another group that used Google Sky Map. In addition to a learning effect, there are studies that have shown positive effects of astronomy apps on attitudes of participants toward the learning content (Tarng et al., 2017; Tian, Endo, Urata, Mouri, & Yasuda, 2013; Yen, Tsai, & Wu, 2013; Zhang et al., 2014). Tian et al., (2013) studied the effect of a learning environment that used an Android-based app for the purpose of lunar phase observation. They reported that the learning system improved the participants' motivation to observe the Moon.

Yen, Tsai, and Wu (2013) compared three instructional approaches used to teach about moon phases. The three designs examined in the study were 2D animation (2D), 3D simulation (3D), and AR. The authors reported that the students in the 3D and AR groups showed higher motivation and attentiveness in learning tasks. Similar positive effects were also reported by Tarng et al. (2017), who studied a mobile app that used motion sensing and automatic positioning. The authors concluded that their participants found the app to be easy to use and made their learning experience more interesting.

Despite their positive results, the above studies also had shortcomings in their research designs. For instance, the study by Tian et al. (2013) used a small sample size of only ten participants. The studies also selected their participants from elementary school students, making the results not generalizable to higher education settings. Moreover, very few studies used research designs that systematically controlled variables affecting the learning experiences of students (Brazell & Espinoza, 2009; Zhang et al., 2014). Brazell and Espinoza (2009) reported such limitations after conducting a meta-analysis of 19 studies. The following study tried to use systematic control of variables in its research design. Despite this strength, though, the researchers used convenience sampling, instead of random assignment of participants into groups. Such a limitation might have an effect on the generalizability of their results.

Zhang, Sung, Hou, & Chang (2014) developed instruction that uses AR-based armillary sphere (a spherical model of astronomical objects on the sky as viewed from Earth) to teach astronomical observation to elementary students in Taiwan. They called the product a mobile digital armillary sphere (MDAS). They evaluated the mobile app for its learning effectiveness and students' interest in making astronomical observations. Their design involved four groups of students. The first group attended a traditional in-class (TC) instruction using a paper-based planisphere. A second group (MC) attended the in-class instruction using MDAS. The third and fourth groups attended outside instruction using paper-based planisphere (TO) and MDAS (MO) respectively.

The results using analysis of variance (ANOVA) showed a significant difference among groups in constellation identification (F (3, 243) = 11.021, p = 0.000) and constellation proportion (F (3, 143) = 5.460, p = 0.001). However, no significant differences were observed among the four groups in constellation deformation (F (3,143) = 2.401, p = 0.063). To identify the details of the above differences in constellation identification, Scheffe's multiple comparison method was used. The MO group scored in constellation identification significantly better than the MC group (p = 0.0000), TC (p = 0.035), and the TO group (p = 0.000). Moreover, the constellation proportion scores were significantly better for MO group than the TO (p = 0.045) and TC (p = 0.003). However, constellation proportion scores were not significantly different between MO and MC groups (p = 0.386). On the performance of outside astronomical observation, the MO group scored significantly better (t = 5.986, p = 0.000) than the TO group. As an affective variable, a score in flow experience of observation was measured. On this variable, the MO group scored significantly higher than the rest of the groups.

Nevertheless, the study had some limitations with regard to the statistical analyses used. They had three dependent variables assessed by their constellation achievement test. To analyze the data, they used ANOVA. According to Hair, Anderson, Tatham, and Black (1995), a set of possibly correlated dependent variables would be better analyzed using MANOVA. Use of multiple ANOVA significance tests have consequences of increasing experiment-wise or an overall Type I error. To solve this problem, the authors could have used MANOVA. Besides, the study also had sampling limitations. The authors used convenience sampling in selecting participants from classes and schools. Such a limitation can have effect on the generalizability of the results.

Summary

To conclude, the reviewed studies showed that astronomy education has also benefited from the technology brought by mobile devices. However, there aren't enough studies that used systematic research designs to isolate the factors that affect learning experiences of students. More research is needed to test the role of important variables attached with the use of mobile devices in astronomy education (Zhang et al., 2014).

Current Educational Uses of Mobile Devices

The practices are categorized into three groups: mode of instructional delivery, social interaction and collaboration, and assessment.

Mobile learning is advancing so quickly that it is becoming even harder to provide a definition that encompasses all its capabilities (Adegbija & Bola, 2015; El-Hussein & Cronje, 2010). Using a thorough meta-analysis of previous studies, El-Hussein and Cronje (2010) explored the status of mobile learning in higher education and developed a succinct definition that was applicable to higher education contexts. From their study, they identified three components of mobile learning and listed them as mobile devices or technology, mobility of learners, and mobility of learning. The component of mobile technology included devices such as mobile phones, smartphones, tablets, personal digital assistant (PDAs) devices, iPods, and similar devices. Hashemi, Azizinehad, Najafi, and Nesari (2011) provided a similar list, which also included mini notebooks or netbooks, Ultramobile PCs, handheld GPS or voting devices, and special portable technologies used in science labs, engineering workshops, or for environmental studies.

El-Hussein and Cronje (2010) used the component "mobility of learners" to refer to the potential of mobile devices to allow people to be engaged in learning without being bound to a particular location and time (p. 17). They contrasted this with using personal computers that were connected by Internet cables in computer labs or classrooms. Such an arrangement allowed learners to engage in learning by being physically present in those labs or classrooms. El-

Hussein and Cronje (2010) stated that mobile technologies had broken such bonds so that learners could access their materials at any time and from anywhere including home, school, coffee shops, etc. Other researchers also include such components into the definition of mobile learning (Cheon, Lee, Crooks, & Song, 2012; Hashemi, Azizinehad, Najafi, & Nesari, 2011).

The third component in the definition of mobile learning by El-Hussein and Cronje (2010) was "mobility of learning" (p. 17). By this phrase, they referred to the dynamics of flow of information in the learning environment of students. It addresses the immense connectivity, flow of information, and interaction that can happen in real time even between two people at the opposite sides of the globe. Mobile technologies enable learners that are distant from each other to share and edit the same document in real time. We also find the inclusion of such capabilities in the definition of mobile learning from other researchers such as Hashemi et al. (2011) and Cheon, Lee, Crooks, and Song (2012). To summarize, in this study, mobile learning is defined as a type of learning environment where a learner can use various kinds of mobile devices to access content from different places (learner mobility), while interacting (mobility of learning) with other learners that might be located anywhere in the world (El-Hussein & Cronje, 2010).

Mode of Instructional Delivery

In mobile learning, instructional content is accessed through mobile devices. Some researchers tried to integrate mobile technologies into existing learning management systems (LMS) like Moodle (Cavus, 2011). Because of the capability of mobile devices to access the Internet, they become handy for students while looking for any information important to their classes. This possibility has given distance education greater power to reach many more students (Chao et al., 2015; Kenny, Park, Van Neste-Kenny, Burton, & Qayyum, 2012). Mobile learning can also focus on stand-alone instruction. It is common to find websites that can be fully accessed through mobile devices. Such websites are commonly called mobile applications or, simply, mobile websites (Martin, Pastore, & Snider, 2012).

Mobile learning may also encourage lifelong learning. Slavkovic and Savic (2015) conducted a survey study with the purpose of assessing how adult participants view mobile learning. They reported that most of their participants owned mobile devices and used them for messaging and Internet surfing. The participants also indicated their interest in using mobile devices for learning about art, recreation, learning a foreign language, etc.

Social Interaction and Collaboration

Mobile learning is also used to promote social interaction and collaboration. Shih and Mills (2007) assessed the practice of mobile learning in a children's literature course at a university. They reported that students were highly motivated by mobile learning. They also indicated that student-teacher interaction was enhanced as a result of using mobile computing. Students were reported to be more encouraged to collaborate with each other. Similar results were also obtained in a study conducted by Brazley (2014) with the purpose of evaluating the use of mobile technologies for teaching architecture students. The author found that teacher-student interaction, real-world-based problems, and decision-making opportunities gave students the most satisfaction with mobile learning.

Lan and Huang (2012) also studied similar uses of mobile devices. They investigated the effects of mobile learning on traffic violations. Their results showed that learners (college and graduate students) viewed mobile learning as useful. The learners preferred mobile learning to lectures about traffic-violation issues because of its potential to promote communication, collaborative interaction, and inquiry-based experiences.

Assessment of Learning

Mobile devices are also used for assessment of student learning. For instance, Bogdanović, Barać, Jovanić, Popović, and Radenković (2014) conducted research to assess students' experience of using mobile devices to take tests and to compare their performance on tests given by mobile devices vs. computers. The results of the study showed that students needed significantly more time when taking the mobile test than computer-based test ($t = 67.17$, $p < .05$). Taking the factor of types of mobile phone, ANOVA results showed a significant effect on test performance, $F(3, 30) = 48.842$, $p = 0.000$. The authors reported that students who used the kinds of phones with large-screen sizes achieved best test results. No significant difference was seen between scores on mobile vs computer tests ($t = 0.682$, $p > .05$).

A growing interest is being observed in assessing students' performance based on the interactions they have with their mobile technology and with one another. Due to the amount of data that is generated through these interactions, student assessment in mobile learning requires borrowing analysis expertise from a field called learning analytics (Agudo-Peregrina, Iglesias-Pradas, Conde-González, & Hernández-García, 2014). More specific studies using learning analytics are presented later in this chapter.

Summary

As seen in the above reviewed studies, mobile learning has been used to provide resources in instruction, assess learning, and offer learners with opportunities for collaboration and social interaction. In the following section, a more detailed review of studies in each of the above categories will be presented.

Current Uses of Mobile Devices in Higher Education

As explained above, mobile learning has gained usage in the academic and social life of students and teachers in higher education. In the following paragraphs of this section, studies on different examples of mobile learning are presented.

Augmented Reality

Augmented Reality (AR) is one of the ways mobile devices are supporting student learning. Majid, Mohammed, and Sulaiman (2015) define AR as supplementing learning objects with video, audio, graphics and other information. The learning objects could be real objects (such as specimens in museums or pictures). For instance, learners can use their mobile devices to scan a barcode on a specimen. This action can open content about the specimen that learners can read, listen to, or watch depending on the format used.

Research on the use of AR has been conducted in different content areas. Some of the content areas include science (Cai, Chiang, & Wang, 2013; Cai, Wang, & Chiang, 2014; Chang, Wu, & Hsu, 2013; Chou & Chanlin, 2014; Yen et al., 2013), mathematics (Kaufmann & Schmalstieg, 2003; Sommerauer & Müller, 2014), engineering (Gutiérrez & Fernández, 2014; Kose, Koc, & Yucesoy, 2013; Martín-Gutiérrez, Fabiani, Benesova, Meneses, & Mora, 2014), computer science (Majid et al., 2015; Souza-Concilio & Pacheco, 2013), and English (Liu & Tsai, 2013). The studies tried to assess two effects of AR: student learning and attitude improvement. Most of the studies on science and mathematics showed that AR improved learning achievement among students (Cai et al., 2014; Chang et al., 2013; Chou & Chanlin, 2014; Sommerauer & Müller, 2014). For instance, Cai, Wang, and Chiang (2014) conducted a case study of an AR simulation system in a chemistry course. They reported that the tool had a significant learning effect on the students. They also indicated that the AR tool was more effective for low-achieving students than high-achieving students.

Studies of learning effects of AR on other content areas are also positive. Use of AR technology for teaching engineering content resulted in improved student learning (Gutiérrez & Fernández, 2014; Kose et al., 2013). In contrast to the previous studies, Liu and Tsai (2013) assessed the effect of using mobile AR in an English composition class. They reported that their participants, after using AR-based mobile learning in their historical-place visits, improved on their ability to express written and visual information, and elevated their skills to access information.

One the other hand, there are also studies in the area of science that did not show a significant learning effect of AR (Cai et al., 2013; Yen et al., 2013). For instance, Cai, Chiang, and Wang (2013) conducted a study on investigating the learning effectiveness of an AR-based experiment in a physics course. The authors reported that the difference between pretest and post-test scores of the experimental group (supplemented with AR technology) was not significantly different than the corresponding scores of the control group (attending traditional lectures).

The other effect of AR that took the focus of researchers was the attitude of students toward their learning experience. All of the above studies indicated that AR-based instruction resulted in improvement of students' attitudes towards their learning experience. For instance, Cai et al. (2014) reported that their students had a positive attitude toward an AR simulation developed in a chemistry course. The authors reported that the students' learning attitudes were positively correlated with their evaluation of the simulation.

The above reviewed studies are not, though, without limitations. The results of some studies (Liu & Tsai, 2013; Souza-Concilio & Pacheco, 2013) have limitations due to small sample sizes. For instance, Kaufmann and Schmalstieg (2003) evaluated a prototype of an AR-based geometry educational tool. They reported positive reactions experienced by their students. However, the results of the study had limitations because it had only 14 participants and it was a pilot project. Another limitation in AR research is in regards to astronomy education. The research about the effect of AR technology on students of astronomy focuses more on elementary schools than higher education (Reid et al., 2014).

To conclude, most of the studies reviewed above revealed that AR-supplemented learning experience could result in an improvement in students' academic performance. Additionally, the studies showed that students expressed positive opinions or reactions to the use of AR in learning environments.

Non-Augmented-Reality Uses

In addition to uses of mobile devices for augmented reality (AR), there are many more applications, including in the assessment of learning. Because of the wide availability of mobile devices, the amount of data generated from students' experiences has become enormous. Using these data for assessment has made it important to use techniques from learning analytics, which is defined by Agudo-Peregrina, Iglesias-Pradas, Conde-González, and Hernández-García (2014) as collecting large quantities of data regarding student interactions with mobile or similar learning environments and analyzing the data for the purpose of improving learning. Even though interest is growing in using learning analytics as an assessment tool (Agudo-Peregrina et al., 2014; Romero-Zaldivar, Pardo, Burgos, & Kloos, 2012; Zuga et al., 2015), the research so far is limited in its scope. More research needs to be done especially on the specific student interactions that could directly relate to students' academic performance.

Teachers have also used mobile devices to reach many students by using podcasts that review or supplement lectures (Evans, 2008; Fernandez, Simo, & Sallan, 2009; Lonn & Teasley, 2009). McKinney, Dyck, and Luber (2009) compared the effectiveness of podcast-based lectures with class-based lectures. They reported that students who attended the podcast lectures performed significantly higher on a posttest than those students who attended the class lectures. However, the study used a small sample size and was from a single small university. Other studies have also reported that mobile devices played positive role in collaboration and social interaction among their students (Ebner, Lienhardt, Rohs, & Meyer, 2010; Holotescu & Grosseck, 2011).

Summary

The studies reviewed above showed some of the current states of mobile learning in higher education. The review covered applications such as augmented reality (AR), learning analytics, podcasting, and other uses that provide learning environments for collaboration and social interaction among students. Most of the reviewed studies on AR-use reported a positive experience of students and improvement in academic performance.

Rationale for Using Mobile Devices in Higher Education

There are two broad rationales for using mobile devices in higher education: motivational effect and learning effectiveness. Each rationale is presented in the following paragraphs.

Motivational Effect

Among the rationale for using mobile devices in higher education is their effect on motivation or attitudes of students towards learning content. A study conducted by Martin and

Ertzberger (2013), for instance, compared student groups based on their attitudes toward learning with iPads, iPods, and computer-based instruction. The results showed that the students who used iPads had the most favorable attitude toward learning, followed by the iPod group, and finally the computer-based instruction group.

Similar results were also reported on a study conducted by Sari (2014). The purpose of the study was to assess learning effectiveness of instruction taught using Information Communication Technology (ICT). The author reported that the motivation and success rate of their university students improved due to use of ICT-based teaching as opposed to traditional approach.

Learning Effectiveness

The other rationale for using mobile devices in higher education has to do with its effect on improving academic performance of students. Some studies have reported that students' performance improved related to use of mobile learning innovations. Noguera et al. (2013) conducted one such study. Their study was focused around development and evaluation of a mobile application on physical therapy content. The results of two separate posttests showed that the experimental group (students who used the mobile app) outperformed significantly higher than the control group (those who did not use the app). On both posttests, no significant gender difference was observed. Even though the experimental design of the study was very strong in many aspects, there was a disproportionate gender distribution among students (73% were female). This could have an impact on the results' generalizability.

Similarly, Dekhane, Xu, and Tsoi (2013) conducted a study with a purpose of assessing improvement in student problem-solving skills and critical thinking in an Information Technology (IT) college course. The study also aimed to examine a change of student interest in computing and the sustainability of their engagement in the IT class. The results indicated that students showed better problem-solving skills and critical thinking on a posttest than on the pre-test. Moreover, the students demonstrated positive attitudes and higher engagement levels compared to those in other (non-IT) classes.

Summary

To conclude, there is evidence that indicates the role of mobile devices in supporting improvements in motivational and learning effects (Bruce-Low et al., 2013; Hwang & Chang, 2011; Sevillano-García & Vázquez-Cano, 2015). Using mobile devices either as a stand-alone technology or together with other technologies could ultimately benefit students and teachers in higher education.

Benefits and Barriers Related to the Use of Mobile Devices in Higher Education

In this section of the manuscript, studies on benefits and barriers of mobile devices are reviewed. The studies that addressed benefits are presented first, followed by those studies that focused on barriers of mobile devices.

Benefits

Mobile devices have advanced to make their benefits visible. As a result, they have enjoyed adoption in different spheres of human activities from personal to professional. Different researchers have conducted studies in order to survey the benefits people have obtained from using mobile devices. Some of these studies are reviewed and presented in this manuscript as follows.

Availability of mobile devices. Mobile devices have become common in almost every aspect of someone’s life. Due to their prevalence, as well as their capabilities, they can be beneficial to use for learning purposes. Studies have shown that students and teachers are more likely to use mobile devices for learning purposes when they perceive that the learning environment is easy to use, resourceful, and widely adopted by their peers (Chen, Sivo, Seilhamer, Sugar, & Mao, 2013; Georgieva, Smrikarov, & Georgiev, 2011; Milošević, Živković, Manasijević, & Nikolić, 2015; Tan, Ooi, Sim, & Phusavat, 2012).

Accessibility to information at any time and from anywhere. Among the factors that enabled mobile devices to penetrate educational institutions is their potential to provide access to information at any time and from anywhere. Different studies have tried to assess the nature of this factor. For instance, Sølvberg and Rismark (2012) conducted a study to assess how students studied within a mobile learning environment. The results showed that students' motivation increased in a learning environment that used mobile devices. Sølvberg and Rismark (2012) also reported that their subjects liked the flexibility that mobile learning provided (any time and any place). Their study, however, had only 14 university students as participants.

In contrast to the above study, a research by Kaganer, Giordano, Brion, and Tortoriello (2013) had much bigger sample ($N = 124$). They used surveys and interviews to examine the integration of an iPad into learning settings. Kaganer et al. discussed that organizations were seeking to shift everyday activities onto personal mobile devices. They reported that students perceived greater accessibility and portability of digital content as a result of using an iPad for learning purpose. Even though this study was limited to iPads only, its results are in alignment with the results reported in the research reviewed before and with other similar studies (Gupta & Koo, 2010).

Convenience for collaborative learning such as using social media. Mobile devices also have benefits in terms of their potential to provide convenience for collaborative learning and social media interaction. To assess this potential, Motiwalla (2007) evaluated an implementation of a mobile learning application that was designed to complement three web-based learning environments. The results indicated that the students found the application useful and a good complementary tool for classroom interaction. Wang, Chen, and Khan (2014) also reported a similar result. They explored the effect of cloud computing on traditional mobile learning. The authors reported that using cloud-based Moodle benefitted their university by saving the cost of operating their own servers. They also indicated that mobile cloud learning facilitated communication and collaboration among students and between students and teachers. Hsu and Ching (2013) also reported collaboration and development of sense-of-community as mobile-learning benefits.

Summary

The above studies have shown the benefits of mobile devices when used for learning purposes. The benefit of using mobile devices is widespread, including their potential to allow learners to access content material from anywhere and at any time, and the convenience of mobile devices for collaborative learning and social interaction.

The benefits of mobile devices can also be harvested for their use in astronomy education. For instance, the prevalence of mobile devices (Milošević, Živković, Manasijević, & Nikolić, 2015) helps to bring astronomy content closer to students compared to planetariums. Moreover, mobile devices empower students to access astronomy content at any time and from anywhere (Sølvberg & Rismark, 2012). Finally, astronomy education can also be improved using collaborative learning and social media interaction that can be made convenient in a mobile learning environment (Hsu & Ching, 2013).

Barriers

As with any technology, mobile devices have their own barriers when we try to use them to our advantage. Some barriers are related to the physical characteristics of the devices themselves, while other barriers are introduced by people who chose to use the devices for wrongdoing. Below are some studies that focused on the barriers of using mobile devices for learning purposes.

Cybersecurity. Cybersecurity is a major problem that challenges mobile technology. A study conducted by Chen and He (2013) assessed online learning providers' awareness of security risks and protection measures. The authors reported that scholars had identified security risks and their solutions. Bloggers, however, did not discuss security in their online posts with great frequency. Out of similar concerns, a study by Patten and Harris (2013) aimed to identify educational recommendations on mobile security issues. The authors indicated the existence of concerns in mobile security and recommended improvements in IT curricula that would train undergraduate students with needed skills. A limitation of the study was that the resulting new curricula was not yet implemented and evaluated.

An additional problem related to cybersecurity is the threat of cyberbullying. Dillon and Bushman (2015) conducted a study to examine the experiences of cyber-bystanders to notice a cyberbullying incident. The results indicated that noticing cyberbullying significantly predicts direct or indirect intervention. The authors reported that around 68% of their participants (cyber-bystanders) noticed cyberbullying, but only 10% directly intervened by engaging with the bully. About 68% of the participants intervened indirectly after the incident and threat were removed.

Small screen size. Small screen sizes of mobile devices have also been a barrier on their use. Martin, Pastore, and Snider (2012) conducted a study to investigate the effect of mobile interface design factors such as screen size, navigation bars, and content design. The authors reported that small screen size of mobile devices forced their subjects to minimize content. The participants also indicated that they used limited navigation tools, namely “back,” “forward,” and “home.” Moreover, they indicated that content design was limited to simple HTML-based tabular layouts with limited content and images to allow faster downloading. Similar results were reported by Motiwalla (2007), who indicated that student users found the keypad and small screens of mobile phones difficult for navigation, reading and typing messages.

Classroom distractions such as texting in class time. Another barrier or limitation of mobile devices is their potential to distract some students in class time. Because mobile devices have functionalities for texting and taking and posting pictures or videos, some students get distracted easily during class time or while they are in a mobile learning environment (Güler, Kılıç, & Çavuş, 2014; Henderson & Chapman, 2012; Kwon & Lee, 2010).

Summary

To conclude, mobile devices come with their own drawbacks when we try to use them for their benefits. The barriers discussed above included vulnerability to security related problems, effects of small screen sizes, and easiness to distract people from learning. This list was not complete in its coverage.

Conclusion

One of the findings of the reviewed research was that physical sciences such as astronomy have been enrolling fewer college students over time (Flohic, 2017). This decrease could be attributed to an unfavorable attitude of students toward the sciences (Bektasli, 2013). Mason and Singh (2016) recommended that instructors give primary focus to student attitudes. Mobile learning could be such a strategy based on the studies reviewed in the manuscript, which showed a positive effect of mobile learning on improving students' motivation or attitude to learning. Different studies that used AR-based mobile technologies, for example, reported improvements in students' learning motivation (Cai et al., 2013; Gutiérrez & Fernández, 2014; Majid et al., 2015; Yen et al., 2013). Some studies also showed that mobile learning benefited students in their academic performance. For instance, AR-based mobile learning has been reported to improve students' academic achievements (Cai et al., 2014; Chang et al., 2013; Gutiérrez & Fernández, 2014; Kose et al., 2013). On the aspect of mobile device uses in astronomy education, there is a need for more research that systematically control variables that affect learning experiences of students (Brazell & Espinoza, 2009; Zhang et al., 2014).

CHAPTER THREE: METHODOLOGY

The purpose of this study was to investigate the effects of using a mobile app-based sky map to teach college students about constellations, stars, nebulae, and star clusters. The research questions guiding this study were:

1. What, if any, are the differences in attitude toward astronomy for students who use a Star Chart mobile app and those who use a print-based sky map, called a planisphere, for identifying constellations, stars, nebulae, and star clusters?
2. What difference exists between students who use a Star Chart mobile app and those who use a print-based sky map (planisphere) in their ability to correctly identify constellations, stars, nebulae, and star clusters?

The study used an experimental design to examine the research questions. Specifically, the study sought to examine the differences between the treatment group that used an app (Start Chart) and the control group that used a print-based sky map (planisphere) for identifying constellations, stars, nebulae, and star clusters.

Details of the research methodology used in this study are presented in the sections that follow. The first section describes the research method and design. This is followed by discussion of the participants. The next two sections provide details about the independent variables and the instruments used in the study. Two sections detailing the data collection procedures and data analyses follow them. Finally, limitations and biases in the study will be discussed in detail.

Method and Design

The research design for the present study was experimental in nature due to the random assignment of participants to two conditions. Creswell (2008) defined experimental designs as procedures in quantitative research in which the investigator determines whether an activity or materials make a difference in results for participants. You assess this impact by giving one group one set of activities (called an intervention) and withholding the set from another group (p. 60).

As required by an experimental design, participants were randomly assigned to one of the two groups by the researcher. Creswell (2008) points out that random assignments help to control most threats to internal validity. Using only a posttest (without a pre-test) minimizes the threats of "testing, instrumentation, and regression" (Creswell, 2008, p. 313).

Participants

Participants

The general population for the study encompassed community college students in the Tennessee Board of Regents (TBR) system, which currently houses 13 community colleges and 27 technology centers. In a report published by the TBR (2014), the community colleges had a total of 86,236 students, out of which 60% were females and 40% males. Seventy percent of the students were less than 25 years of age. Ethnically, Whites, Blacks, and Hispanics made up 73.8%, 16.8%, and 3.6% of the students, respectively.

An invitation to participate was sent by email to all students of the college. Participation was voluntary. The sample used in this study consisted of 60 students at a TBR community college in western Tennessee. In terms of student numbers, the college is among the smallest colleges in the state of Tennessee.

Power Analysis

For data analysis, the researcher used a special case of MANOVA called Hotelling's T^2 test (Hair, Anderson, Tatham, and Black, 1995). For this method, VanVoorhis and Morgan

(2007) recommend a sample size of 30 (per group) as a minimum required to obtain a statistical power of 0.8 for a medium effect size at α-level of 0.05. Fraenkel and Wallen (2003) and Hair et al. (1995) also recommended this sample size as a minimum requirement. Therefore, each group had an equal number of participants (30).

Having an equal sample size in each group makes statistical tests more robust to any possible violations of assumptions (Hair et al., 1995). Thus, no attempt was done by the researcher to recruit more than 30 participants per group. Keppel and Wickens (2004) discuss that estimation of sample size does not need to be precise. They stated that effect size and power calculations are never known to within more than about 10 percent. Therefore, due to such statistical reasons and time constraints to complete the current study, the researcher did not try to recruit more participants than needed.

Consent Process

The University of Memphis's Institutional Review Board granted permission to use human subjects for educational research purposes. Participants completed an informed consent form (see Appendix A).

Independent Variable

The independent variable was the type of sky map used. The independent variable had two levels: a mobile app-based sky map called Star Chart and a print-based sky map, commonly called a planisphere.

There are various app-based sky maps available for free or for purchase (Fraknoi, 2011). Sky Chart was selected for this study because of its cost (free) and its ability to be downloaded on different platforms such as Android, iOS, and so forth. It also has a good level of accuracy to show constellations very similar to the real sky. Its augmented-reality feature also has visual representation (images of constellations), which is important for science apps as described by Zydney and Warner (2016). The images of constellations help students to learn their patterns or shapes. Images of constellations can also provide learners with visual clues to remember their names and match their images (example: Orion the hunter; Palen et al., 2018). Moreover, the app allows users to search and explore astronomical objects. Zhang et al. (2014) consider such features important because they give learners autonomy to guide or monitor their learning experiences. On the other hand, the planisphere used in this research was selected for this study because it is an extremely common instrument used by professional and amateur astronomers (Hughes & Stott, 1995). Moreover, it is free for anyone's use (Sky & Telescope, 2007). Hughes and Stott (1995) explain that a planisphere has been the traditional sky map used since more than 2,000 years ago. Hence, the researcher chose to compare instructional uses of the new technology (Star Chart) with the traditional sky map (planisphere).

Participants in both conditions completed the same activities. The treatment group used a mobile app-based sky map to identify constellations, stars, nebulae, and star clusters that are relatively bright. The control group used a print-based sky map. The following sections provide a brief description of each type of sky map.

Star Chart

Star Chart (see Figure 1) is a free mobile-based sky-map app that works on different platforms. Star Chart, similar to a dome planetarium, displays many kinds of astronomical objects (e.g., stars, planets, galaxies, nebulae, moons, and constellations) in all parts of the sky. It can show many objects on the screen that are even invisible to the eye in the night sky. However, by using the features of mobile devices, Star Chart can do more than what can be done by the ordinary projector-based or dome planetariums. For instance, app-based sky maps allow people to observe the real night sky (not simulated) while using the apps as guides. Moreover, mobile sky maps add personal experience (e.g., location-based sky viewing and zooming) and the technology of augmented reality to the functions of indoor planetariums (Tarng et al., 2017). Depending on where they are located, sky map apps can use the device's GPS, compass, and other sensors to find the location of the observers and show the sky right above them. For instance, if people point their phone or other mobile device toward one of the cardinal points (example: East) at an altitude of 30^0 above their horizon, the app displays that part of the sky in real-time. If users then move the phone to an overhead position (90^0 above horizon), the app shows that part of the sky. Since the horizon depends on latitude of the location of users, people at the North Pole versus people in Memphis see different constellations when they look overhead and, yet, the app uses its sensors (GPS, compass, and accelerometer) to show both observers their respective part of the sky. Moreover, the app can display instructional content about any astronomical object that the observer chooses to study in more detail. For the purpose of training or supporting users on how to use the app, Star Chart includes a user guide document that can be downloaded for free on the mobile device or that can be accessed from the Internet without downloading (Star Chart, n.d.).

Figure 1. Screenshot of Star Chart. Star Chart (n.d.). Retrieved from https://lh3.ggpht.com/ mGuFgS1lkkFezKHWr_ydALo0RgGCn0pQeeDaioz YumQ0bZjST1wqyqcj6vKrCsZGFEQ =w1366-h604

Planisphere

There are many varieties of planispheres, two-page print-based sky maps shaped as a wheel that can be rotated about a central point. The one used in the current study is shown in Figure 2. It displays a portion of the sky depending on settings around the wheel. The settings include geographic direction that the observer is facing, month of the year, date within the month, and time when the observation is taking place.

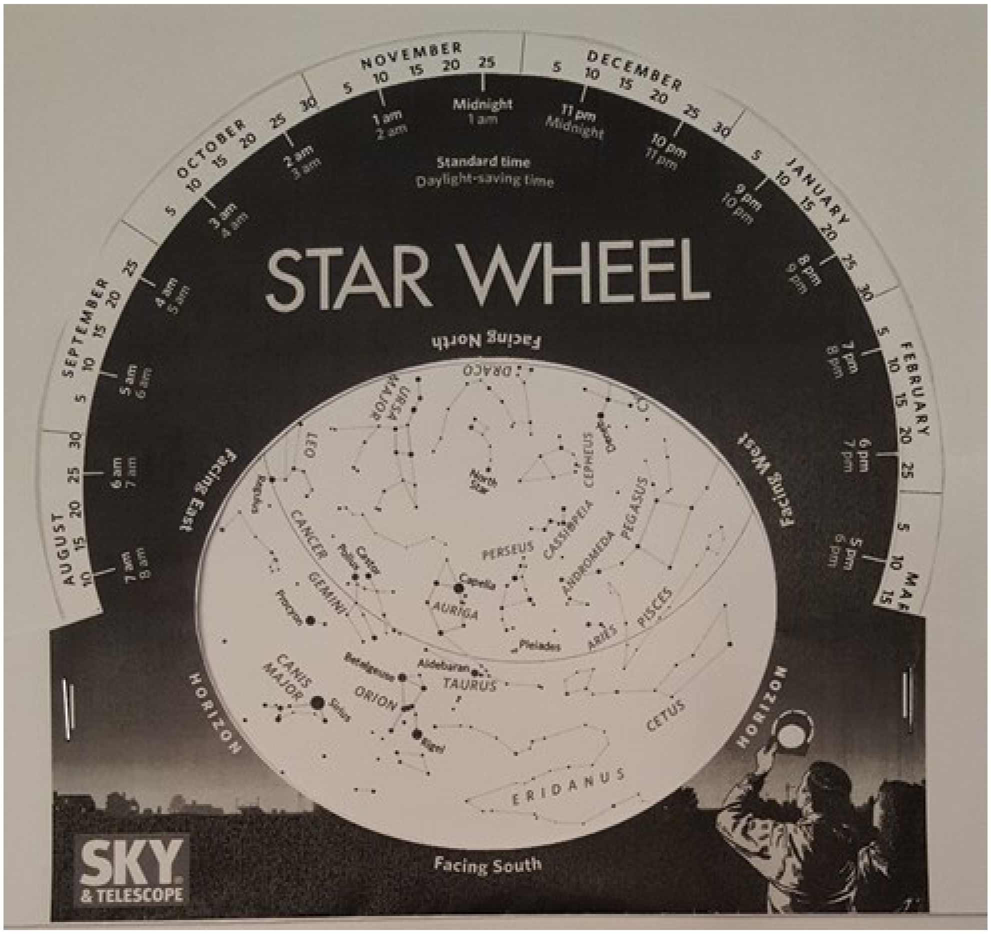

Figure 2. Planisphere. Sky & Telescope (2007). Retrieved from http://www.skyandtelescope.com/observing/astronomy-stargazing-projects/make-a-star-wheel/

Some planispheres, like the one used in the current study, are made to be used only on the northern hemisphere of Earth, at middle latitudes (30 to 50 degrees North). Other planispheres have a front side for observers in the northern hemisphere and backside for those in the southern hemisphere. Unlike app-based sky maps, a planisphere cannot show astronomical objects such as the Sun, Moon, planets, or Comets since they are mobile relative to distant stars. The planisphere used in this study was selected because it is commonly used among astronomers (Hughes & Stott, 1995). It is also lightweight, free, and useful to teach students about constellations, stars, nebulae, and star clusters. Using the planisphere from this study is simple (choose and face one cardinal direction, hold the planisphere with that direction down, and rotate the wheel to match time and date of observation). For the full version of the planisphere from Sky & Telescope (2007), see Appendix B.

Instruments

In this study, two instruments were used to measure the dependent variables. The first instrument is the Astronomy Attitude Scale (Türk & Kalkan, 2015), which measures attitude of students toward astronomy. The second one, Astronomy Content Test, measures students' identifying ability of sky constellations, stars, nebulae, and star clusters (Mallon, 1980).

Astronomy Attitude Scale

The Astronomy Attitude Scale (AAS) is a questionnaire (see Appendix C) containing 27 items measuring students' attitudes toward astronomy. Each item is scored on a five-point Likert-type scale (1 = *Totally Disagree* and 5 = *Totally Agree*). For items that are negatively worded, the scores are reverse coded (5 = *Totally Disagree* and 1 = *Totally Agree*). The range of possible scores is 27-135 points. Some examples of the questions are:

- It is a waste of time to try to understand astronomy subjects.
- I believe that I will use my astronomy knowledge in many places during my life.
- Thanks to astronomy, I can observe the events around me better.

The instrument has good reliability and validity (Türk & Kalkan, 2015). The authors stated that the scale had been reviewed by experts for content validity. The instrument has also good reliability as indicated by a Cronbach alpha consistency coefficient value of 0.912. This scale is primarily developed for middle school students (Türk & Kalkan, 2015). However, one of the authors of the instrument successfully used it for college students (Türk, 2016). In that study, the author examined correlations between student scores in AAS and achievement in astronomy content as a whole (measured by an instrument called Astronomy Achievement Test). The researcher reported that pre-service teachers' astronomy achievement and attitudes toward astronomy showed a positive and significant correlation ($r = 0.165$, $p < 0.05$). However, unlike Türk & Kalkan (2015), Türk (2016) did not report validity/reliability measures for the college students.

AAS has five factors or subscales as dimensions of the overall attitude variable. Türk & Kalkan (2015) used exploratory factor analysis to identify the five factors, which they named as daily life, application, being interested, self-confidence, and liking. The researcher of this current study used total scores of AAS, instead of scores of the subscales, due to the limited sample size.

Astronomy Content Test

The Astronomy Content Test (see Appendix D) is a paper-and-pencil test developed to measure students' knowledge regarding bright constellations, stars, nebulae, and star clusters. It focuses on the ability to identify the astronomical objects visible to the naked eye. Students do not use sky maps when taking the test. The test has 22 questions with a minimum score of 0 and a maximum score of 22 (1 point each).

According to Mallon (1980), the test was validated by expert reviews for content validity. Additional validity evidence was collected by comparing scores of students tested using the instrument and scores of the same students that tested using planetarium sky. Then, a Pearson r correlation between the two scores was calculated and came out to be 0.86 (Mallon, 1980). Creswell (2008) states that a correlation of 0.6 or more is considered good. This method of validation is called convergent evidence by Whiston (2009) and convergent validity by Creswell

(2008). To examine reliability, test-retest and internal consistency methods were used. The Pearson *r* value for the test-retest method was reported as 0.88 (Mallon, 1980), which is a good level of reliability (Creswell, 2008). For the internal consistency method, a *KR20* value was indicated as 0.745 (Mallon, 1980), which shows good consistency among the items of the instrument (Fraenkel & Wallen, 2003). This instrument was primarily developed for elementary students (Mallon, 1980). However, Hintz, Hintz, and Lawler (2015) successfully used a modified form for high school and undergraduate students. In their published paper, though, they did not report any validity and reliability measures for their samples. Therefore, this current study did not use their version. Despite such a lack of validation data for higher education students, however, the instrument was still relevant for college students because the content covered in the instrument is taught in introductory astronomy courses offered in higher education settings (Bennett, Donahue, Schneider, & Voit, 2018; Chaisson & McMillan, 2018; Palen et al., 2018).

Procedure

The procedure for this study took place in a 1 hour and 20 minute session in a lab at the college, in which each group had a separate session. The researcher administered the informed consent, gave a lecture, and provided a demonstration on how to use the sky map. Then participants practiced using their sky maps and completed the AAS and ACT. Table 1 provides a summary of the tasks and estimated times for completion. Details of the procedure components follow after the table.

Table 1

Summary of Tasks and Estimated Times for Completion

Task	Time (Minutes)
Administer informed consent	4
Lecture	5
Demonstration	10
Practice	45
Participants complete the AAS and ACT	16

Recruitment of Participants

Recruitment of participants was conducted by the researcher of this study. The researcher sent an email to all students in the college using an email-list. One more reminder email was sent using the email-list. The first 60 respondents were selected for the study. According to the recruitment script, participants used phone or email to contact and inform the researcher of their willingness to participate in the study. Accordingly, the researcher prepared a numbered list and used the list to randomly assign participants into either the treatment group or control group. The researcher used the online tool random.org to generate a random set of integers, which was used to create the treatment group. The rest of the participants made up the control group. There were separate sessions for the experimental and control groups. The researcher conducted both sessions.

Lecture

During each session, the researcher gave an explanation about the definition of constellations and their purposes. The explanation was supported by projection of sky on to a screen using SkyGazer 5.0. He explained that constellations are used to locate any astronomical object in the sky such as a star, a planet, and a nebula. They are also useful in informing people where in the sky some events are expected to happen. For instance, when a meteor shower is expected to happen in a particular night, astronomers inform the public in which constellation the event will happen. Knowing such information helps observers know the direction they need to orient themselves for those events. The researcher also explained how ancient people used constellations for navigational purposes. To clarify such uses, the researcher showed how the constellation of the Big Dipper could be used to figure out the cardinal direction North on Earth. He showed participants how to start from the North direction and identify all the other cardinal directions (South, East, and West).

As part of the lecture, the researcher emphasized that people need to know the constellations before using them for practical purposes. He pointed out that this is one reason why sky maps are needed. The researcher explained that sky maps are helpful in guiding novice observers to learn how to identify constellations, bright stars, nebulae, and star clusters. They serve the same purpose that road maps do in helping strangers navigate an unfamiliar city.

Demonstration

The researcher demonstrated to the participants how to use their respective sky maps to identify bright constellations, bright stars, nebulae, and star clusters. Detail steps are presented below for both the app and planisphere groups.

Planisphere group. The following activities were repeated for each of the directions: East, West, North, South, and upwards (overhead).

1. Using SkyGazer 5.0, the researcher projected onto screen a part of the sky in one of the above directions (e.g., West).

2. He pointed laser light to one of constellations (e.g., Gemini) visible on the screen. It should be noted that he had disabled all labels on SkyGazer so that it wouldn't show names of any astronomical object on the screen – just as it would be on the real sky.
3. The researcher told them that we needed to use planisphere to identify the name of the constellation that he pointed to on the screen.
4. He set the month, date, and time on the planisphere to correspond those displayed on the screen. To do this step, the researcher had to only turn the wheel part of planisphere (which had the month and date information) relative to the part of planisphere that showed time information. While doing this step, he held the planisphere with its "Facing West" label down, to match the direction chosen in step 1.
5. Then, he pointed to Gemini constellation on the planisphere to show the students that it matched the constellation on the screen. That way, the researcher read the name of the constellation from the planisphere and told them that the constellation on the screen was Gemini. When doing this step, he walked around to show the students closely how the constellation looked like on the planisphere.

Star Chart group. The following activities are repeated for each of the directions: East, West, North, South, and upwards (overhead).

1. Using SkyGazer 5.0, the researcher projected onto the screen a part of the sky in one of the above directions (e.g., West).
2. He pointed laser light to one of constellations (e.g., Gemini) visible on the screen. It should be noted that the researcher had disabled all labels on SkyGazer so that it wouldn't show names of any astronomical object on the screen – just as it would be on the real sky.

3. The researcher informed the students that he would use the app Star Chart to help him identify the constellation he was pointing to on the screen.
4. He then faced towards the direction chosen in step 1, and held the iPad at about 45^0 above horizontal. At this time, the app (Star Chart) used different sensors of the iPad to automatically display the sky of the month, date, and time of observation. This display of the sky was live and had augmented-reality feature as defined by Majid et al. (2015). The iPad sensors that the app accessed were: GPS (to find the location), digital magnetometer or Compass (to tell the direction the researcher was facing), and g-accelerometer (to find the orientation angle of the device). It should be noted that the above live and augmented-reality features were only doable by mobile devices with such sensors, but not by computers.
5. Then, the researcher pointed to Gemini constellation on the app to show students that it matched the constellation on the screen. That way, he read the name of the constellation from the app to learn that the constellation on the screen was Gemini. When doing this step, the walked around to show the students closely how the constellation looked like on the app. In addition to showing the name of the constellation, the app overlaid image of the constellation – another component of the app's augmented-reality features.

Practice

Each demonstration was then followed by a 45-minute session where participants used their respective sky maps to practice identifying constellations, bright stars, nebulae, and star clusters. During the practice session of each group, the researcher asked students to identify a constellation, gave feedback, and provided help to participants who needed it. The steps of the practice session mirrored those of the demonstration listed above, except this time the students (instead of researcher) did the identifying task. An example of this task would be: the researcher would point to a constellation (e.g., Auriga) (steps 1 and 2 of demonstration), ask the students to use their maps to identify it (steps 3 – 5 of demonstration), and walk around to check if they were doing the task correctly. If he learned that a particular student needed help with the task, the researcher would provide it accordingly. Students were also encouraged to discuss the task and help one another. Finally, the researcher would provide the name of the constellation to the whole student group. Using this same approach, the researcher covered different directions of the sky such as East, West, North, South, and straight up. In order to follow these instructions, the planisphere group completed the tasks while sitting at their desks. They did not change their orientation. They only had to turn the whole planisphere so that they could hold the chosen direction downward. Participants in the app group, on the other hand, had to turn their whole body and the iPad to face the direction chosen. Even when they were looking for the straight-up direction (overhead), they had to hold the iPad over their head and look upward. When they did so, the iPad had to use its sensors (GPS, compass, and accelerometer) to display how that portion of the real sky would look like at that moment. If students shifted their positions, the app shifted the view on their screens. Thus, body positioning was a major part of the app instruction.

The above pattern of activities was common to both groups. In the app group, however, the students were free to explore the app more on their own while the researcher was helping other students who needed help. For instance, some were observing the planet Saturn, its rings, and moons by using their fingers to zoom in on the screen. The researcher did not help students when they were doing such explorations. Students in the planisphere group were also free to explore on their own beyond the identifying task. However, the planisphere was relatively limited in its capability to support such explorations.

After completing the practice, each participant was asked to complete two data collection instruments: the Astronomy Attitude Scale (AAS) and the Astronomy Content Test (ACT). Participants had a total of 16 minutes to complete both instruments. They could fill in the instruments in whatever order they preferred. After completing them, participants put both instruments in a packet and submitted it to the researcher. Then the participants were thanked and excused from the room.

Data Analysis

The two research questions have a common independent variable, which is type of sky map. This variable is on a nominal scale with two levels or groups (users of app- and print-based sky maps). Each research question has its own dependent variable. One option of testing the two hypotheses associated with the questions was to conduct two independent-samples *t* tests. According to Hair et al. (1995), however, such analyses inflate experiment-wide Type I error from $\alpha = .05$, for 1 dependent variable, to $\alpha = .10$ (or $1\text{-}.95^2$) for two dependent variables. To avoid the experiment-wide error rate at $\alpha = .05$, the authors recommend using Multivariate Analysis of Variance (MANOVA), which is used for multiple dependent variables that may be correlated. For analysis with two levels of independent variable, a special type of MANOVA known as Hotelling's T^2 was used.

Before conducting data analysis, it is important to check if MANOVA assumptions are met (Hair et al., 1995). The first assumption that needed to be tested was "equality of variance-covariance matrices" (p. 275) across the groups. In this study, however, this assumption was disregarded because both groups had equal sample sizes (Hair et al., 1995; Tabachnick & Fidell, 2001). The second assumption that the researcher checked was if the two dependent variables were normally distributed. For this purpose, graphical analysis and statistical tests of normality were used. Hair et al. (1995) explains that a normality probability plot compares distribution of actual data with that of a normal distribution. If a data distribution is normal, they stated, the line representing the data will follow a straight diagonal line. For statistical testing of normality, the researcher used Shapiro-Wilks and Kolmogorov-Smirnov tests, which are available in SPSS (Hair et al., 1995). If this normality assumption is violated, they recommended to use transformations (inverse or logarithmic) and normalize the distribution accordingly. Hair et al. (1995) also stated that modest violations of normality can be accommodated with moderate sample sizes, if they are due to skewness and not outliers. Tabachnick and Fidell (2001) also indicated that a sample size that produces 20 degrees of freedom (*df*) makes a test robust against violations so long as equal sample sizes and two-tailed tests are used.

Another assumption of MANOVA is linearity. This assumption expects pairs of dependent variables to be linearly related so that the power of the statistical analysis can be increased. MANOVA also assumes absence of multicollinearity and singularity among dependent variables. In other words, if the dependent variables have a Pearson's correlation of 0.9 or more, then multicollinearity and singularity problems arise. Accordingly, the researcher ran analyses to verify that the assumptions were satisfied. Finally, the researcher made sure that outliers were excluded from the dataset because MANOVA tests are very sensitive to outliers (Hair et al., 1995). They recommend statistical test of Mahalanobis D^2 measure to help with detecting outliers. This is a measure of the distance in multidimensional space of each observation from the mean center of the observations. The authors recommend a very conservative level (0.001) as a cut-off value for the significance of the statistical test.

Hotelling's T^2 is a special case of MANOVA and it looks for a linear combination of a set of dependent variables that gives greatest difference between two sample groups. It tests the significance of such differences while keeping Type I error at $\alpha = .05$. Hotelling's T^2 uses the F distribution with p and (N_1+N_2-p-1) degrees of freedom for the numerator and denominator respectively. The first degree of freedom p stands for number of groups, which was 2 for this study. Whereas, in the second degree of freedom N_1 and N_2 stand for sample size in group 1 and 2, respectively. For this study, the second degree of freedom was 57 (30+30-2-1). Based on statistical tables, the critical value of this F distribution was F_{crit} (2, 57) = 3.159.

According to Hair et al. (1995), the critical value for Hotelling's T^2 can be calculated as,

$$T^2_{crit} = \frac{p(N_1 + N_2 - 2)}{N_1 + N_2 - p - 1} * F_{crit} \tag{1}$$

For this study, the above equation results in,

$$T^2_{crit} = \frac{2(30+30-2)}{30+30-2-1} * 3.159$$

$$= 6.429$$

Interpretation of significance test result involve comparing a computed value of Hotelling's T^2 with the critical value (6.429). If the computed value exceeded 6.429, then the conclusion would be the two sample groups belonged to two different populations. If not, then both null hypotheses of the study would be retained.

If significant difference were to be obtained between the two samples, then post hoc tests would be done to investigate whether the dependent variables separately were different for the two groups. For this analysis, pairwise comparison of means would be conducted on each of the dependent variables while maintaining Type I error at $\alpha = .05$ (Hair et al., 1995).

As a summary, Table 2 shows alignment between research questions, data sources or instruments, and data analysis methods.

Table 2

Alignment between Research Questions, Data Sources, and Analysis

Research Question	Data Source	Data Analysis
1. What, if any, are the differences in attitude toward astronomy for students who use the Star Chart mobile app and those who use a print-based sky map called a planisphere?	Astronomy Attitude Scale	MANOVA -- Hotelling's T^2, followed by pairwise comparison of means.
2. What difference exists between students who use the Star Chart mobile app and those who use a print-based sky map (planisphere) on their ability to correctly identify constellations, stars, nebulae, and star clusters?	Astronomy Content Test	MANOVA -- Hotelling's T^2, followed by pairwise comparison of means.

Limitations

As explained in a previous section, the study was conducted at one of the colleges housed under the TBR system. The college is one of TBR's smallest, commonly called 2-year institutions. This choice set a limitation on the generalizability of the study's results to the population of students in other TBR colleges. In other words, it would pose a threat to external validity of the study, as explained by Creswell (2008). Additional threats to external validity may come from the selection of only volunteer participants for the whole sample used in the study. This limitation could not be controlled by random assignment of participants to the two groups of the study (Creswell, 2008).

In this study, one of the instruments used for data collection was the Astronomy Content Test, primarily developed for elementary school students (Mallon, 1980). Since it was used for college students in this study, this may pose a threat to internal validity (Creswell, 2008). Therefore, this was a limitation the researcher chose to work under due to lack of validated and reliable similar instruments intended for college students. However, other researchers used the instrument successfully to measure knowledge in college students (Hintz et al., 2015).

This research did not collect data to assess how scores of participants would change in a long-term period. In other words, any observed differences in scores of the two groups in the study could not be extrapolated in any way to implicate how the scores might change in the future. It was a limitation within which the researcher completed the study.

Biases or Subjectivities

The participants were expected to respond to data collection instruments in person while the researcher was present. It is unknown if this might have caused biases in the way the participants responded to the questions.

CHAPTER FOUR: RESULTS

The purpose of this study was to investigate the effects of a mobile app-based sky map (Star Chart) in teaching college students about constellations, bright stars, nebulae, and star clusters. Two components of the effects were studied. The first one was on the attitude of participants toward astronomy. The second effect was the ability of students to identify constellations. This chapter presents the results of data analysis of the study. Descriptive statistics of the participants are described first, followed by a presentation of the results, which are organized by the research questions of the study. Finally, the chapter closes with a summary of the findings.

Descriptive Statistics

Demographics

There were 60 participants (20 male, 40 female). The majority of participants (83.3%) were less than 25 years old.

Attitude Variable

In the study, participants' attitudes towards astronomy were measured using the instrument Astronomy Attitude Scale (AAS). Means, standard deviations, and sample sizes were presented for the overall participants of the study and for the two groups (Table 3).

Table 3

Attitude Scores of Participant Groups

	Group	*M*	*SD*	*N*
Attitude_towards_Astronomy	Planisphere	82.9667	15.86035	30
	App	94.2667	16.31148	30
	Total	88.6167	16.93766	60

Learning Variable

The level of learning achieved by participants of the study was measured using an instrument called the Astronomy Content Test (ACT). Since the content tested was primarily associated with constellations, the term “constellation_learning” was used in Table 4 to refer to scores measured by the ACT. Descriptive statistics for this variable are presented in Table 4.

Table 4

Learning Scores of Participant Groups

	Group	*M*	*SD*	*n*
Constellation_learning	Planisphere	12.7667	3.89237	30
	App	13.1333	3.52071	30
	Total	12.9500	3.68425	60

Testing the Research Questions

The following research questions were examined:

1. What, if any, are the differences in attitude toward astronomy for students who used the Star Chart mobile app and those who used the print-based sky map, a planisphere, for identifying constellations, stars, nebulae, and star clusters?

2. What difference exists between students who used the Star Chart mobile app and those who used the print-based sky map (planisphere) in their ability to correctly identify constellations, stars, nebulae, and star clusters?

To answer the above questions, the researcher used Multivariate Analysis of Variance (MANOVA). Since the independent variable of the study (type of sky map) has two levels, a special type of MANOVA known as Hotelling's T^2 was used. The same statistical test was used for both research questions of the study. As discussed in Chapter 3, MANOVA requires data to satisfy some parametric assumptions. The following paragraphs discuss how the assumptions were checked.

Assumptions of Statistical Tests

The first assumption checked was related to data outliers. For MANOVA tests to stay valid, outliers should be excluded from analysis. A statistical test known as Mahalanobis distance was used to detect outliers. A very conservative level ($p = 0.001$) was used as a cut-off value for the significance of the statistical test. In this study, the minimum obtained probability value was 0.008. This p value (corresponding to the maximum Mahalanobis distance) exceeded 0.001, indicting absence of data outliers (Hair et al., 1995).

The next assumption checked was multivariate normality of each dependent variable. To assess this assumption, graphical plots and statistical tests were used. For statistical testing of normality, the researcher used Shapiro-Wilks and Kolmogorov-Smirnov tests (Hair et al., 1995). As can be seen from Figures 3-6, both dependent variables (*Attitude towards astronomy* score and *Constellation learning* score) seem to align well with the diagonal line of normal distribution in all groups.

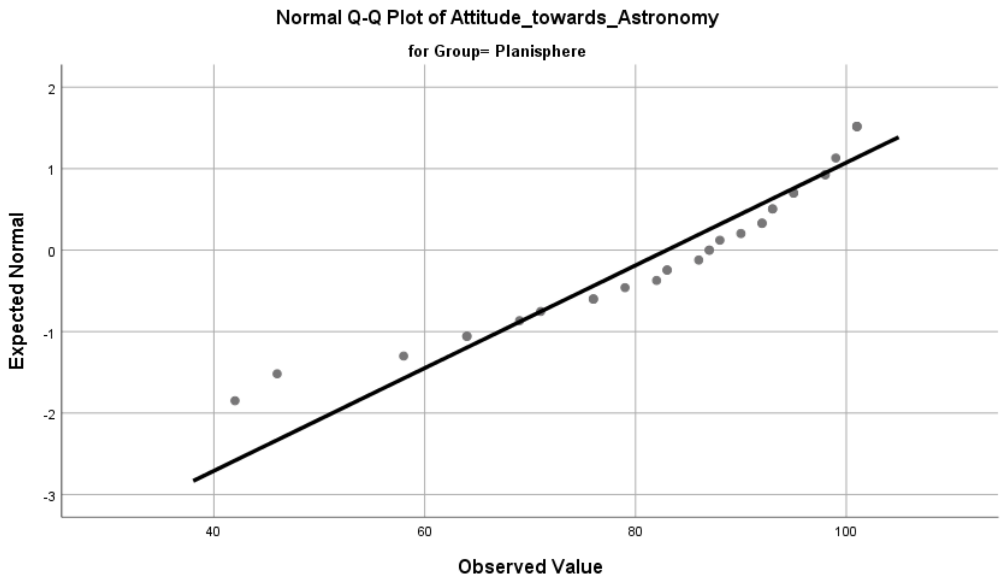

Figure 3. Normality Q-Q plot of attitude towards astronomy for planisphere group.

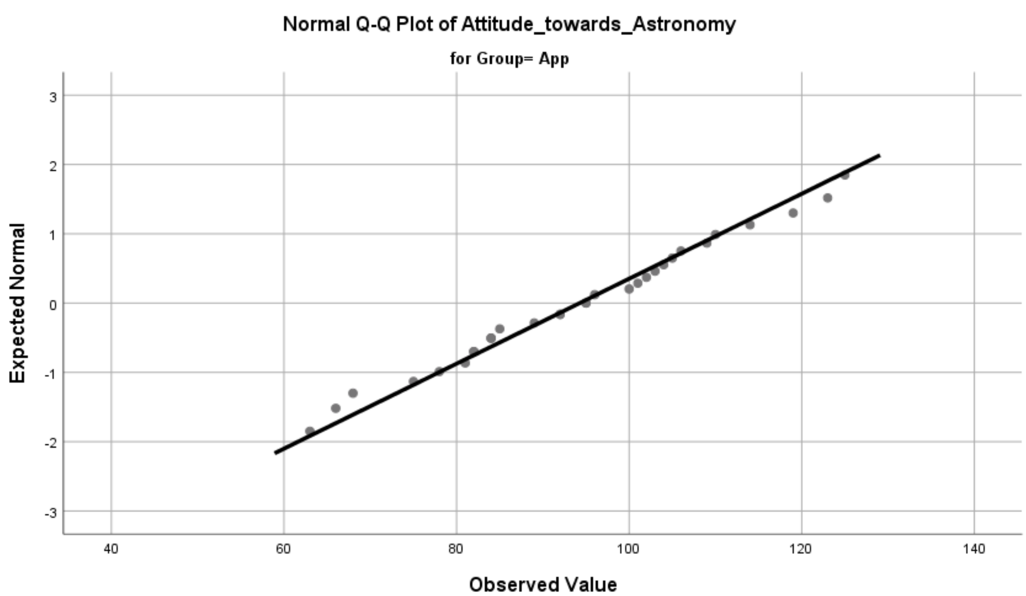

Figure 4. Normality Q-Q plot of attitude toward astronomy for app group.

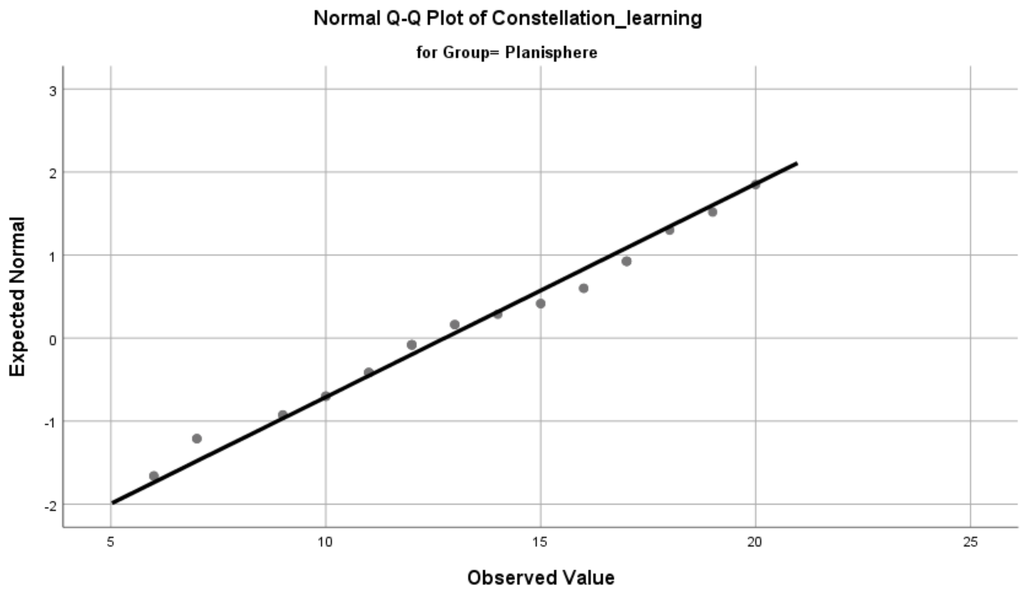

Figure 5. Normality Q-Q plot of constellation learning for planisphere group.

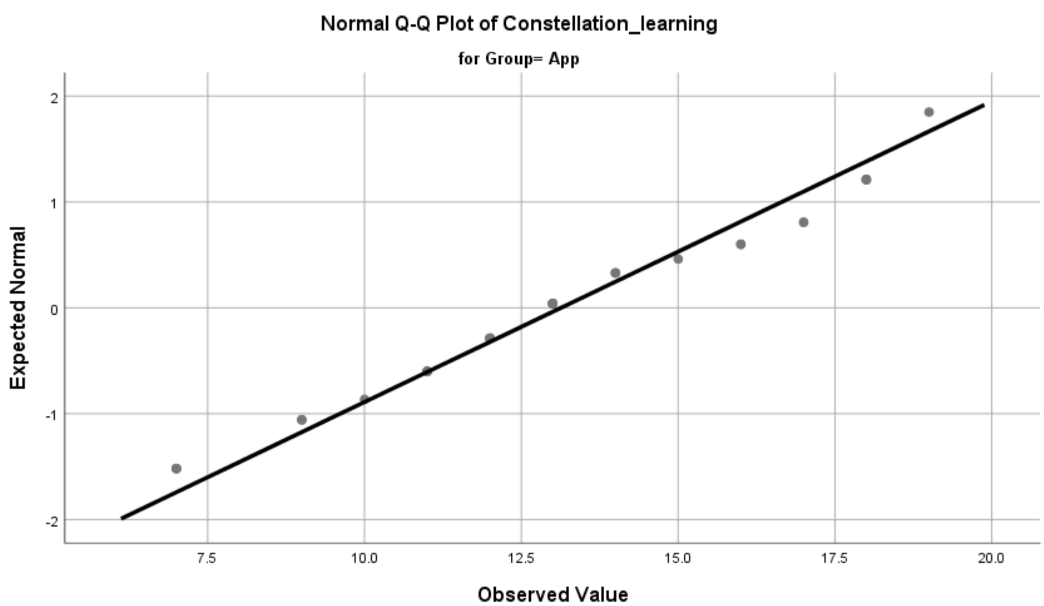

Figure 6. Normality Q-Q plot of constellation learning for app group.

Besides, both Shapiro-Wilks and Kolmogorov-Smirnov test results indicated that *Constellation learning* scores are normally distributed in both groups while *Attitude towards astronomy* scores are only normally distributed in the group that used the app-based sky map (Tables 5 and 6). The *Attitude towards astronomy* scores of the planisphere group failed to satisfy both statistical normality tests. For instance, the obtained Shapiro-Wilks significance value (0.007) did not exceed the cut-off value (0.05) to satisfy the normality requirement. Despite this shortcoming, the researcher decided to continue the data analysis since MANOVA is robust for modest normality violations if they are not caused by outliers (Hair et al., 1995; Tabachnick & Fidell, 2001).

Table 5

Statistical Normality Test for Attitude toward Astronomy

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	*df*	*Sig.*	Statistic	*df*	*Sig.*
Attitude_toward_Astronomy	Planisphere	.143	30	.123	.897	30	.007
	App	.082	30	.200*	.982	30	.881

*This is a lower bound of the true significance.
[a] Lilliefors Significance Correction

Table 6

Statistical Normality Test for Constellation Learning

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	*df*	*Sig.*	Statistic	*df*	*Sig.*
Constellation _learning	Planisphere	.111	30	.200[*]	.965	30	.423
	App	.115	30	.200[*]	.951	30	.176

[*] This is a lower bound of the true significance.
[a] Lilliefors Significance Correction

Another assumption checked was the absence of multicollinearity between dependent variables. If the correlation (Pearson *r*) between two dependent variables was low, separate ANOVAs would be better than the MANOVA. On the other hand, high correlation (greater than 0.9) is problematic for MANOVA due to overlap of information from the correlated variables. As can be seen from Table 7, the obtained correlation for this study was moderate indicating there was no problem of multicollinearity between the two dependent variables (Hair et al., 1995).

Table 7

Multicollinearity Test between Dependent Variables

		Attitude toward Astronomy	Constellation Learning
Attitude toward Astronomy	Pearson Correlation	1	.308*
	Sig. (2-tailed)		.017
	N	60	60
Constellation Learning	Pearson Correlation	.308*	1
	Sig. (2-tailed)	.017	
	N	60	60

* Correlation is significant at the 0.05 level (2-tailed).

The last MANOVA assumption checked was the equality of the variance-covariance matrix. To test equality of variance, the researcher used Levene's test. As can be seen from Table 8, the distribution of both dependent variables satisfies the equivalence of variance assumption.

Table 8

Levene's Test of Equality of Error Variances

	F	*df1*	*df2*	*Sig.*
Attitude toward Astronomy	.129	1	58	.721
Constellation Learning	.536	1	58	.467

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.[a]
[a] Design: Intercept + Group

The researcher also used Box's test to check equality of covariance matrices of the dependent variables. This test was also satisfied as can be seen in Table 9.

Table 9

Box's Test of Equality of Covariance Matrices

Box's M	3.497
F	1.122
df1	3
df2	605520.000
Sig.	.339

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.[a]

[a] Design: Intercept + Group

As discussed above, the assumptions required of MANOVA were reasonably satisfied (Hair et al., 1995; Tabachnick & Fidell, 2001). As a result, the researcher decided to continue with the planned data analysis. The next paragraphs will present the results of the analysis systematically.

MANOVA Results

The intention of MANOVA is to test if participant groups are significantly different on a linear combination of dependent variables (Hair et al., 1995). The group factor for this study was the type of sky maps that participants used. It had two levels: a print-based sky map called planisphere and an app-based sky map called Star Chart. The dependent variables for this study were attitude of participants towards astronomy and learning of constellations by participants.

Table 10 shows the results of the MANOVA. The analysis shows that the two groups of the study are significantly different in linear combination of the dependent variables (Hotelling's

Trace = 0.132, $F(2, 57) = 3.751$, $p < .05$, multivariate effect size $\eta^2 = 0.12$). In other words, the participants who used the app-based sky map were significantly different from those who used planisphere when compared based on their attitude towards astronomy and their learning of constellations. For MANOVA, partial Eta squared ($\eta2$) is used to measure effect size (Keppel & Wickens, 2004). The authors listed $\eta2$ of 0.01, 0.06, and 0.15 as minimum values for small, medium, and large effect sizes respectively. The obtained $\eta2$ value for this study was, thus, on the higher end of medium effect size. To know the exact source of the above difference, the researcher conducted pairwise comparisons between the groups for each of the dependent variables. Since these comparisons directly correspond to the research questions of the study, the discussion is organized below under each question.

Table 10

Multivariate Tests or MANOVA Results [a]

Effect		Value	*F*	Hypothesis *df*	Error *df*	*Sig.*	Partial Eta Squared
Intercept	Hotelling's Trace	35.039	998.600 [b]	2.000	57.000	.000	.972
Group	Hotelling's Trace	.132	3.751 [b]	2.000	57.000	.029	.116

[a] Design: Intercept + Group

[b] Exact statistic

Research question one. The first research question states "What, if any, are the differences in attitude toward astronomy for students who use the Star Chart mobile app and those who use the print-based sky map, called a planisphere, for identifying constellations, stars, nebulae, and star clusters?" The corresponding null hypothesis for this research question is:

"Students who use the Star Chart mobile app will have no significant difference in attitude toward astronomy as those using a print-based sky map, called a planisphere."

Table 11 shows the mean scores of attitude towards astronomy for both groups. A difference of 11.300 was found between the two mean scores after each group used their respective sky maps. The pairwise comparison analysis (done using a multivariate Bonferroni test) shows that the mean difference between the attitudes toward astronomy of those two groups was significantly different from zero, at the .05 alpha level. Thus, the null hypothesis stated above was rejected. In other words, participants who used app-based sky map (Star Chart) showed significantly different attitudes towards astronomy when compared to those who used the print-based sky map (planisphere).

Table 11

Attitude Scores of Participant Groups

	Group	*M*	*SD*	*n*
Attitude toward Astronomy	Planisphere	82.9667	15.86035	30
	App	94.2667	16.31148	30

Research question two. The second research question states "What difference exists between students who use the Star Chart mobile app and those who use the print-based sky map (planisphere) in their ability to correctly identify constellations, stars, nebulae, and star clusters?" The question has a null hypothesis which can be described as: "There will be no significant difference in identifying constellations, stars, nebulae, and star clusters between students who use the print-based sky map and those who use the Star Chart mobile app."

Table 12 shows the mean scores of constellation learning of both groups. The difference between the two mean scores of the abilities of participants to correctly identify constellations was 0.367. A pair-wise comparison test (multivariate Bonferroni) was done to compare the significance of the differences between the means of the scores of the two groups. The results showed that there was no significant difference between app-based and print-based sky map users. Therefore, the above-stated null hypothesis was accepted.

Table 12

Constellation Learning Scores of Participant Groups

	Group	*M*	*SD*	*n*
Constellation Learning	Planisphere	12.7667	3.89237	30
	App	13.1333	3.52071	30

Additional Analysis

As part of data analysis, reliability measures were calculated for the two data-collection instruments used in this study. Cronbach's coefficient alpha reliability value of 0.930 was calculated for the instrument Astronomy Attitude Scale (AAS). The second data collection instrument used in the study was the Astronomy Content Test (ACT). For this instrument, *KR20* was calculated and the value was 0.775.

Summary

In this chapter, the statistical tests used were discussed first. This was followed by descriptive data and results of the MANOVA and follow-up tests for each research question. The analysis showed that app-based sky map users showed significantly different attitudes toward astronomy, when compared with print-based sky map (planisphere) users. On the other hand, the two groups did not show a significant difference on their learning ability to correctly identify constellations, stars, nebulae, and star clusters.

In the following chapter, the results will be discussed within the context of related literature. The results will also be explained in terms of the implications they have on the practices of astronomy education. Finally, recommendations for future research will be proposed.

CHAPTER FIVE: DISCUSSION AND CONCLUSION

The previous chapter presented the findings of the study in detail. This chapter will discuss those findings by putting them in the context of relevant literature. The discussion will first present a summary of the study. This will be followed by deliberation of the findings and how they relate to relevant previous research. The chapter will then present the implications of the results for practitioners. The discussion proceeds to deliberation of recommendations for further research. Finally, a conclusion section will summarize the whole substance of this study.

Summary of the Study

The purpose of this study was to investigate the effects of using a mobile app-based sky map to teach college students about constellations, stars, nebulae, and star clusters. The name of the app was Star Chart. The first effect studied was concerning students' attitudes toward astronomy after they used the mobile app to learn about sky constellations. The second effect was the learning that took place as participating college students identified astronomical objects after using the mobile app.

This study used a quantitative research method. The researcher used an experimental design. There was one group (experimental) that used an app called Star Chart. A second group (control) used a traditional (print-based) sky map, generally referred to as a planisphere. As required by experimental design, participants were randomly assigned to the two groups by the researcher.

In this study, two well-validated and reliable instruments were used. The first instrument, the Astronomy Attitude Scale (see Appendix C), was used to measure participant attitudes toward astronomy. The second one, the Astronomy Content Test (see Appendix D), measured the abilities of students to identify sky constellations, stars, nebulae, and star clusters. The researcher of this study conducted the recruitment of participants. The researcher sent emails to all students in the community college where the study took place. Participants were informed that their participation would be voluntarily. To this end, they were included in the study after they each signed a consent form.

The participants were randomly assigned to either the experimental or control group. Each group had 30 participants. The researcher met with each group separately for one hour and 20 minutes in the community college's campus. During this meeting, participants used their respective maps to learn about and practice identifying constellations, stars, nebulae, and star clusters. The researcher showed a projection of the sky onto a screen in a physics lab room of the college. Participants were guided to make sure that they used the maps appropriately. Specifically, the researcher supported participants in identifying bright constellations, stars, nebulae, and star clusters. After the one-hour learning and practice session, each participant completed the two instruments.

This study included the following research questions:

1. What, if any, are the differences in attitudes toward astronomy of students who use the Star Chart mobile app and those who use the print-based sky map, called a planisphere, for identifying constellations, stars, nebulae, and star clusters?
2. What difference exists between students who use the Star Chart mobile app and those who use the print-based sky map (planisphere) in their ability to correctly identify constellations, stars, nebulae, and star clusters?

To answer the above questions, the researcher used Multivariate Analysis of Variance (MANOVA), specifically Hotelling's T^2. Before conducting the analysis, the data were checked and verified that MANOVA assumptions were not violated. Following the MANOVA, post hoc analyses were conducted using pairwise comparison tests (multivariate Bonferroni) for both of the dependent variables (attitude towards astronomy and ability to identify constellations and other bright objects). The results of the analysis are discussed in the next section.

Discussion of the Findings

Previous researchers have tried to study the effectiveness of mobile devices in different aspects of students' learning experiences (Martin & Ertzberger, 2013; Sung et al., 2016). This study focused on two components of the participants' learning experiences. They are attitude toward astronomy and ability to identify constellations. Improving students' attitude toward learning is crucial in astronomy education (Slater & Tatge, 2017). An unfavorable attitude of students toward astronomy and other physical sciences plays a role in the declining number of college students enrolled in those sciences (Bektasli, 2013). Science instructors are advised to focus specifically on developing students' attitudes towards science content (Mason & Singh, 2016). The contribution of this current study to attitude formation in astronomy education is discussed below. The findings of the study are discussed using the research questions as organizing themes.

Research question one. The results of the analysis pertaining to the first research question indicated the existence of significant difference in the attitudes of the two groups toward astronomy. Participants who used the app-based sky map (Star Chart) developed a more positive attitude toward astronomy when compared to those who used the print-based sky map (planisphere). Similar results have been reported in studies done by Tarng et al. (2017) and Tian et al. (2013). The finding of the study also showed that the observed difference between the groups had effect size on the higher end of the medium category, per the guideline in Keppel & Wickens (2004).

The above result can be understood in the context of importance of positive attitude in the learning experience of students. In their review of many years of planetarium education research, Slater and Tatge (2017) underlined that enhancing positive attitude in planetarium visitors had been a more important target than learning the names of stars and constellations. If learners have negative attitudes towards the content they are expected to learn, it makes it difficult for teachers or other educators to successfully help them to attain instructional objectives. Therefore, the app-based sky map used in this study played a better role in influencing participants to develop positive attitudes toward astronomy than the print-based sky map. Consequently, when teaching college students about constellations, using mobile app-based sky maps may help to make their learning experiences enjoyable.

Based on the observed differences in attitude toward astronomy between the two groups in this study, one can ask if it was due to the novelty effect of technology which can wane away with time as users become accustomed to the technology (Van Roy & Zaman, 2018). Jeno, Vandvik, Eliassen, and Grytnes (2018) explain that there are two types of novelty: product (technology) novelty and motivational novelty. They used product novelty to refer to the new features that a technology offers. They defined motivational novelty as the potential or capability of a product to satisfy the intrinsic motivation of its users.

Research shows that only technology that responds to psychological needs of learners has a motivational effect over and above the contribution of product or technology novelty (Jeno, Vandvik, Eliassen, & Grytnes, 2018; Shroff & Keyes, 2017). From their experimental study, Jeno et al. (2018) concluded that the mobile-learning app provided the basic psychological needs of the app users more than the other two groups in the study (traditional textbook and digital textbook users). In the current study, when compared to the print-based sky map (planisphere), it can be argued that the Star Chart app has more motivational and product novelty. Star Chart (n. d.) lists many features of the app that have the potential to satisfy the psychological needs of users of the app. For instance, one of that tasks that the participants did in the practice session of the study was to identify the Orion nebula. For planisphere users, this particular task was completed once they located the nebula. Start Chart users, on the other hand, might have continued to engage in activities beyond identifying the nebula. If they chose to do so, they had the opportunity to tap on the nebula and learn facts about it such as its diameter, distance from Earth, and apparent brightness. They could also zoom in to view the image. Such features of the app has the potential to satisfy psychological needs of learners such as autonomy, freedom, or choice, which in turn increase their intrinsic motivation or doing the activity with interest and enjoyment (Jeno et al., 2018; Shroff & Keyes, 2017).

Star Chart (n.d.) also listed that the app could overlay all 88 constellations with imagery such as a great bear for Ursa Major (The Big Dipper) constellation, a lion for Leo constellation, and a bull for Taurus constellation. In contrast, the planisphere does not show the images of constellations. Those features of the Star Chart app could have invited the app group to explore in more detail the Zodiac or birth constellations of themselves, family members, or their friends. Engaging in such activities could have given the app users opportunities to satisfy their related psychological needs, which have to do with making them feel related or needed in their social circles (Jeno et al., 2018; Shroff & Keyes, 2017).

The features mentioned above enable the Star Chart app to have more motivation and technology novelty compared to a planisphere (Jeno et al., 2018). In this current study, the attitude toward astronomy of Star Chart users was significantly different than that of planisphere users. The difference also had a substantial effect size. Given the superiority in motivational and technology novelty of the Star Chart app over the paper-based planisphere, it could be argued that the observed difference in attitude towards astronomy was over and above a technology novelty effect (Jeno et al., 2018). Given the potential of the app to support the psychological needs of college students, the observed difference in this study could also be hypothesized to continue over time (Van Roy & Zaman, 2018). This hypothesis can be tested using longitudinal study, which is discussed later in the recommendations for future research.

Important features/qualities of app-based sky maps. The following paragraphs discuss some literature on important features or qualities of app-based sky maps and their relationship with positive attitude.

Zydney and Warner (2016) explained that many apps for science learning have location-aware functionality. Zhang et al. (2014) referred to such function as mobility. Based on their research, they concluded that mobility feature of their app contributed to increasing their students' interest in astronomical observations. The app used in this current study accessed sensors (GPS, digital magnetometer (compass), and G-accelerometer) of an iPad to display a simulation of the real-time sky as viewed from the location of observations. The observed attitude difference between the two groups of this study might be influenced by the mobility feature of the app (Zhang et al., 2014).

Zhang et al. (2014) also discussed the importance of accuracy feature of the augmented reality displayed by an app-based sky map. They underlined that constellations displayed by an app should have high levels of accuracy to look similar to the actual constellation on the sky. If this feature is compromised, they state, learners can get frustrated during astronomy observations and develop negative attitudes. Based on experience of the researcher with multiple app-based sky maps, he was able to witness a good level of accuracy for the app used in the current study.

Thus, the observed positive attitude of app-group in the study might also be increased by accuracy level of the app (Zhang et al., 2014). In contrast, any kind of planisphere is made for a range of latitudes, most common between 30 to 50 degrees, with an average of 40^0 latitude. While the planisphere shows the same constellations for all users between 30 to 50 degrees of latitude, the actual constellations on the sky (specially near the horizon) differ for users at 35^0 latitude, for instance, compared to the average (40^0) latitude. App-based sky maps solve this problem using the sensors of the mobile devices (GPS, digital magnetometer (compass), and G-accelerometer).

Based on their review of studies on science apps, Zydney and Warner (2016) also identified visual/audio representation as common feature in many of apps used for science learning. This feature refers to adding visual/audio components as part of the content presented in augmented-reality-based (AR-based) learning environment of the apps. As explained in Chapter 2, Star Chart overlays images on the constellations displayed on mobile devices. Such feature might have helped with increasing motivation of the app group similar to the findings reported by Yen et al. (2013).

Zhang et al. (2014) also discussed the importance of feature of an app to allow its users to search and explore constellations and stars. They concluded that such features help to enhance learners' motivation during navigation of constellations. As discussed in Chapter 3, the app group in the current study had opportunities to self-explore any astronomical object in the app. These features might have helped them to enjoy their learning environment and develop positive attitude compared to planisphere group (Zhang et al., 2014).

To conclude, the above-mentioned qualities of Star Chart app might be associated with the attitude difference observed in this study between the app and planisphere groups. The reviewed literature support that those qualities have potential to develop positive attitudes in app-based sky map users.

Research question two. Findings that examined the second question indicated that there was no significant difference between the two groups in their ability to identify constellations, stars, nebulae, and star clusters. Participants who used the app-based sky map developed the ability to identify constellations comparable to those who learned the skill using the traditional print-based sky map. This result implies that students who use app-based sky maps will not be disadvantaged in their ability to identify constellations, stars, nebulae, and star clusters compared to those who used the traditional sky map or planisphere. For instance, if teachers only need to teach their students how to identify constellations, both tools could do the job comparably, according to the findings of this study. Often, however, they would want to use the tools for other contents of astronomy as well. As was explained in Chapter 3, the app has many features that could support students learning more than identifying constellations, stars, nebulae, and star clusters. Moreover, students could learn more about astronomy using many features of the app without needing help from their teachers. An example of such learning could be zooming-in to a planet, galaxy, moon, or star cluster and learning about their physical characteristics. As a contrast, the planisphere has no such interactive capability. On the other hand, any content students could learn using a planisphere, they could also learn it using the app.

There are available studies with similar findings related to this research question. The findings, such as by Tarng et al. (2017), indicated no significant difference in learning achievement between groups who used app-based content and other traditional approaches. The authors reported that even though app-based sky map users found the learning experience interesting, they did not perform different than their peers in the other two groups (Google Sky Map users and those with print-based sky maps).

To conclude, the results of the analyses concerning both research questions of this study can be synthesized as the app-based sky map helped the participants to develop a more positive attitude toward astronomy compared to those who used the traditional sky map called a planisphere. With regard to the ability of participants to identify constellations, however, the app-based sky map was not significantly different than the planisphere. The cumulative interpretation is that users of the app-based sky map enjoyed their learning experience better than Planisphere users, while acquiring comparable ability in identifying constellations, stars, nebulae, and star clusters. In this aspect, the app-based sky map seems to have played the same role as dome planetariums. After reviewing many studies, Slater and Tatge (2017) reached the conclusion that the planetarium's strongest role seemed to focus on enhancing attitudes, values, and interests than remembering names and positions of constellations.

Discussion of Reliability Measures

According to Fraenkel and Wallen (2003), it is important to run reliability analyses for the sample used in the study. As presented in the previous chapter, the calculated Cronbach's α for Astronomy Attitude Scale (AAS) was 0.930. Whereas, for the Astronomy Content Test (ACT), the calculated *KR20* value was 0.775. The following subsections will interpret and discuss the reliability measures for each instrument.

Astronomy Attitude Scale (AAS). As explained in Chapter 3, the AAS used a five-level Likert-type scale ranging from 1 (*Strongly Disagree*) to 5 (*Strongly Agree*). For this interval scale, Worthen, White, Fan, and Sudweeks (1999) recommended calculating Cronbach's coefficient alpha as a reliability measure. In general, they wrote that Cronbach's coefficient alpha values of at least 0.7 could be interpreted as a good level of reliability for an instrument. Accordingly, the calculated reliability value for AAS (0.930) strongly indicates that the instrument was reliable.

The authors of AAS (Türk & Kalkan, 2015) reported a Cronbach's α of 0.912 using a sample from elementary school students. One of the authors also used the instrument for pre-service students (Türk, 2016). In this manuscript, the instrument was used for college students. Therefore, the value of Cronbach's coefficient alpha obtained in this study indicates that the instrument is reliable for entering college students.

Astronomy Content Test (ACT). In Chapter 3, ACT was described as a test that assessed students' ability to identify constellations. Thus, the possible responses to each question are dichotomous: either correct or incorrect. Worthen et al. (1999) recommend using *KR20* as an appropriate measure for reliability of a test with dichotomous items or questions. They suggest that a *KR20* value of 0.7 shows a good level of reliability for an instrument. In this study, the calculated *KR20* value was 0.775, which indicated that ACT had a good level of reliability.

At the end of Chapter 3, one of the limitations listed for this study had to do with the fact that the ACT was not originally developed for college students. Mallon (1980) developed the ACT and used elementary school students to calculate the reliability measure, which he reported as $KR20 = 0.745$. Although a modified version of the test was used with college students (Hintz et al., 2015), the authors did not report reliability measures for their version. In this study, the original ACT was used for college students. Considering the reliability measure calculated in this study ($KR20 = 0.775$), it can be concluded that ACT was a reliable test for participants involved (Worthen, White, Fan, & Sudweeks, 1999). Hence, this study indicated that ACT could be reliably used for college students as well.

Implications for Practice

Those who strive to introduce technology into their teaching can use the results of this research to support their decisions. Specifically, the results can help astronomy or science teachers to justify their choice to incorporate app-based sky maps into their lessons. This research showed that students developed better attitudes toward astronomy when using app-based sky maps than the traditional print-based one (planisphere). Such technology can help teachers to provide enjoyable learning experience for their students.

The ultimate purpose of teachers is, of course, student learning. If teachers are going to adopt technology, they should see that the technology would at least not distract their students from learning. This study showed that students who used app-based sky maps learned as well as those who used paper-based sky map. Therefore, teachers can use this result to be convinced that using the app-based sky map will not have negative effect on the academic performance of their students.

The above benefits of the study to teachers is further confounded by the fact that the app-based sky map is freely available for anyone's use. Teachers, students, or schools do not have cost requirements to introduce such technology for the benefit of their students. This would be possible due to wide availability of mobile devices among students, as reported in a study done by Galanek, Gierdowski, & Brooks (2018). According to the study, US college and university students have significant access to smartphones (95%) and laptops (91%). Moreover, mobile apps such as Star Chart can be downloaded in various platforms of mobile devices. The app has versions for platforms such as Android, iOS, Windows, and others.

In addition to benefitting teachers, the results of this study have practical implications for various community members who work to introduce societies to astronomical adventures. For instance, there are many astronomy clubs whose sole purpose is to involve people in learning interesting astronomy events. Leaders of such clubs can learn from the results of this study that app-based sky maps help users to have better attitude and enjoy astronomy. Using such mobile apps can be useful to attract more people into their social gatherings. Astronomy club leaders can help their audiences to freely download the apps and use them to browse through the sky and learn about different constellations visible from their locations. Similarly, science museum guides can also use this study to make informed decisions when they introduce app-based sky maps in their effort to educate visitors.

To summarize, the results of this study have shown that learners can develop positive attitudes toward astronomy when they are given opportunities to use app-based sky maps as opposed to traditional print-based ones. Their ability to identify constellations is as good as when they use the traditional sky maps. Since app-based sky maps are also available freely and for various platforms of mobile devices, they can be added to the technology tools available for teachers and other community members involved in astronomy education. They can use the results of this study to justify that their adoption of the technology is based on evidence.

Recommendations for Further Research

Due to time constraints to conduct the study, the researcher was forced to use a simulated sky instead of a real evening sky. For the participants to learn how to identify constellations, stars, nebulae, and star clusters, the researcher showed them live and local projections of the sky onto a screen. As a control variable, this condition was used for both experimental and control groups. Even though the advancement of such digital-planetarium technology produce an accurate simulation of the real local sky at the time of observation, future researchers can assess the generalizability of the results of this study in the context of real night sky observation sessions.

The observed difference in the attitudes toward astronomy of both groups was based on a one-time measurement (not repeated measurements). As it was explained in detail in the discussion section above, due the motivational features of the Star Chart app, the obtained difference was above the novelty effect. Accordingly, it was hypothesized that the observed difference could be sustained for a long time. Longitudinal studies such as the one conducted by Van Roy and Zaman (2018) showed the sustainability of motivational effects over a long period of time. Thus, the hypothesis is recommended to be tested by future researchers.

As presented in Chapters 4 and 5, an overall student attitude toward astronomy was used to compare the two groups in this study. However, the instrument used to measure the attitude variable (Astronomy Attitude Scale, AAS) had five subscales in it. One of the limitations of this study was that the two groups were not compared based on the subscales due to limited sample size. Thus, comparison of groups based on the subscales of AAS is recommended for future research using large sample size.

As explained in Chapter 3, one of the limitations of this study was that it used the Astronomy Content Test (ACT) for college students, even though it was originally developed for elementary school students. Among the concerns was that the instrument might have a ceiling effect when used for college students. Worthen, White, Fan, and Sudweeks (1999) defined the ceiling effect as when most of students score very high in an easy test. Looking at the mean and standard deviation values of the groups of students in this current study, the ceiling effect did not seem to be a problem. Moreover, the instrument was validated by its author (Malone, 1980) for its ability to measure what it was meant to measure (constellation identification). When we identify constellations visually, we look for patterns or shapes that stars appear to make. For instance, we identify the Orion Constellation by recognizing the 'kind of X' shape or pattern that its stars appear to make on the sky. As explained in Chapter 3, convergent validity (Creswell, 2008) was established by testing students using the ACT and a planetarium-simulated sky and assessing if the two scores correlate. The authors reported a Pearson correlation value of r = 0.86, which is considered good for educational research (Creswell, 2008). In other words, measuring constellation identification skill using ACT is as valid as using a planetarium-simulated sky.

Nevertheless, it was not known if there were related skills that were not measured by the instrument when used for college students. This concern with the instrument becomes more important if students are to be tested using the real sky or AR. This was a limitation of the study. Thus, future researchers are advised to consider developing and/or validating similar instruments that could be used with a real sky or augmented reality setting for college students.

Additional recommendations include adding another independent variable (age) to this study. When doing this, two possible routes can be taken depending on how one operationally defines the variable age. If participants are divided into groups of ages, then age is defined as a categorical or nominal variable, which will require a different research methodology. On the other hand, age of participants can be taken as is, which will make it an interval or scale variable. Therefore, either way, further studies can be developed by extending the research design to include age as an additional independent variable (Fraenkel & Wallen, 2003; Hair et al., 1995).

Another research recommendation is related to the mobile app (Star Chart) that one group of the participants used. There are many constellation apps available for mobile device users.

Future studies can try to replicate the results of this study using other available mobile apps. Teachers and other astronomy educators can benefit more if similar studies are done using different app-based sky maps.

The last recommendation for further research is to extend the content around which this study was done. This research compared experiences of students using app- and print-based while learning about constellation identifications. However, the app (Star Chart) has more educational uses or content in addition to helping students to identify constellations. Those uses were not studied in this research. Another researcher could study how the app affects students while learning those other topics and compare the students' experiences with other students studying the same topics in a traditional way, which may be print-based content or teacher-based lessons.

Conclusion

This research found out that college students who used mobile app-based sky map (Star Chart) developed a positive attitude toward astronomy that was significantly different than those who used a traditional print-based sky map (planisphere). On the learning aspect, the study showed that using the Star Chart app helped students to develop the skill of identifying constellations to a comparable level with those who used the planisphere. Cumulatively, the study demonstrated that college students can use app-based sky maps and learn how to identify constellations equally as with traditional maps, but with better attitude and enjoyable learning experiences.

This study contributed to the limited research on the role of mobile devices in astronomy education, due to the relative newness of the technology or its use for educational purposes. It has also extended the scope or generalizability of similar results in the area of dome-based planetarium education. Slater and Tatge (2017) implied that the most important role of the planetarium in astronomy education seemed to lean toward promoting positive attitude, interest, and value, rather than remembering astronomical content. As shown in this study, a similar role can be played by sky maps installed on mobile devices in the form of apps. This role, however, is significantly empowered by the vast affordability of mobile devices and freely available app-based sky maps. Hence, teachers and other astronomy educators are encouraged to use the results of this study to justify any initiative to add app-based sky maps into their technology repertoire.

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APPENDIX A

Consent to Participate in a Research Study

The Effects of Mobile App-based Sky Map in Teaching College Students about Constellations

WHY ARE YOU BEING INVITED TO TAKE PART IN THIS RESEARCH?

You are being invited to take part in a research about effects of mobile app-based sky map in teaching college students about sky constellations, stars, planets, and other astronomical objects. If you volunteer to take part in this study, you will be one of about 60 people to do so.

WHO IS DOING THE STUDY?

The person in charge of this study is Aklilu Maasho, who is a faculty in your college, but also doing doctoral study at University of Memphis, Department of Instructional Design and Technology. He is being guided in this research by Dr. Andrew Tawfik.

WHAT IS THE PURPOSE OF THIS STUDY?

By doing this study, we hope to learn the effects of app-based sky map in teaching college students about sky constellations. Specifically, we will focus on learning abilities to identify constellations and on assessment of attitudes toward astronomy.

ARE THERE REASONS WHY YOU SHOULD NOT TAKE PART IN THIS STUDY?

Volunteers younger than 18 years of age will be excluded from participating in this study. All volunteers who satisfy the age requirement can participate in this study, until the maximum number or sample size is reached, which is 60.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST?

The research will be conducted at your college campus. You are expected to spend up to one hour and 20 minutes.

WHAT WILL YOU BE ASKED TO DO?

If you volunteer for the study, first, you will be asked to read and sign this consent form. Then, the researcher will randomly (by chance) assign you to either of two groups.

As part of your group, you will meet with the researcher for one hour. During this meeting, participants will use their respective sky maps to learn and practice the skills of identifying constellations and other astronomical objects. Afterwards, you will be asked to fill-in two data collection instruments (questionnaire).

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?

To the best of our knowledge, the things you will be doing have no more risk of harm than you would experience in everyday life.

WILL YOU BENEFIT FROM TAKING PART IN THIS STUDY?

You will not get any personal benefit from taking part in this study.

DO YOU HAVE TO TAKE PART IN THE STUDY?

If you decide to take part in the study, it should be because you really want to volunteer. You will not lose any benefits or rights you would normally have if you choose not to volunteer. You can stop at any time during the study and still keep the benefits and rights you had before volunteering. As a student, if you decide not to take part in this study, your choice will have no effect on your academic status or grade in the class.

IF YOU DON'T WANT TO TAKE PART IN THE STUDY, ARE THERE OTHER CHOICES?

If you do not want to be in the study, there are no other choices except not to take part in the study.

WHAT WILL IT COST YOU TO PARTICIPATE?

There are no costs associated with taking part in the study.

WILL YOU RECEIVE ANY REWARDS FOR TAKING PART IN THIS STUDY?

As compensation for your time, you will receive $10 if you complete the study, which is expected to take up to one hour and 20 minutes. There will be no pro-rated payment for early withdrawal from the study.

WHO WILL SEE THE INFORMATION THAT YOU GIVE?

No one, not even members of the research team, will know that the information you give came from you. You will not write your name at any of the data-collection instruments, which you will put them yourself in collection packets without the knowledge of the researcher. This consent form will be secured in locked cabinet drawers within the office of the researcher. The form will be stored for three years after the completion of the study. The researcher will destroy the form after the three years.

CAN YOUR TAKING PART IN THE STUDY END EARLY?

If you decide to take part in the study, you still have the right to decide at any time that you no longer want to continue. You will not be treated differently if you decide to stop taking part in the study.

The individuals conducting the study may need to withdraw you from the study. This may occur if you are not able to follow the directions they give you, or if they find that your being in the study is more risk than benefit to you.

WHAT IF YOU HAVE QUESTIONS, SUGGESTIONS, CONCERNS, OR COMPLAINTS?

Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now. Later, if you have questions, suggestions, concerns, or complaints about the study, you can contact the investigator, Aklilu Maasho at XXX or XXX, or via email at XXX, or his dissertation advisor Dr. Andrew Tawfik, The University of Memphis, who can be contacted at XXX. If you have any questions about your rights as a volunteer in this research, contact the Institutional Review Board staff at the University of Memphis at XXX. We will give you a signed copy of this consent form to take with you.

____ ____________

Signature of person agreeing to take part in the study Date

____

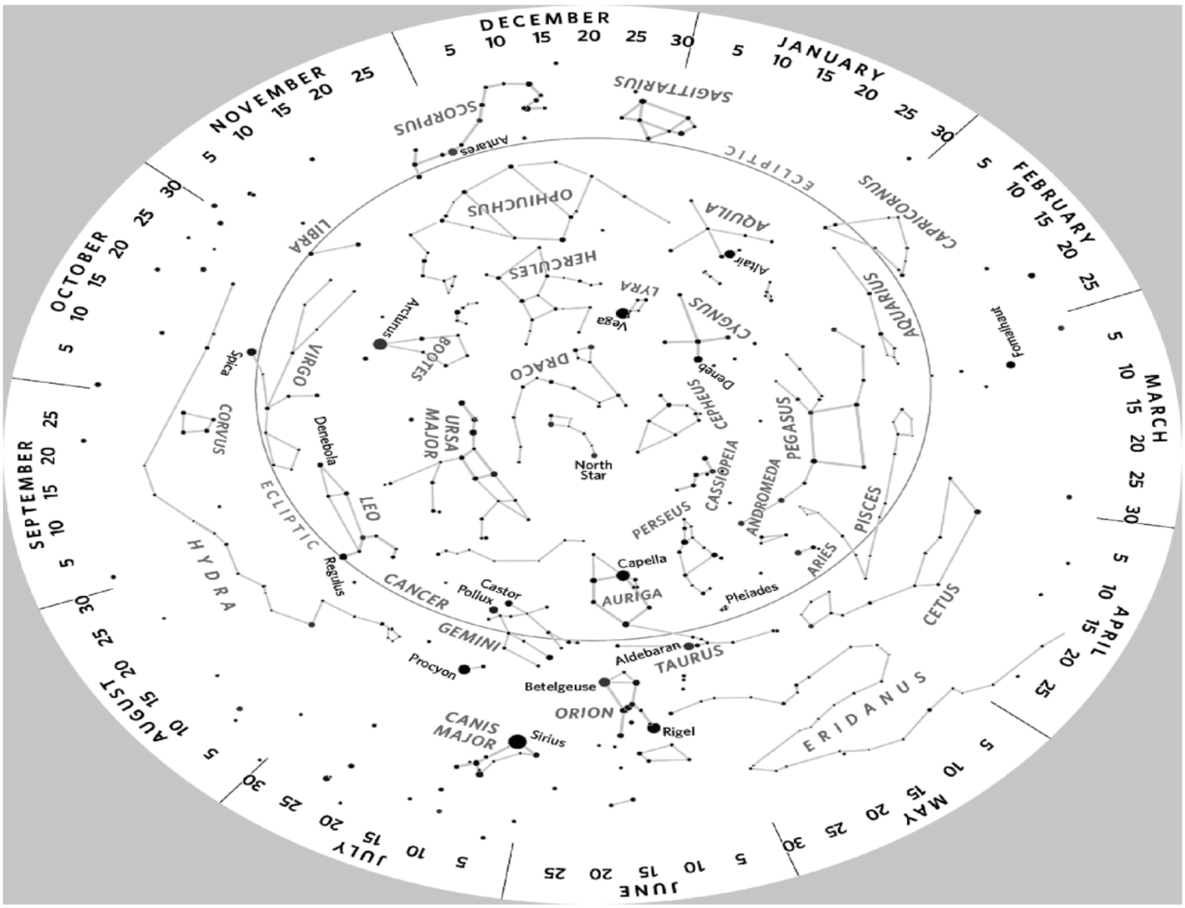
Printed name of person agreeing to take part in the study

____ ____________

Name of authorized person obtaining informed consent Date

APPENDIX B

Planisphere




STAR WHEEL
Standard time
Daylight-saving time
Midnight
1 am
11 pm
Midnight
1 am
2 am
10 pm
11 pm
2 am
3 am
9 pm
10 pm
3 am
4 am
8 pm
9 pm
4 am
5 am
7 pm
8 pm
5 am
6 am
6 pm
7 pm
6 am
7 am
5 pm
6 pm
7 am
8 am
Facing North
Facing East
Facing West
HORIZON
HORIZON
Facing South
SKY
& TELESCOPE

APPENDIX C

Astronomy Attitude Scale

	Female ☐ Male ☐ Age: 25 or more years ☐ Less than 25 years ☐	Totally disagree	Disagree	Indecisive	Agree	Totally agree
1.	Astronomy is a field that I like.					
2.	I like getting astronomy lessons.					
3.	I am assertive about the field of astronomy.					
4.	I get very bored while listening to astronomy lesson.					
5.	It is a waste of time to try to understand astronomy subjects.					
6.	I forget the astronomy subjects in a short time.					
7.	I don’t like talking about astronomy with my classmates.					
8.	I want to learn astronomy subjects by conducting experiments.					

9.	Astronomy is an extremely technical field.					
10.	I can learn the science of astronomy.					
11.	Astronomy is a complex field.					
12.	Astronomy is an insignificant field.					
13.	I understand astronomy subjects better when they are applied.					
14.	I understand astronomy subjects better on hands-on models					
15.	It is easy to understand astronomy concepts.					
16.	I get the feeling that I will fail in astronomy exams.					
17.	I feel under stress in astronomy lesson.					
18.	I feel unconfident when I have to do my astronomy homework.					
19.	Astronomy is in every phase of life.					
20.	I believe that I will use my astronomy knowledge in many places during my life.					
21.	I am interested in new developments in astronomy.					
22.	I follow current developments in astronomy.					

23.	Thanks to astronomy, I can observe the events around me better.					
24.	Thanks to astronomy, I can have knowledge about nature.					
25.	Thanks to astronomy, I comprehend the importance of science in my life.					
26.	I like trying to understand natural phenomena by using my knowledge in astronomy.					
27.	Astronomy subjects increase my interest in science.					

APPENDIX D

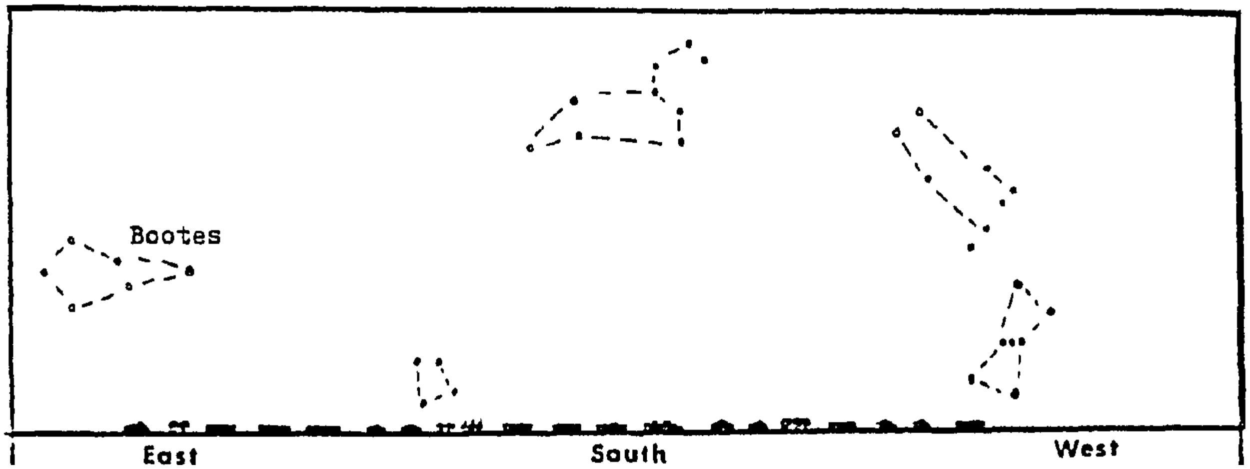
Astronomy Content Test

Please answer questions 1 to 7 by marking “X” under “Yes” or “No” column.

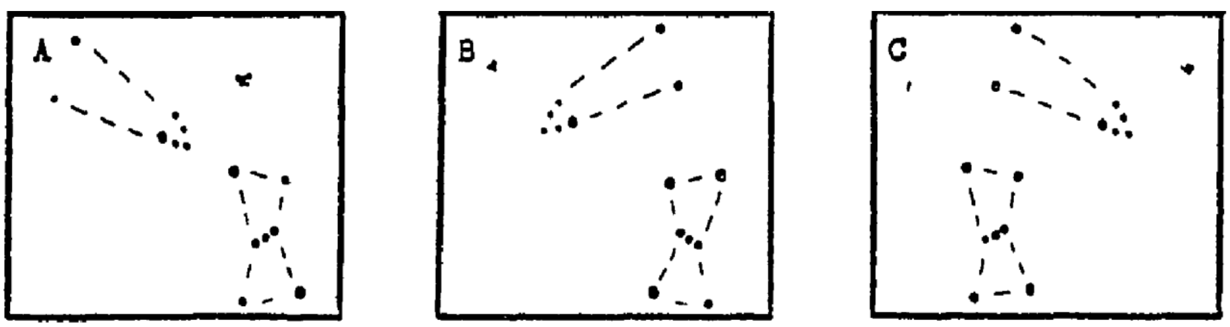
	Question	Yes	No
1.	Constellations are things that can be seen in the sky in the night time and in the day time.		
2.	Constellations may be fun to hear about but they cannot help us to find objects in the sky.		
3.	A star map can help us to find constellations in the sky.		
4.	A star map tells you how far away the stars are in the sky.		
5.	Constellations can help us to find directions on earth.		
6.	Constellations can help us to find other objects in the sky.		
7.	If you see two stars next to each other in the sky on one night, they will move away from each other on other nights.		

8. Here is star map. In which direction should you look to see the constellation "Bootes"? Look at the star map and circle your answer below.

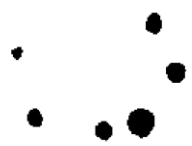
North South East West



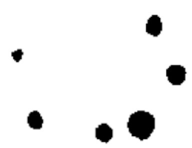
9. Which of these star maps most looks like the sky around "Orion the hunter"? Put a circle around A, B, or C on the maps.



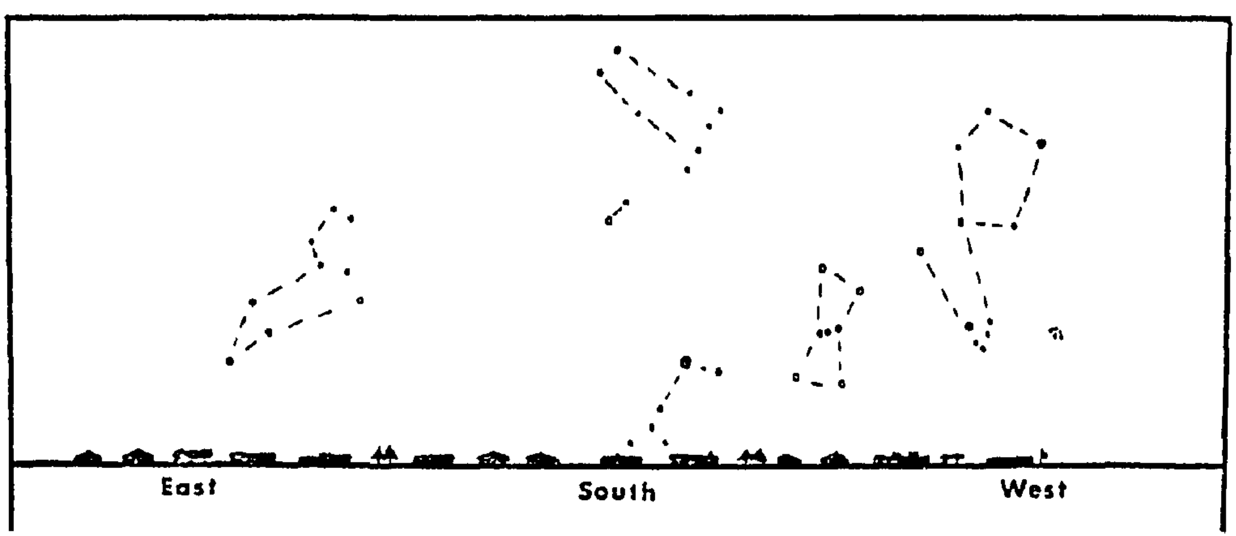
10. On the star map below, put a circle around the brightest star.



11. On the star map below, put a circle around the dimmest star.

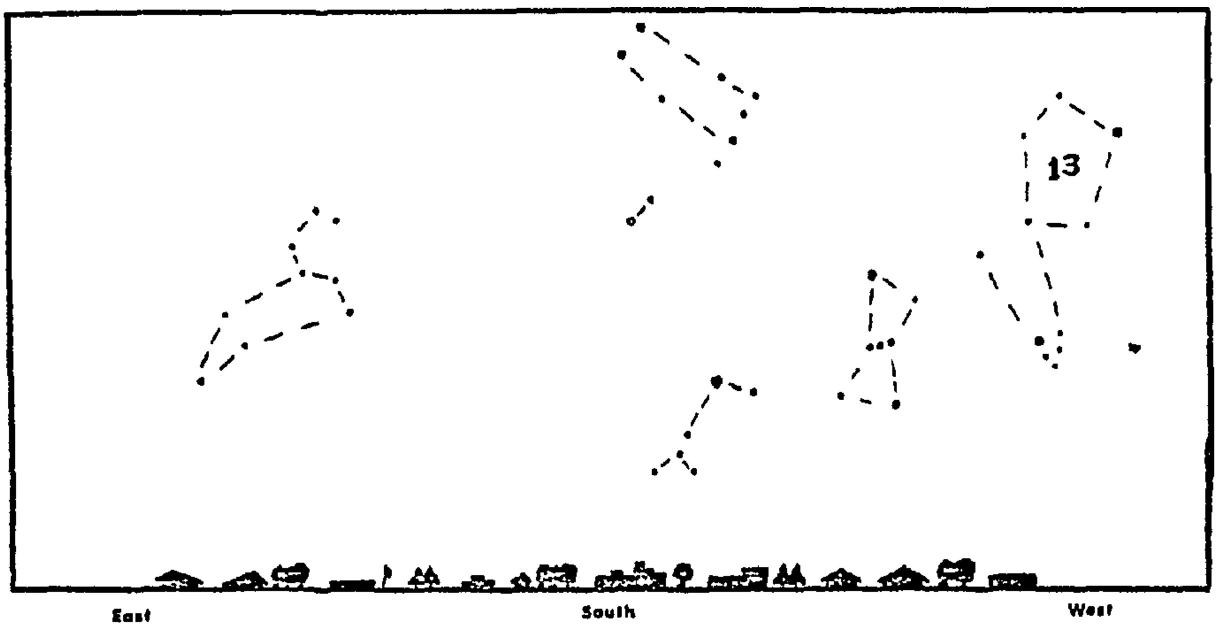


12. Planet Mars must be put on this star map. It should be in the "South West" part of the sky and about half way up. Put an “X” mark on the map for Mars.



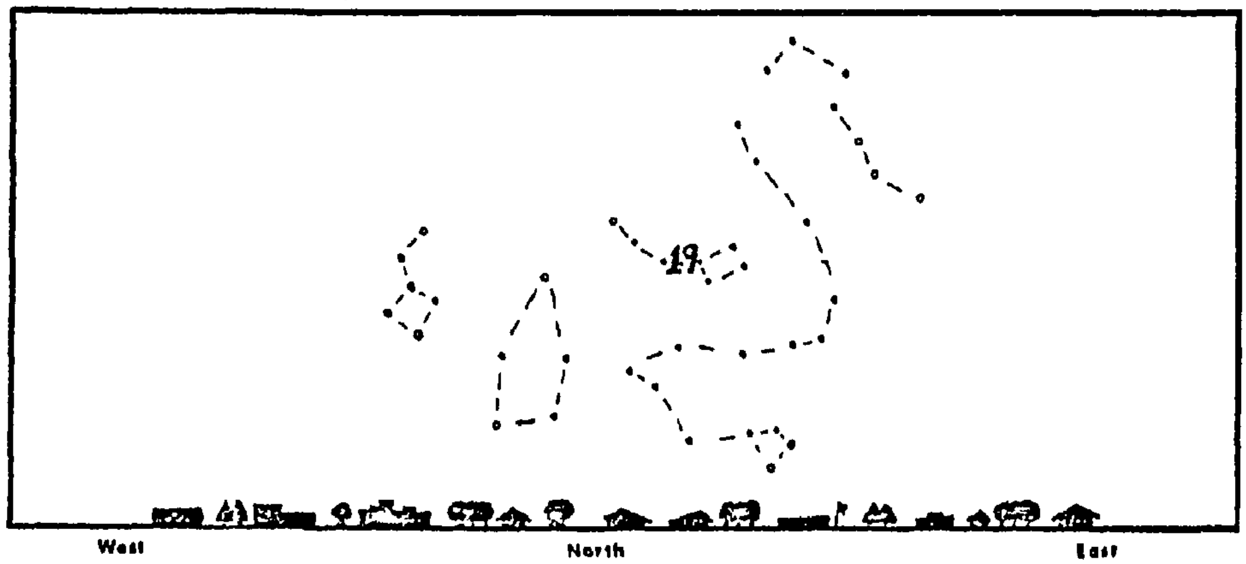
13 - 18. Here is a map of the sky. Find each of the following things put its number on top of its place on the map. Number 13 has already been done for you.

13. Auriga the charioteer	14. Orion the hunter	15. Leo the lion
16. Taurus the bull	17. Canis Major the big dog	18. Gemini the twins



19 – 24. Here is a map of a different part of the sky. Find each of the following things put its number on top of its place on the map. Number 19 has already been done for you.

19. The Little Dipper	20. The Big Dipper	21. Polaris, the north star
22, Cassiopeia the queen	23. Cepheus the king	24. Draco the dragon



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University of Memphis
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Memphis, TN 38152-3370

Nov 9, 2017

PI Name: Aklilu Maasho
Co-Investigators:
Advisor and/or Co-PI: Andrew Tawfik
Submission Type: Initial
Title: The Effects of Mobile App-based Sky Map in Teaching College Students about Constellations
IRB ID: #PRO-FY2018-89

Expedited Approval: Nov 3, 2017
Expiration: Nov 3, 2018

Approval of this project is given with the following obligations:

1. This IRB approval has an expiration date, an approved renewal must be in effect to continue the project prior to that date. If approval is not obtained, the human consent form(s) and recruiting material(s) are no longer valid and any research activities involving human subjects must stop.

2. When the project is finished or terminated, a completion form must be submitted.

3. No change may be made in the approved protocol without prior board approval.

Thank you,
James P. Whelan, Ph.D.
Institutional Review Board Chair
The University of Memphis.