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Using Mobile Learning to Support Students' Understanding in Geometry: A Design-Based Research Curriculum Study

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Abstract: Mobile learning offers new affordances to teaching and learning, such as learning that is contextualized, personalized, and unrestricted by temporal and spatial constraints (Crompton, 2013a). In this study, the affordances of mobile learning were utilized as students learned about angles. Using a design-based research methodology a local instruction theory was developed on how students can learn about angle concepts through mobile learning activities. The local instruction theory is comprised of two components: (a) an exemplary mobile learning curriculum for 4th grade students to study angle concepts, and (b) additions to the scholarly theories in how students learning about angle using mobile learning.

Introduction

Many educators and governments have advocated for educational reforms to utilize digital technologies in classroom instruction (Bereiter & Scardamlia, 2006; Common Core State Standards Initiative, 2010). Digital technologies can be used to support mathematics teaching and learning. For example, technology offers the opportunity for students to actively participate and reorganize the way they see mathematical concepts (Stohl-Lee, Hollenbrands, & Holt-Wilson, 2010), and the various mathematical representations can reveal various different methods to solve problems, with the potential to positively affect the students' thinking and learning processes (Heid, 2005). With attributes, such as the graphical capabilities, technologies were quickly identified as environments facilitating the construction of geometric understanding (Clements & Battista, 1989).

Angles are particularly difficult concepts for elementary students to grasp in geometry and students often develop many misconceptions and difficulties (Clements & Battista, 1989). A review of the literature reveals two strategies that appear to have been successful in supporting students with angle concepts, these are the use of (DGE; e.g., Laborde, Kynigos, Hollebrands, & Strasser, 2006) and real-world connections (e.g., Mitchelmore, 1998). Mobile learning can provide a way of bringing these two strategies together. Digital technologies are constantly evolving and becoming more personalized. The use of mobile technologies is becoming ubiquitous throughout today's society. These digital technologies are also seeping into educational establishments. Mobile learning offers new affordances to teaching and learning, such as learning that is contextualized, personalized, and unrestricted by temporal and spatial constraints (Crompton, 2013a) which may provide a way for students to learn about angle concepts in a more comprehensible form. The purpose of this study was to use design-based research to develop a local instruction theory. The local instruction theory contributes to the theories of how students come to understand angle concepts while using mobile learning and an exemplary mobile learning curriculum is developed for teaching angle and angle measure. This curriculum can be utilized and adapted by educators to fit their class needs.

Theoretical Framework

Mobile Learning

Mobile learning is "Learning across multiple contexts, through social and content interactions, using personal electronic devices" (Crompton, 2013b, p.4). This definition includes the four central constructs of mobile learning which are learning pedagogies, technological devices, context, and social interactions (Crompton, 2013a), that have been used to extend the boundaries of traditional learning. The term *context* refers to the subject content and the environment in which the learning takes place. Learning can take place seamlessly across multiple environments with the portability of the device. Therefore, students can learn in the real-world in which they live, connecting typically decontextualized subjects, often taught with text books, to tangible contextualized concepts. A relatively new subcategory of mobile learning has developed called context-aware ubiquitous learning (Lonsdale, Baber, Sharples, & Arvanitis, 2004) that specifically involves students learning in the real world while interacting with the environment. For example, students may be photographing angles in the local environment using a mobile device, such as an iPad, then measuring the angle using apps on that same device.

Dynamic geometry environments are now available on mobile devices, such as SketchPad Explorer (2012). With this application, specific add-ons, for example, Measure a Picture (Steketee & Crompton, 2012), allow the students to interact with the real world to take photographs of physical objects in the environments and use tools within the program to measure those angles. A small number of researchers have used mobile learning and more specifically context-aware ubiquitous learning to study geometry in the real world (e.g. Elisson & Ramberg, 2012), and at this time there are none who have studied angle and angle measure using this approach. This study involves the use of mobile learning to support students in learning angle concepts. Students used a dynamic geometry environment called *Measure a Picture* and activities were designed to take place in real-world settings.

Geometry

School geometry involves interlinked concepts, axiomatic representational systems and ways of reasoning that mathematize spatial objects, relationships, and transformations. Although geometry forms the foundation of learning in mathematics and other academic subjects (Clements, 2004), it is often ignored by curriculum writers and teachers until high school (Clements, 2004; Lehrer et al., 1998). With this delayed focus on this subject, empirical evidence shows that a large number of students in the United States have insufficient knowledge and understanding of geometric concepts (Mullis, Martin, Beaton, Gonzalez, Kelly, & Smith, 1997; 1998). The use of digital technologies has appeared to be beneficial in mathematics, yet, mathematics teachers are often the most resistant to students using technologies for learning (Crompton, & Keane, 2012). This opposition is often due to a lack of understanding and training in how to use technology in teaching (Crompton, 2011). In this study, DBR is being used for its intended purpose– to bridge the gap between research and practice and provide a curriculum that teachers can use to teach angle concepts using mobile learning.

Methods

Participants

A total of 62 participants were involved in this study; two fourth grade teachers and the students taught by the two teachers were recruited for the study. The participants were a convenience sample as this was one of a few schools in the Southeastern United States to have class sets of iPads. There were 30 fourth grade students in each class and four students were randomly selected out of each class to complete the pre and post instruction clinical interviews. This particular grade was chosen as the Common Core State Standards requirements state that teachers should formally begin teaching angle and angle measurement in fourth grade.

Design-Based Research Protocol for this Study

The specific DBR selected for this study was developed by Gravemeijer & van Eerde, 2009). This DBR was designed for studies involving mathematics. This DBR study consisted of two macro cycles with one teaching experiment occurring in each macro cycle. Each teaching experiment involved seven days of mini cycles of instructional experiments and reflection. The macro cycles for this study are illustrated in Figure 1. Note the occurrence of the three phases within each macro cycle: (a) the design of the instructional materials, (b) classroom based teaching experiments and mini cycle analysis, and (c) the retrospective analysis of the teaching experiments which informed the next macro cycle. At the beginning of macro cycle one, the researcher conducted a thorough review of the literature surrounding mobile learning and how students come to understand angle and angle measurement. Using the information gathered in this literature review, the conjectured local instruction theory was created. The local instruction theory is made up of two components, (a) a theory of how students learn angle concepts while using mobile learning, and (b) an exemplary curriculum of how to teach angle concepts using mobile learning. The day before the teaching experiment, the clinical interview was administered to the four students from the first class. Next, using the instructional materials, the first teaching experiment was conducted over seven consecutive school days. The teaching experiment was the implementation of the exemplary curriculum developed in the initial stage of the macro cycle. During the teaching experiments, the co-researcher and witness observed and took notes on the classroom instruction, and the instruction was videotaped.

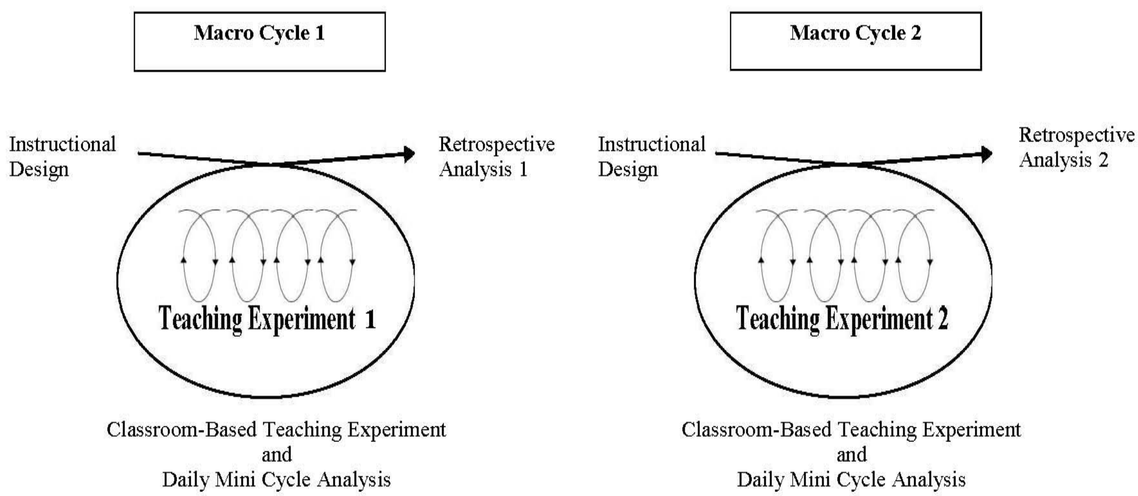

Figure 1. A Diagrammatic Representation of the Study.

Students' work was collected at the end of each day. Also, at the end of the day's instruction, the researcher, co-researcher, and witness met to discuss the lesson and these conversations were audio recorded. Following this meeting, the researcher completed a daily reflection journal. During each daily mini cycle in the teaching experiment, the researcher utilized the collected data to modify the next day's instruction when necessary. During the retrospective analysis, in the final stage of the macro cycle, all these data were reviewed. The conjectured local instructional theory was then revised before repeating the entire process again in a different class for the second macro cycle. The local instruction theory came from the final retrospective analysis.

Data Sources

One of the distinct characteristics of DBR methodology is that the researcher's develop a deeper understanding of the phenomenon while the research is in progress. Therefore, it is essential that the research team collect a comprehensive record of the entire process (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). A list of the various data components is provided in Table 1. These data are used in the mini cycle daily reflections and the retrospective analysis from macro cycle one and two.

Table 1
Data Sources and when these Data were Analyzed

	Select Students for Interviews	Daily Mini Cycle Analysis	Retrospective Analysis 1 Macro Cycle 1	Retrospective Analysis 2 Macro Cycle 2

Pre instruction Clinical Interview	✓		✓	✓
Post instruction Clinical Interview			✓	✓
Co-Researcher and Witness Classroom Observations		✓	✓	✓
Whole-class and Small Group Video			✓	✓
Daily Mini Cycle Reflection		✓	✓	✓
Artifact Collection			✓	✓
Researcher Reflection Journal		✓	✓	✓

Scally's (1990) clinical interview was used in this study. The credibility of Scally's clinical interview has been determined with 83% reliability and the content validity of the instrument established. Furthermore, Scally's study provided evidence for her to claim that the instruments and scoring procedures could be used effectively by other researchers and in other settings. The design underpinning Scally's interviews is threefold: the discovery of cognitive activities (structures, processes, and thought patterns), the identification of cognitive activities, and the evaluation of levels of competence (Ginsburg, 1981). The interviews were based around van Hiele's levels of geometric thinking (van Hiele, 1957/1984).

Findings

Students showed growth on the van Hiele levels of geometric thinking in the post instruction test from the pre instruction test. More importantly, the students who held many of the typical misconceptions about angle and angle measurement did not hold the same misconceptions in the post instruction test. Two of the common misconceptions were that the length of the rays (lines) on angles determined the size of the angle and that orientation of the angles was an important angle attribute. Students in the post instruction interview were able to say that these angle attributes did not matter in measuring and identifying angles. In addition, they would often point to the environment in which they were taking the test to prove this point. In the activities, the research team observed that the students used the extendable ray lengths in the application to match what was in the photograph of the angle. It seemed that this was helpful in dispelling the misconception about the length of the rays. From the video and researcher observations of the activities, students appeared to be using the devices to mathematize their environments much more easily than the students did without the devices.

As the students worked through the activities using the iPads, the researchers noticed from these data gathered that small additions were made to the van Hiele indicators. The most significant additions were made to angle measure and sorting angles. These revised indicators can be found in Figures 2, and 3.

Sorting Angles

Sorts on the basis of what they "look like"; student includes angle categories, such as acute, but describes them as looking like acute angles.

Includes non-salient attributes, such as orientation and length of the rays when sorting angles.

Student excludes relevant properties when sorting such as the 90° benchmark.

Student may mention some properties in the sort but sorting is inconsistent.

Visualization
Van Hiele Level One

Student sorts angles by properties but is not able to justify the sort, or a need to justify the sort.

Student is able to sort in a generalized manner, such as using angle categories, acute, obtuse, right, straight angles. (Not on a looks like basis.)

Student is able to sort, by connecting to benchmark measures, such as 90° and 180° and describes by using degrees, such as larger than 90°.As long as student used degrees correctly, the correct terminology does not have to be used.

Analysis
Van Hiele Level Two

Informal Deduction
Van Hiele Level Three

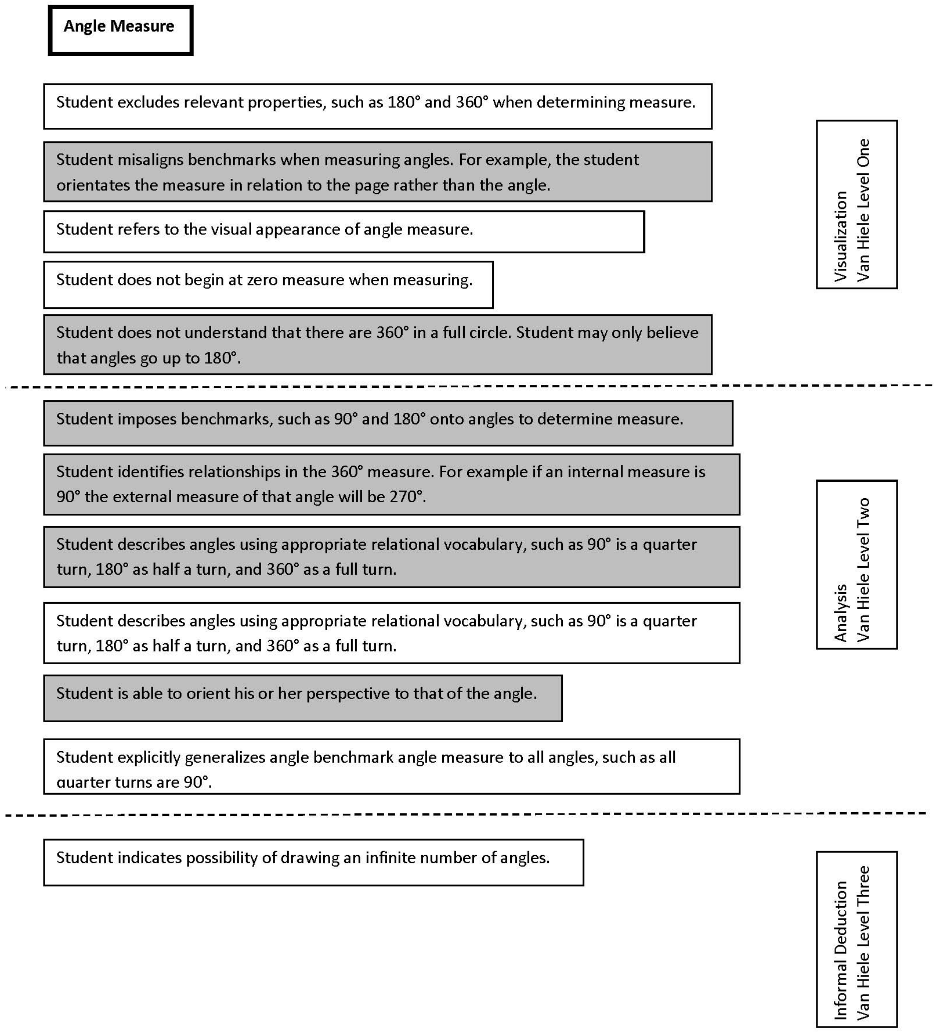

Figure 3. van Hiele Angle Measure Indicators of Students Involved in Mobile Learning Activities

Various changes were made to the mobile learning curriculum following the final retrospective analysis. Due to the page limit restrictions, the full curriculum cannot be shown here, but it can be found at https://www.dropbox.com/s/buiy5lgve7qh4m2/DBR%20Lessons.pdf In Table 2 an overview of the Instructional Sequence can be found. This will give the reader some idea of the mobile learning activities and how the real-world settings were included.

Table 2
Overview of the Instructional Sequence

Lesson	Learning Progression	Instructional Activity
1	Recognize angles as geometric shapes that are formed whenever two rays share a common endpoint. Identify angles in a real-world setting.	Students are introduced to the concept of angle via projected images of different examples of angles in different orientations with sides of different lengths. The term angle is introduced. Students look for angles in the real-world.
2	Identify angles in a real-world setting. Begin to recognize that there are an infinite number of angles.	Students are introduced to the application Sketchpad Explorer and taught how to use the DGEs to take photographs and how to use the

		dynamic protractor. Students take photographs of angles in a real-world setting disregarding orientation and length of rays. Students will use the tools in the DGEs to highlight the angles found.
3	Recognize and compare angles based on size using non-standard and standard language (right, obtuse, acute, and straight angles).	Students will work in groups making angles with straws and compare size of those angles using non-standard language. Introduced to the terms: right, obtuse, acute, and straight angles. Using the benchmark of 90° on the dynamic protractor, students find examples of right, obtuse, acute, and straight angles in a real-world environment. An angle gallery will be created from the screenshots. Students will work in pairs to discuss the categorization of an angle in the real-world and check their accuracy using QR codes.
4	Recognize acute, obtuse, right, and straight angles in different contexts (real-world and paper and pencil. Recognize salient attributes of angle.	Students work in groups to categorize acute, obtuse, right, and straight angles. Class discussion to create a table of important and non-important attributes of angles.
5	Understand that angles can be measured with reference to a circle and that angles are fractions of a circle. Experience using a nonstandard unit of measure (a wedge). Recognize that the attribute being measured is the space between the two line segments caused by the turn of the line segments. Understand that angles are measured by units called degrees. Understand that benchmarks can be made for angle measures. For example, a full circle turn is 360°, therefore a straight angle is 180° and a right angle is 90°. Recognize that there an infinite number of angles.	Wedge activity to create benchmarks. Using the wedges to measure a set of materials such as a coat hanger, books, scissors, and a car ramp, noting that the latter two can be changed to vary angle size.
6	Recognize that the same angle can appear to be a different size depending on different visual perspectives (positions). Understand that angles are defined by particular attributes which involve angle as a turn (e.g., "two rays, the common endpoint, the rotation of one ray to the other around that endpoint, and measure of that rotation"; Clements and Sarama, 2009, p.186).	Students work in pairs to photograph and measure angles from different perspectives. Work in groups to create a poster to define angle to students who have not yet studied angle.

Conclusion

In this study, the researchers used DBR to develop a local instruction theory of how 4th grade students come to understand about angle and angle measure through mobile learning. Aligned to DBR methodology, the local instruction theory is comprised of two components: (a) an exemplary curriculum, and (b) additions to the scholarly theories. Using a cyclical iterative process of anticipation, enactment, evaluation, and revision (Gravemeijer & van

Eerde, 2009) over two macro cycles, a sequence of instructional materials were developed. The activities used a mobile learning approach which had the students making real-world connections to mathematics with the use of iPads and the Sketchpad Explorer app which is a dynamic geometry environment. This curriculum and the apps used in this study are freely available for educators to adapt to the needs of the students in their classrooms. The curriculum can provide a springboard for educators to begin to understand the affordances of mobile learning in a mathematics classroom and develop other mobile learning activities that are context-aware, enabling students to contextualize mathematics to make sense of difficult concepts.

The researchers were also able to add to the scholarly theories in how students learn about angle and angle measure with mobile learning. Specifically, additions were made to the indicators of van Hiele's levels of geometric thinking (van Hiele, 1957/1984) from when students use mobile learning to study angle concepts. Overall, mobile learning appeared to be a valuable pedagogy for introducing students to angle concepts. Students showed considerable gains in understanding angle, and typical misconceptions were entirely eradicated by the end of the short curriculum. As the students were able to connect with multiple different angles in the environment, and then use the application on the iPad to further explore the angles, that these practices appear to extend students' understanding of angle and angle measure.

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