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SMARTPHONE-AIDED SCIENCE APPLICATION IN TEACHING SCIENCE

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Abstract

Low achievement in science is a persistent concern among Grade 10 students of Co Tek Chun National Trade School, Pagadian City, where classroom instruction remains largely teacher-centered even as students are increasingly surrounded by smartphones and other digital devices. Mobile learning promises to extend learning opportunities, yet empirical evidence on its effect on science achievement, particularly in the Philippine context, remains limited. This study determined the effect of a smartphone-aided science application, compared with the conventional (lecture) method, on the science achievement of Grade 10 students. A pretest–posttest, two-group experimental design was used with 70 Grade 10 students in two sections of 35 each. Section Mercury (experimental) was taught with the Earth's Landform and Earth Explorer applications on smartphones, and Section Mars (control) was taught with the lecture method, in two one-hour trial runs (Plate Tectonics; Earth's Interior). Achievement was measured with 20-item teacher-made pretests and posttests and expressed as mean percentage score (MPS). Data were analyzed with descriptive statistics and t-tests at the 0.05 level of significance using SPSS. The groups did not differ at pretest ($p = .740$ and $p = .699$). The experimental group's MPS rose from 23.71 to 67.43 in the first trial run and from 34.29 to 75.71 in the second, an average increase of 152.59%. The control group's MPS rose from 24.43 to 37.00 and from 33.43 to 44.57, an average increase of 42.39%. Posttest differences between groups were significant in both trial runs ($t(68) = 11.607$ and 11.308, both $p < .001$). Students taught with the smartphone-aided science application showed markedly greater gains than those taught by lecture, and the results are consistent with the conclusion that the application improves science achievement for the topics studied. Because intact sections were compared in a single school, replication with larger and more varied samples, longer exposure, and retention measures is recommended.

Keywords: *smartphone-aided science application; mobile learning; science education; conventional method; lecture method; student achievement; Grade 10; Philippines*

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INTRODUCTION

Background

Technology has a fundamental impact on the educational system and now plays a significant role in teaching and learning, whether in support or administrative functions. Educational technologies have become increasingly important because of the rapid proliferation of the internet, personal computers, and smartphones. Computers and the internet offer efficient use of time and ease of access to educational materials for students and staff alike, and most schools and universities have adopted learning management systems such as Blackboard and Moodle. This revolution in information and communication technology has facilitated communication, data sharing, and collaboration among students and between students and their lecturers. In recent years, wireless computing devices have become ubiquitous on college campuses (Motiwalla, 2007), and mobile devices such as smartphones, personal digital assistants, tablets, and personal computers give people the freedom to use what they need, where and when it is needed (Trifonova & Ronchetti, 2007).

Mobile devices have become more affordable, effective, and easy to use (Nassuora, 2012). They can extend the benefits of e-learning systems (Motiwalla, 2007) by giving university students opportunities to access course materials and information and communication technology, to learn in a collaborative environment (Nassuora, 2012), and to obtain formative evaluation and feedback from instructors (Crawford, 2007). They can extend learning beyond university settings by providing flexible, portable, and independent learning environments and by allowing communication among students and between students and lecturers (Khaddage et al., 2009). They also allow students and lecturers to use spare time, such as time spent traveling, to work on assignments or lesson preparation (Virvou et al., 2005).

Smartphone-aided learning, or mobile learning (m-learning), is regarded as a new stage in the development of computer support and distance learning (Georgiev et al., 2004). It is a learning paradigm created by mobile devices and wireless networks that supports accessible and collaborative education at all levels, and it is considered the next step after e-learning and distance learning, further enhancing learning anytime and anywhere (Milrad, 2003). Salmon (2004) considered it the fourth generation of the electronic learning environment. It can be defined as any sort of learning that occurs when the learner is not bound by location or time, supported by mobile devices that present learning content and allow wireless communication between lecturers and students (Dye et al., 2003).

Increasing numbers of students own cell phones, and many of these are smartphones with still and video cameras, global positioning systems, internet access, and computing power comparable to desktop computers of only a few years ago. A number of chemical educators already use these devices for instruction. By the time they reach college, many students have created video content and shared it on websites such as YouTube, and it has become easy to create two-dimensional barcodes that embed a web address and connect a smartphone browser to a website (Benedict & Pence, 2012). Good teaching requires the ability to adapt to new technology and to create learning atmospheres that meet rapidly changing demands, anticipating the mental processes of the learner. Teachers are also expected to promote interactive, concrete, and manipulative approaches in introducing complex topics, with mathematics and science giving the greatest evidence for the spiral progression approach (Johnston, 2012).

Designing effective and innovative educational mobile applications nevertheless remains a challenge. Applications need to be accessible to teachers who are not tech-savvy as well as those who are, to foster active-learning pedagogies, to enable flexible and creative use, and to fit within the curriculum (Price et al., 2014). The popularity of mobile devices has changed the way people learn, communicate, and live, and new technologies such as social networking, podcasting, and science mobile applications are accelerating changes in mobile-assisted learning environments by extending learning opportunities and reshaping learning styles. The widespread use of smartphones has brought millions of mobile applications to students to help them learn more efficiently (Looi et al., 2010).

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Smartphone-Aided Science Applications and Mobile Learning

A smartphone-aided science application, also known as a science mobile application, is a computer program designed around science concepts to run on mobile devices such as smartphones and tablet computers. Most such devices are sold with several bundled applications, such as a web browser, email client, calendar, mapping program, and an application for buying music or other media. In this study, the effect of the application was gauged by comparing students' achievement, expressed as the mean percentage score, from pretest to posttest, and this achievement served as the basis for judging the effectiveness of the application in teaching science.

Looi et al. (2010) transformed a primary science curriculum for delivery through mobile technologies in a Singapore primary school, where a teacher enacted the lessons over the 2009 academic year. The students received 21 weeks of mobilized science lessons co-designed by teachers and researchers to exploit the affordances of mobile technologies for supporting inquiry learning in and outside class. Among the six mixed-ability primary classes in the school, the experimental class performed better than the others on traditional science assessments, and students were found to learn science in personal, deep, and engaging ways and to develop positive attitudes toward mobile learning. Price et al. (2014) noted that the enhanced capabilities of modern smartphones, together with increased access to mobile-networked environments and geospatial systems, create opportunities for new educational experiences that support a geospatial approach to science and foster new ways of thinking about science. With recent advances in smart mobile devices and their growing penetration among students, it is likewise possible to use these devices to promote higher-order thinking skills in the lecture environment (Cheong et al., 2012).

Mobile learning, or the use of smartphones in education, is the "exploitation of ubiquitous handheld technologies, together with wireless and mobile phone networks to facilitate, support, enhance and extend the reach of teaching and learning" (Brown, 2010, p. 28). In contrast to distance learning or e-learning, it is shorter in duration, instantly usable, and allows users to personalize content, enter data, and generate content (Brown, 2010). It "focuses not on the learners and technologies but on the interactions between them, emphasizing that learning is a social process" (van 't Hooft, 2008, p. 13), and it provides digital content around which students engage and construct knowledge socially (Brill & Park, 2008). Mobile learning technologies may afford learners greater control and the ability to access, aggregate, create, and share information in a variety of media formats across space and time (van 't Hooft, 2008). Although mobile and wireless devices vary widely, they share several characteristics (Brill & Park, 2008; Chuang, 2009; Dieterle, 2004; Looi et al., 2009; Peters, 2007; Rogers & Price, 2008):

- *Connectability*: wireless connection to the internet through Wi-Fi.
- *Portability*: always at the fingertips of the user.
- *Instant accessibility*: devices can be switched on and off instantly.
- *Flexibility*: data can be collected using a wide variety of peripheral extensions.
- *Economic viability*: much of the computing capability and expandable storage of laptops at a fraction of the cost.
- *Social interactivity*: collaboration, active participation, co-creation of knowledge, and critical reflection.
- *Context sensitivity*: the ability to gather data unique to the current circumstance (location, time), giving access to authentic contexts.
- *Individuality*: flexibility for each learner to follow a self-directed, personalized learning path.

Many smartphone capabilities used daily for personal purposes can be used for learning when included in purposefully designed instructional activities. Integrating Web 2.0 tools on smartphones may promote student-centered pedagogies (Cochrane & Bateman, 2010) and more effective relationships between learners and their instructors and peers, because such tools facilitate creative practice, participation, production, and the exchange

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of experiences and ideas that lead to the social construction of knowledge (Greenhow et al., 2009; Pachler & Daly, 2009). Military training offers an example: the U.S. Army Learning Concept emphasized that learners are accustomed to connecting with peers across networks and that this habit should be leveraged to build social networks for formal and informal information sharing (U.S. Department of the Army, 2010). Wikis, which are information pages built from the input of many contributors, can likewise support activities in which students create their own knowledge of a content area, develop capabilities for knowledge representation, organization, sharing, and updating (Zhang, 2009, as cited in Menaker & Tucker, 2010), and social networking sites allow students to collaborate, receive feedback on each other's work, and share resources. Restricted networks suited to classroom use can be established so that students collaborate only with one another.

The literature nonetheless contains few examples of empirical research on mobile learning; most reports are anecdotal and based on case studies. Survey and interview findings from instructors and students suggest benefits for instructor workload and student outcomes. For example, giving learners more autonomy in finding the most appropriate resources for a task may reduce pressure on instructors to constantly update traditional materials for learners with diverse experiences. Other reported student benefits include better acquisition of knowledge and higher-order thinking skills (critical self-reflection, analysis, and synthesis), higher motivation, more engagement with peers, better attendance, preparation for class, participation, self-directed learning, and a more collaborative relationship with the instructor (Murray, n.d.; van 't Hooft, 2008). Vahey and Crawford (2002) reviewed case studies from 102 instructors who received Palm Education Pioneer grants to use wireless handheld technologies in their classrooms. They found that handhelds increased students' self-directedness, initiative, cooperation, collaboration, autonomy, and homework completion. Teachers in turn created activities that let students work independently at their own pace, which made students more motivated and creative, improved the teaching of specific content, and reduced wasted classroom time. Private industry has also reported positive outcomes from smartphone-based training, including reduced completion time, higher exam scores, and greater satisfaction (Brown, 2010). Closer to the present study, Horton (2011) found that students significantly increased their science knowledge from pretest to posttest after using a media-enriched program, that they were motivated and enjoyed the experience, and that motivation scores were significantly and positively related to posttest science knowledge.

The Conventional (Lecture) Method

Conventional teaching places the teacher in control of the learning environment. Power and responsibility rest with the teacher, who acts as instructor, mainly through lectures, and as decision maker on curriculum content and specific outcomes. Students are regarded as having "knowledge holes" that must be filled with information, so that the traditional teacher views learning as something the teacher causes to occur (Novak, 2011). The approach is as old as formal teaching itself, involving a directed flow of information from teacher to student, whose mastery is then tested through exercises. Too often, however, such exercises test the student's pattern-matching abilities, and what appears to be excellent teaching may in fact be facilitated pattern matching.

Researchers who have studied traditional instruction are consistent in their definitions. Comparative studies introduced the idea of the "passive student" (Hake, 1997), and traditional instruction has since been described as a "lecture and questioning method" in which students study the textbook, the teacher supplies concepts, facts, terms, and diagrams, class periods are lecture-based and involve note taking from a chalkboard or whiteboard, and students are expected to answer teachers' questions (Sungur & Tekkaya, 2006, as cited in Castillo, 2006).

Cabal (2010) explained that the traditional method has been observed to contribute to students' poor performance in mathematics. In a traditional lesson, the teacher answers homework questions, teaches the new lesson, and assigns homework that students may start in class if time permits. Students become bored as they sit passively while the teacher works problems on the board, and afterwards both students and teachers are often frustrated because individual needs go unmet. Uwameiye and Ogunbameru (2005), in their comparative analysis of two methods of teaching financial accounting at the senior secondary level, concluded that teachers' predominant use

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of the conventional method was a contributory cause of student failure, that guided discovery would improve achievement and reverse the failure trend, and that teachers should be trained in guided discovery.

Traditional instruction should not, however, be dismissed outright. It still has devoted advocates. It can convey more material in a given amount of time than other methods; students can learn a great deal about a subject, and it works well with both larger and smaller classes. Learning under this approach is chiefly associated with the classroom and is often competitive; the content and delivery of the lesson are considered most important, and students master knowledge through drill and practice, such as rote learning, without the content necessarily being learned in context (Theroux, 2002).

Students' Level of Achievement

Students' achievement is considered a vital indicator of good schooling and of educational efforts directed toward high levels of attainment. Educationalists have increasingly sought the factors that influence achievement, and studies of personal, school, and family factors have demonstrated the importance of all three domains (Anselmus, 2009). Learning is measured by academic performance, that is, how well a student meets the standards set by a school or institution, and as career competition intensifies, parents, legislators, and education departments pay growing attention to how well students do in school (Bell, 2014). Tuckman (2003) noted that achievement labels the observable manifestation of knowledge, skills, concepts, understanding, and ideas.

Grades on examinations indicate a candidate's ability, mastery of content, and skill in applying learned knowledge to particular situations, and success on examinations is generally taken as a crucial indicator that a student has benefited from a course of study (Wiseman, 2001; Fishman, 2006). Authentic academic achievement should ideally involve examination of the whole person, covering academic ability and the ability to apply practical skills. Even so, Harrison (2008) argued that although an examination is not a perfect measure of educational success, it is an important indicator in education systems and cannot be ignored. These views provide the basis for measuring achievement through tests in the present study.

The Problem and Rationale

Low achievement in science is a source of frustration in the classroom. It has been a source of frustration for the high school science teachers of Co Tek Chun National Trade School, Pagadian City, who find it hard to accept that only a few students give the lesson their full attention. According to Markova (1992), what teachers fail to realize is that each student is digesting the lesson differently and is in a different state of consciousness. This leads teachers to examine their strategies and rethink how to relate to their students. Recent studies point to multiple intelligences and individual differences, yet teachers still largely adopt traditional ways of teaching. Markova (1992) cited the observation that people remember about 10% of what they hear, 20% of what they see, and 90% of what they do, yet most teaching still follows one style: the teacher talks and the students listen and learn.

To reach students' way of thinking, teachers should acclimatize to current societal trends. In a technology-saturated world, smartphones have become indispensable because they simplify routine work and save time, and a smartphone with an Android operating system offers a distinct experience and a great opportunity for students to learn while meeting their need to keep pace with society's trends and thinking patterns (Cheong et al., 2012). Mobile learning is of great interest at present, with advocates expecting that mobile devices could transform education, engage students, and personalize learning. Numerous studies abroad have demonstrated the significance of mobile learning and its devices; the use of mobile learning devices in special education, for example, is supported by a handful of studies. However, the Philippines lags behind in mobile and e-learning, and this should not prevent teachers and parents from considering mobile learning devices, particularly where learners benefit greatly from them (Odilao & Bautista, 2014).

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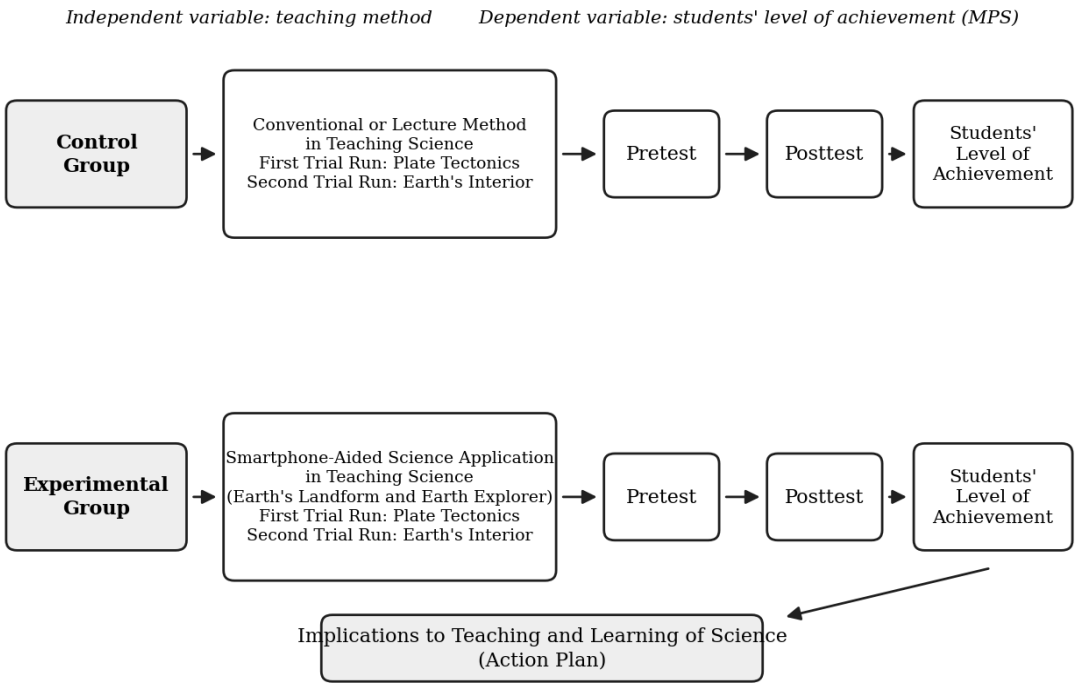
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The researcher is a science teacher at Co Tek Chun National Trade School whose students have placed in the Division Science Quiz Bee for two consecutive years and, in 2016, won second place in the National Techno-Science Quiz (group category). From two years of public school teaching, the researcher observed that learners are increasingly absorbed by devices such as smartphones, tablets, computers, and televisions, and that the quality of teaching and learning needed to be upgraded to meet the interests of technologically native students. One way to benefit from these technologies in formal instruction is to employ smartphone-aided science applications. The approach used in this study includes the Earth Explorer application, with videos and animations supporting Earth science concepts such as the biosphere, hydrosphere, and lithosphere, and the Earth's Landform application, which presents the processes that alter Earth's landforms, as substitutes for conventional classroom exposition. Knowledge of the relationship between such applications and achievement can inform teachers' adaptation to technological change and thereby the improvement of student performance in science.

Conceptual Framework

The study compared students' performance under the conventional strategy and under the smartphone-aided science application in teaching science (Figure 1). Two groups of students underwent experimentation. In both groups, the teaching method served as the independent variable, and students' academic achievement, measured by pretest and posttest, served as the dependent variable.

Figure 1. Conceptual framework of the study.



The conventional or lecture method is "teacher-dominated instruction" that is deeply teacher-centered (Broughton, 2008). The teacher is the source of knowledge, and learners are passive receivers. From a science perspective, however, inquiry-oriented instruction engages students in the investigative nature of science, with the focus on the active search for knowledge or understanding to satisfy curiosity. Emphasis on inquiry does not preclude the use of textbooks or other instructional materials, and as instructional technology advances there will be more options for using a variety of materials to enrich inquiry-oriented instruction (Haury, 1993). The smartphone-

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aided science application is a form of mobile learning that uses a range of smartphones and Android-based technologies to deliver instruction and curricular content.

Sever and Oguz-Unver (2013) reported that video benefits teaching in two ways. First, it stimulates students' concentration and motivation throughout the teaching process (e.g., Roskos-Ewoldsen & Roskos-Ewoldsen, 2001; Hazen et al., 2002; Hoover, 2006; Oishi, 2007). Second, it helps students conceptualize and internalize difficult and abstract topics (e.g., Verran, 1992; Harwood & McMahon, 1997; Liedtka, 2001; Herron et al., 2002; Green et al., 2003; Brunvand & Fishman, 2007; De Leng et al., 2007; Palmer, 2007; White, 2007). Their study also emphasized the need for technology-supported teaching strategies in achieving educational productivity.

Objectives and Research Questions

This study aimed to establish the effects of the smartphone-aided science application in teaching science to Grade 10 students of Co Tek Chun National Trade School during the first semester of school year 2016–2017. Specifically, it sought to answer the following questions:

1. What is the level of achievement of students using the smartphone-aided science application (experimental), as revealed in the pretest and posttest results of the first and second trial runs?

2. Is there a significant difference in the level of achievement of students using the smartphone-aided science application (experimental) between the pretest and posttest of the first and second trial runs?

3. What is the level of achievement of students using the conventional method (control), as revealed in the pretest and posttest results of the first and second trial runs?

4. Is there a significant difference in the level of achievement of students using the conventional method (control) between the pretest and posttest of the first and second trial runs?

5. Is there a significant difference in the level of achievement between the experimental group and the control group in the first trial run?

6. Is there a significant difference in the level of achievement between the experimental group and the control group in the second trial run?

7. Based on the results, what implications for the teaching and learning of science can be developed?

Hypotheses

The following hypotheses were tested at the 0.05 level of significance:

1. **H1.** There is a significant difference in the level of achievement of students using the smartphone-aided science application (experimental) between the pretest and posttest of the first and second trial runs.

2. **H2.** There is a significant difference in the level of achievement of students using the conventional method (control) between the pretest and posttest of the first and second trial runs.

3. **H3.** There is a significant difference in the level of achievement between the experimental and control groups in the first trial run.

4. **H4.** There is a significant difference in the level of achievement between the experimental and control groups in the second trial run.

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Significance of the Study

Effective teaching and learning result in better student performance. The findings are expected to benefit the following groups:

- *Science teachers*: determining the effect of smartphone-aided science applications will help them improve their teaching strategies and give them flexibility in presenting technological materials in line with students' capability to use these technologies.

- *Students*: when teachers employ such applications, students have the opportunity to practice higher-order thinking skills, understand their learning strengths and weaknesses in science, and improve their academic achievement.

- *Parents*: the study shows the effort teachers exert in teaching science to their children and the effort children exert in their studies, and it raises awareness of the academic support children need in science.

- *School heads and Department of Education officials*: the results can serve as baseline data for programs, projects, and supervisory strategies that improve and sustain science achievement.

- *Other researchers*: the results provide baseline data on which to anchor further investigation, conclusions, and recommendations.

Definition of Terms

The following terms are used throughout the study and are defined as follows:

- *Conventional or lecture method*: a traditional method of teaching in which the teacher provides instructional strategies and explanations on the topic being discussed.

- *Pretest*: a test designed for the two topics and given to the control and experimental groups of Grade 10 students to assess whether they were suitably prepared for the course of study.

- *Posttest*: a test administered after the smartphone-aided science application and the conventional method were used with the experimental and control groups, respectively, to determine differences in learning outcomes.

- *Smartphone*: a mobile phone with an advanced mobile operating system that combines features of a personal computer operating system with features useful for handheld use, such as those of a personal digital assistant, media player, and GPS navigation unit. Most smartphones can access the internet, have a touchscreen interface, run third-party applications, and are camera phones.

- *Smartphone-aided science application*: also known as a science mobile application, a computer program designed around science concepts to run on mobile devices such as smartphones and tablet computers.

- *Earth Explorer*: a smartphone-aided science application for earth science that engages students in exploring the Earth's interior, biosphere, hydrosphere, and human geography and gives detailed facts on the evidence supporting plate movement.

- *Earth's Landform*: a smartphone-aided science application for earth science or integrated science that engages students in exploring Earth's landforms and plate tectonics, how they change, and how they affect humans.

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- *Students*: the enrollees in Grade 10 of Co Tek Chun National Trade School.
- *Students' performance or level of achievement*: the extent to which a student has achieved educational goals. In this study, it refers to the difference between students' pretest and posttest scores, expressed as mean percentage scores, in evaluating the smartphone-aided science application in teaching science.
- *Teachers*: persons teaching Grade 10 science at Co Tek Chun National Trade School.

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METHODS

Research Design

The study used a pretest–posttest, two-group experimental design to determine the significance of differences in learning when the smartphone-aided science application was used in teaching science. Key (2000) described an experimental research design as a blueprint of the procedure that enables the researcher to test hypotheses by reaching valid conclusions about relationships between independent and dependent variables. According to Spector (2003), experimental design occurs when the subjects and conditions studied are manipulated by the investigator. It typically compares two groups, usually two approaches; the group receiving the new treatment is the experimental group and the other is the control group.

Pretest–posttest designs expand on the posttest-only design with nonequivalent groups and are among the simplest methods of testing the effectiveness of an intervention. One group receives the treatment, the control group receives none over the same period but undergoes exactly the same tests, and statistical analysis determines whether the intervention had a significant effect. The design improves internal validity but sacrifices some external validity, because without a completely untreated baseline there is no way to judge whether pretesting itself influenced the results; for example, children given an educational pretest may try harder in their lessons. The design also faces a practical problem common in educational research: when two groups attend the same school, they may mix outside lessons and share ideas, potentially contaminating the results, whereas drawing groups from different schools introduces the risk of selection bias because randomization is not possible (Shuttleworth, 2009).

The design allows the researcher to compare the final posttest results of the two groups as an indication of the overall effectiveness of the treatment, to see how each group changed from pretest to posttest, and to compare the pretest scores to check that the groups were equivalent at the start. If the control group also improves significantly, the researcher must seek the reasons for that improvement (Shuttleworth, 2009). The use of a control group raises ethical questions, because the control group may be disadvantaged relative to the group receiving the new treatment. The researcher nevertheless chose to investigate the topic under controlled conditions, with careful attention to measuring what took place.

Research Environment

The study was conducted at Co Tek Chun National Trade School (CTCNTS) in Sunrise Village, Barangay Tiguma, Pagadian City, during the first semester of school year 2016–2017. The school is one of two public technical-vocational schools in the East District of Pagadian City. In school year 2016–2017 it had 18 teaching personnel, three of whom taught science. It is located in an urban subdivision housing project in front of the Pagadian City Water District station, is accessible by land transportation from most sides, and is roughly five kilometers from the city market. Educational technologies readily available at the school included light microscopes, functional computers with internet connections via Wi-Fi, LED televisions, and overhead projectors.

Academically, the school belongs to the mid-performing public high schools in the Division of Pagadian City, with a 55% average mean percentage score (MPS) in science over the previous two years. It placed in the Division Science Quiz Bee for two consecutive school years and recently participated in the National Science Quest, winning the National Techno-Science Quiz, but it aims to improve the quality of students' science performance more broadly.

Participants

The participants were all 70 Grade 10 students officially enrolled at CTCNTS in school year 2016–2017. Before the school year began, they had been distributed heterogeneously into two sections, Mercury and Mars, with the

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same number of achievers and non-achievers in each. A systematic sampling based on students' performance and achievement in their final grades of the previous school year was used to divide the two sections into two groups (Table 1). Section Mercury (35 students) formed the experimental group and was taught with the smartphone-aided science application, and Section Mars (35 students) formed the control group and was taught with the lecture method. All officially enrolled students of both sections were included. The same students took part in both trial runs of their respective methods. Each experimental student was temporarily given a functional smartphone with the science applications pre-installed for the duration of the experiment. No internet connection was needed because the applications were installed in advance and could be used offline.

Table 1. Sampling results for the Grade 10 students

Group	Section (Trial 1)	Section (Trial 2)	n
Control	Mars	Mars	35
Experimental	Mercury	Mercury	35
Total			70

Instruments

Two types of lesson plans served as instruments for teaching, one for the experimental group (smartphone-aided science application) and one for the control group (conventional method). Teacher-made, 20-item tests served as the pretest, given before instruction, and the posttest, given after instruction, in each trial run. The tests were adapted from the Grade 10 Science Learner's Module of the Department of Education and measured the level of thinking. Items were multiple-choice with four options, and the first-trial posttest also included a short matching-type section.

To validate the instruments, the researcher submitted the list of applications and demonstrated how they would be used. The questionnaires and their tables of specification were submitted to the thesis adviser for corrections and revisions, and the questionnaires were then pilot-tested before copies were reproduced and administered to the participants. Tables 2 and 3 show the tables of specification for the pretests and posttests of the two trial runs, which were the same for the conventional and experimental groups. Each test had 20 items distributed as 60% easy, 30% average, and 10% difficult, and each topic was allotted one hour of discussion.

Table 2. Table of specifications for the pretest (both groups, first and second trial runs)

Trial run	Topic	Hours	Items	Easy (60%) item nos.	Average (30%) item nos.	Difficult (10%) item nos.
First	Plate Tectonics	1	20	3, 4, 5, 9, 11, 12, 14, 15, 17, 18, 19, 20	6, 7, 8, 10, 13, 16	1, 2
Second	Earth's Interior	1	20	3, 6, 7, 12, 13, 14, 15, 16, 17, 18, 19, 20	4, 5, 8, 9, 10, 11	1, 2

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Table 3. Table of specifications for the posttest (both groups, first and second trial runs)

Trial run	Topic	Hours	Items	Easy (60%) item nos.	Average (30%) item nos.	Difficult (10%) item nos.
First	Plate Tectonics	1	20	3, 4, 5, 7, 10, 11, 12, 13, 14, 18, 19, 20	1, 8, 9, 15, 16, 17	2, 6
Second	Earth's Interior	1	20	1, 2, 4, 5, 6, 7, 13, 14, 15, 16, 17, 18	3, 8, 10, 11, 12, 19	9, 20

Instructional Intervention

Two topics from the Grade 10 earth science curriculum were taught in two trial runs of one hour each. In the first trial run (Plate Tectonics), students were expected to understand the distribution of active volcanoes, earthquake epicenters, and major mountain belts, to describe the different types of plate boundaries, and to explain the processes that occur along them. In the second trial run (Earth's Interior), students were expected to describe the internal structure of the Earth, describe the possible causes of plate movement, and enumerate the lines of evidence that support plate movement. The lesson plans of the two groups shared the same objectives and references (Grade 10 Science Learner's Module; *Science and Technology for the Modern World*), the same lesson structure, and the same generalization. Each lesson began with class routine (opening prayer, attendance of study participants, the pretest, collection of assignments) and a review of the previous lesson, followed by motivation, discussion, valuing or application, generalization, and the posttest as assessment.

Control group (conventional method). The teacher delivered the concepts through "talk and chalk," using the learner's module, chalk, and pictures of geologic landforms and events or of the Earth's interior. In the first trial run, the lecture covered the two types of crust (oceanic crust being denser), subduction at oceanic–continental and oceanic–oceanic convergence with the associated volcanoes, trenches, island arcs, earthquakes, and tsunamis, mountain building at continental–continental collision, and spreading at divergent boundaries, together with the effects of divergence between oceanic and continental plates. In the second trial run, the lecture covered the crust, mantle, and core; the reasons for studying Earth's layers; changes in seismic wave velocity as evidence of density boundaries; the asthenosphere; and the fit of the continents as evidence that they were once joined.

Experimental group (smartphone-aided science application). Students used smartphones, tablets, or laptops in place of chalk and pictures. The review of the previous lesson used a video presentation on the YouTube application. In the first trial run, the teacher used the Earth's Landform application to motivate students to navigate the plate boundaries on Earth's crust and discuss how boundary types affect landform formation, and to deliver the lesson content and demonstrate the relationship between plate tectonics and geologic formations and events. In the second trial run, the Earth Explorer application was used to navigate the Earth's interior and deliver the lesson, and students had one-on-one, hands-on interaction with the lines of evidence supporting continental drift, seafloor spreading, and plate tectonics.

Data Gathering Procedure

The researcher first asked permission from the Office of the Schools Division Superintendent of Pagadian City and from the school principal to conduct the study at CTCNTS. The two sections were then divided into the control and experimental groups as described above. Before the two methods were administered, both groups took

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a pretest, which allowed pretest–posttest comparison and checked baseline equivalence. The respective methods were then administered in the first and second trial runs, each followed by the posttest. The tabulation, analysis, and interpretation of data were carried out with the help of a statistical adviser.

Statistical Analysis

Descriptive and inferential statistics were used, with the Statistical Package for the Social Sciences (SPSS) employed for accuracy and convenience. Descriptive statistics described the conditions of the two groups. The mean percentage score (MPS), the average of students' percentage scores in each group, was the descriptive measure because it gives a reliable and stable description of students' performance and achievement. The percentage increase from pretest to posttest was computed as (posttest MPS − pretest MPS) ÷ pretest MPS × 100, and MPS values were interpreted using the scale in Table 4. A two-sample *t*-test was used to test the significance of differences between the smartphone-aided science application and the conventional method, and between pretest and posttest scores within groups. All hypotheses were tested at the 0.05 level of significance.

Table 4. Descriptive equivalents of mean percentage scores

MPS range	Descriptive equivalent
90.0–100	Excellent
80.0–89.9	Very good
70.0–79.9	Good
60.0–69.9	Fair
50.0–59.9	Poor
Below 50	Very poor (failed)

Because the within-group pretest–posttest comparisons involve the same students measured twice, the original independent-samples results were supplemented in the present manuscript with paired-samples *t*-tests and effect sizes (Cohen's *d*) recomputed from the raw scores reported in the thesis appendix ($n = 35$ per group per trial run). The additional analyses are labeled in the tables.

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RESULTS

Results are presented in the order of the research questions. Raw-score standard deviations (out of 20 items) were computed from the thesis appendix data.

Achievement of Students Using the Smartphone-Aided Science Application

Table 5. Level of achievement of students using the smartphone-aided science application (experimental), pretest and posttest, first and second trial runs

Trial run	Pretest MPS	Descriptive equivalent	Posttest MPS	Descriptive equivalent	Increase from pretest to posttest (%)
First (Plate Tectonics)	23.71	Very poor	67.43	Fair	184.39
Second (Earth's Interior)	34.29	Very poor	75.71	Good	120.79

Note. Mean raw scores (SD) out of 20: first trial run, pretest 4.74 (1.80) and posttest 13.49 (2.03); second trial run, pretest 6.86 (1.77) and posttest 15.14 (2.17).

In the first trial run, the experimental group's pretest MPS was 23.71 (very poor), and its posttest MPS was 67.43 (fair), an increase of 184.39%. In the second trial run, the pretest MPS was 34.29 (very poor), and the posttest MPS was 75.71 (good), an increase of 120.79%. The experimental group therefore improved in both trial runs (Figure 2, left panel).

Achievement of Students Using the Conventional Method

Table 6. Level of achievement of students using the conventional or lecture method (control), pretest and posttest, first and second trial runs

Trial run	Pretest MPS	Descriptive equivalent	Posttest MPS	Descriptive equivalent	Increase from pretest to posttest (%)
First (Plate Tectonics)	24.43	Very poor	37.00	Very poor	51.45
Second (Earth's Interior)	33.43	Very poor	44.57	Very poor	33.32

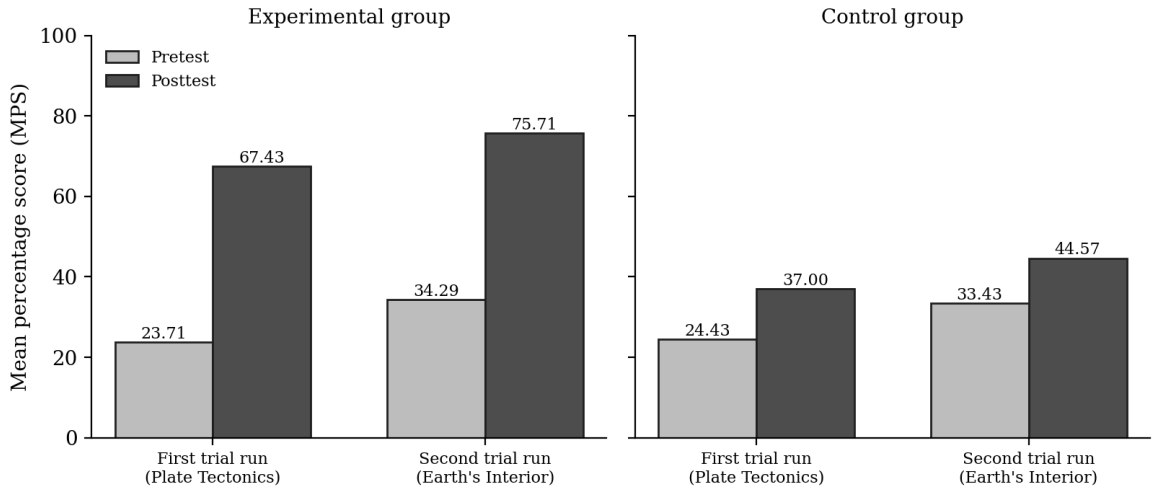
Note. Mean raw scores (SD) out of 20: first trial run, pretest 4.89 (1.78) and posttest 7.40 (2.34); second trial run, pretest 6.69 (1.92) and posttest 8.91 (2.43).

The control group's pretest MPS was 24.43 (very poor) in the first trial run and 37.00 at posttest (still very poor), an increase of 51.45%. In the second trial run, the pretest MPS was 33.43, and the posttest MPS was 44.57, both very poor, an increase of 33.32%. The control group also improved, but its posttest scores remained in the failing range in both trial runs (Figure 2, right panel).

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Figure 2. Pretest and posttest mean percentage scores of the experimental and control groups in the first and second trial runs



Comparison of the Two Methods

The posttest MPS of the experimental group was higher than that of the control group in both trial runs (Figure 3). Table 7 and Figure 4 summarize the percentage increase from pretest to posttest. The experimental group's average increase of 152.59% was far greater than the control group's 42.39%.

Figure 3. Posttest mean percentage scores of the experimental and control groups by trial run

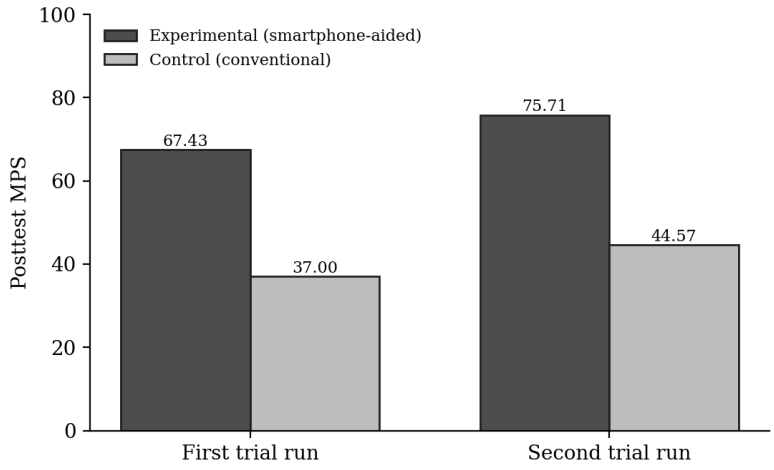


Table 7. Summary of the increase in students' level of achievement from pretest to posttest (%)

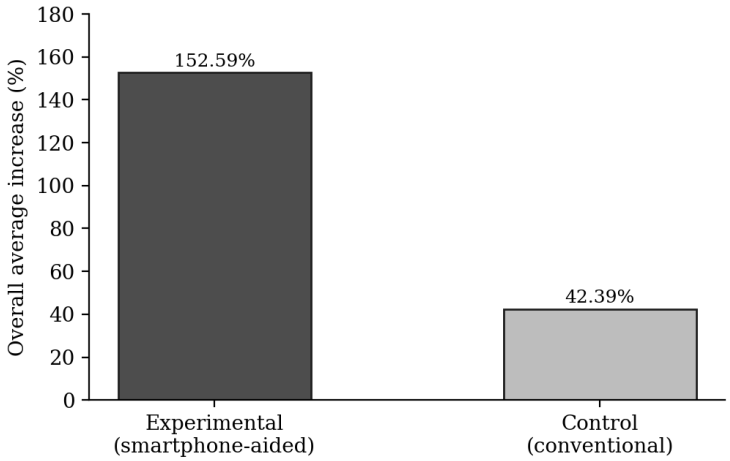
Group	First trial run	Second trial run	Overall average
Experimental	184.39	120.79	152.59
Control	51.45	33.32	42.39

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Note. The overall average is the mean of the two trial-run increases. The control value (42.385) was reported as 42.38 or 42.39 in different parts of the original thesis; it is rounded to 42.39 here.

Figure 4. Overall average percentage increase from pretest to posttest



Tests of Hypotheses

Hypotheses 1 and 2: pretest versus posttest within groups

Table 8 shows that the difference between pretest and posttest scores was statistically significant for the experimental group (H1) and for the control group (H2) in both trial runs. The paired-samples analysis added in this manuscript gives the same conclusions, and the effect sizes were very large for both groups but larger for the experimental group.

Table 8. Tests of difference between pretest and posttest scores within groups

Group	Trial run	*t* (df = 68)[a]	*p*	Paired *t* (df = 34)[b]	Cohen's *d*[b]	Decision
Experimental	First	19.02[c]	< .001	18.61	3.15	H1 supported
Experimental	Second	17.51	< .001	17.17	2.90	H1 supported
Control	First	5.06	< .001	12.69	2.14	H2 supported
Control	Second	4.26	< .001	11.84	2.00	H2 supported

Note. [a] Independent-samples *t*-test as reported in the original thesis. [b] Added in this manuscript from the raw scores in the thesis appendix; Cohen's *d* here is the mean difference divided by the SD of the paired differences. [c] Reported as 19.20 in the original thesis; recomputation from the appendix data gives 19.02.

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Hypotheses 3 and 4: experimental versus control group

Table 9. Tests of difference between the experimental and control groups at pretest and posttest

Trial run	Test	*t* (df = 68)	*p*	Cohen's *d*[a]	Decision
First (H3)	Pretest	0.334	.740	−0.08	No significant difference
First (H3)	Posttest	11.607	< .001	2.77	Significant difference
Second (H4)	Pretest	0.388	.699	0.09	No significant difference
Second (H4)	Posttest	11.308	< .001	2.70	Significant difference

Note. [a] Added in this manuscript from the raw scores in the thesis appendix, using the pooled standard deviation (experimental minus control).

The two groups did not differ significantly at pretest in either trial run (p = .740 and p = .699), which indicates that they started at comparable levels. At posttest, the experimental group scored significantly higher than the control group in both the first trial run, $t(68) = 11.607$, $p < .001$, and the second trial run, $t(68) = 11.308$, $p < .001$. Hypotheses 3 and 4 were therefore supported for posttest scores: the level of achievement of students improved after the two strategies were employed, and the improvement was significantly greater under the smartphone-aided science application.

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DISCUSSION

Principal Findings

Both groups improved from pretest to posttest, but the gains of students taught with the smartphone-aided science application were far larger. The experimental group moved from the very poor range at pretest to the fair range (first trial run) and the good range (second trial run), whereas the control group remained in the very poor range at posttest in both trial runs. Because the two groups were statistically equivalent at pretest, the significantly higher posttest scores of the experimental group in both trial runs are consistent with the conclusion that teaching with the smartphone-aided science application was more effective than the lecture method for the two topics studied. The result was replicated across two different topics, Plate Tectonics and Earth's Interior, which strengthens the consistency of the finding, although the two trial runs involved the same students and are not independent samples.

Interpretation in Light of the Literature

The results agree with earlier reports that mobile and media-enriched instruction improves science learning. Looi et al. (2010) found that a mobilized science curriculum helped an experimental class outperform comparison classes on traditional assessments, and Horton (2011) found significant pretest-to-posttest gains in science knowledge after students used a media-enriched program. The applications used here, Earth Explorer and Earth's Landform, deliver videos, animations, and interactive navigation of plate boundaries and Earth's layers. Such features may help students concentrate and stay motivated and may help them conceptualize and internalize difficult and abstract topics (Sever & Oguz-Unver, 2013), and they allowed students individual, hands-on interaction with the content, in line with the observation that people retain far more of what they do than of what they only hear (Markova, 1992). Smartphone-aided learning also offers an option for self-study by making materials readily available and accessible (Eschenbrenner & Nah, 2007), facilitates interaction between students and teachers in the classroom (Lam et al., 2011), and is likely to become one of the most effective ways of delivering educational materials in the future (El-Hussein & Cronje, 2010). Teaching strategies shape the learning environment, and an effective teacher selects strategies that engage students in learning (Hudson, 2007). The present results indicate that adding a technology-based strategy that suits technologically native students was a productive selection for these lessons.

The control group's significant improvement is also worth noting, because it shows that lecture-based instruction does raise scores (see Hypothesis 2), as defenders of the traditional method maintain, and as the design anticipated: when the control group also improves, the reasons should be examined (Shuttleworth, 2009). Part of that improvement may reflect instruction itself and part may reflect familiarity with the test format from the pretest. Even so, the control group's gains were much smaller and left students in the failing range, which supports the concern in the literature that lecture-dominated, teacher-centered teaching leaves many students' needs unmet (Cabal, 2010; Uwameiye & Ogunbameru, 2005).

Implications for Teaching and Learning

In answer to the seventh research question, two implications were drawn. First, teachers' competencies in reaching instructional objectives can be developed by teaching science with smartphone-aided science applications. Second, such applications can enhance learning and support positive long-term memories of science education; the action plan in the original thesis (Appendix H) was proposed for this purpose. The second implication should be read as a proposal for further study, because the present study measured achievement at the end of each lesson and did not measure retention.

For science teachers, the findings suggest a practical way to present technological materials flexibly and to improve strategies in line with students' ability to use these tools. For students, they suggest an opportunity to

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practice higher-order thinking and to better understand their strengths and weaknesses in science. For parents, they show the effort that teachers and children put into science learning and the kind of academic support children need. For school heads and Department of Education officials, they provide baseline data for programs, projects, and supervisory strategies to improve and sustain science achievement, and for other researchers, they provide a baseline for further investigation.

Limitations

The study was limited to Grade 10 students of one school, to two one-hour lessons on two earth science topics during a single semester, and to standardized teacher-made instruments; other factors that might influence students' academic performance were beyond its scope. The groups were two intact sections of 35 students each, so assignment to conditions was not random; baseline equivalence was supported only by the pretest comparison. In this design, pretesting may itself influence results; the experimental group received loaned smartphones and may have been affected by novelty, and contamination between sections of the same school cannot be excluded (Shuttleworth, 2009). The same students took part in both trial runs, the tests were teacher-made and validated by the adviser and pilot testing, and the original thesis does not report reliability coefficients or whether the same teacher taught both groups. Finally, no delayed posttest was given, so the durability of the gains is unknown. These considerations argue for caution in generalizing the results beyond the studied context.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on the findings, the following conclusions were drawn. There was a significant difference between the pretest and posttest achievement of students using the smartphone-aided science application in both trial runs, and there was likewise a significant difference between the pretest and posttest achievement of students using the conventional method in both trial runs. There was no difference between the experimental and control groups at pretest in either trial run. There was a significant difference between the groups at posttest in both trial runs, in favor of the smartphone-aided science application. The study therefore concludes that using the smartphone-aided science application resulted in better student achievement than the conventional method for the topics studied.

Recommendations

Based on the findings and conclusions, the following recommendations are forwarded:

1. Teachers may use smartphone-aided science applications in teaching selected science topics to bring innovation to learning, enhance students' interest in science, stimulate the transfer of learning to real-life situations, and meet the needs of technologically native students.

2. Science teachers may use smartphone technology as an innovative way of imparting knowledge, as part of coaching and learning in an information technology presentation environment, to arouse and sustain students' interest, since students enjoy using smartphones, tablets, or computers at school, at home, or elsewhere when they have time to explore.

3. Science teachers may explore smartphone-aided science applications to break the monotony of classroom lectures and to encourage the use of innovative devices such as smartphones, tablets, and computers in activities that teach science concepts and skills.

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4. School administrators may encourage teachers to attend seminars, regular workshops, and symposia through universities on the learning competencies in science so that they are exposed to new teaching strategies, including smartphone-aided science applications.

5. The inclusion of mobile teaching or smartphone-aided science applications in science instruction is further recommended, together with extensive studies with longer exposure to the strategy to strengthen the conclusions reached.

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