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Effect of Dynamic Geometry Software on Male and Female student's Achievement in Geometry in Nasarawa State, Nigeria

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ABSTRACT

This paper reports on data taken from a gender study of senior secondary school one students in Nasarawa State on learning aspects of geometry using dynamic geometry software. Dynamic geometry software promises direct manipulation of geometrical objects and relations. This paper reports aspects of a research study deigned to examine the impact of using such software on male and female student conceptions. Analysis of the data from the study indicates that, while the use of dynamic geometry software can assist students in making progress towards more mathematical explanation (thereby provide a foundation on which to build further notions of deductive reasoning in mathematics), the 'dynamic' nature of the software influences the form and explanation, especially in the early stages. The focus for the analysis is the students' evolving mathematical explanations as they tackle problems involving the construction of various quadrilaterals. The use of dynamic geometry software can assist students in making progress towards more mathematical explanation (and thereby provide a foundation on which to build further notions of deductive reasoning in mathematics), and the 'dynamic' nature of the software influences the form of explanation, especially in the early stages. This underlines the vital role of the teacher in ensuring that the students' ability to devise explanations moves from reasoning to more general mathematical language.

Keywords: Dynamic Geometry Software, procedural knowledge, Computer-based learning, 'drag' facility, geometrical construction.

INTRODUCTION

According to Adebo (2014), what students learn is greatly influenced by how they are taught. Some methods of teaching are completely out of phase with background and local environments of the learners particularly in Nigeria. Integration of instruction into real-world problems is a persistent argument. Students appear to benefit from knowing how to execute a strategy (procedural knowledge), knowing why the strategy works (conceptual knowledge), and knowing where the strategy works (contextual knowledge). General agreement prevails that students will best learn if they realize how the concepts are directly applied to their future lives.

Computer-based learning environments continue to be a seductive notion in mathematics education. The promise is that through using particular software in carefully-designed ways, it is possible for learners simultaneously to use and come to understand important aspects of mathematics, something that in other circumstances can be particularly elusive. One type of promising computer-based learning environment features what is commonly referred to as the "direct manipulation" of mathematical objects and relations. In the domain of geometry, examples of such software include *Cabri-géomètre, Sketchpad, Inventor, Thales, Cinderella, Dr Geo,* and others. Such software is often called dynamic geometry software, Hanna (2015).

The Nature of Dynamic Geometry Software

According to Laborde (2013), the various different forms of dynamic geometry software typically share certain crucial attributes. One attribute that distinguishes such packages from simple drawing programmes is the ability to specify the geometrical relationships between objects created on the computer screen, such as points, lines, and circles. This is primarily done by specifying that, for instance, a particular point is on a line, or that one line is parallel to another line. A second attribute of such software, and probably the defining one, is the ability to then explore graphically the implications of the geometrical relationships established in constructing a figure. This is usually achieved through use of the 'drag' facility. This is the ability to 'grab' elements of the geometrical figure, using the computer mouse, and observe how the various parts of the figure respond dynamically as the chosen element is 'dragged' around the screen. As this dragging takes place, the display gives the impression that the geometrical figure is being continuously deformed, while, at the same time, maintaining the geometrical relationships that were specified in the original construction. This means that when one line is dragged, any line which has been specified to be parallel to the line being dragged also moves, but in such a way that it always remains parallel to the first line.

By operating in this fashion, dynamic geometry environments appear to have the potential to:

- Provide students with 'direct experience' of geometrical theory and thereby break down what can all too often be an unfortunate separation between geometrical construction and deduction.

- Make it possible for students to focus on what varies and what is invariant in a geometric figure.
- Enable students to gain more a meaningful idea of proof and proving.

It is possible to identify, however, aspects of the nature of the software environment that are likely to impact on geometrical conceptions developed by those using the software to learn aspects of geometry. For example, within any particular DGS there are likely to be some or all of the following:

- Points that cannot be dragged.
- Dragging effects that are determined by the software designer.
- Objects that look identical but behave differently.

These aspects of the behaviour of the software are likely to impact on the learner. It is also important for such learners to be able to discern properly between an image that just "looks right" and one that includes the necessary geometrical construction for its particular geometrical properties to remain invariant when any element used in its construction is dragged. Other concerns about the software relate to the opportunity afforded by the software of testing a myriad of diagrams through use of the 'drag' function provided by the DGS, or of confirming conjectures through measurements. These latter concerns may mean that use of the software, rather than enhancing the learning of proof and proving, may actually *reduce* the perceived need for deductive proof (Hoyles and Jones, 2012).

THEORETICAL FRAMEWORK

The theoretical framework for this study was derived from research in the following areas:

- Theoretical models of the teaching and learning of geometrical concepts.
- Theoretical perspectives on the teaching and learning of proof and proving by both male and female students.
- Socio-cultural perspectives on learning, especially the idea of the mediation of tools by male and female students.
- Theoretical perspectives on the role of technological tools in the learning process.

The framework involves, amongst other things, moving from identifying geometrical figures by their properties (which are seen as independent) to recognising that a particular property of a figure precedes or follows from other properties and that relationships exist between different figures. For proof and proving to be meaningful activities for students, the various functions of proof and proving have to be communicated to the students in an effective way. For students in SS1 a focus on explanation, taken as a discourse establishing the validity of statements about suitable geometrical objects, seems likely to be productive.

Using dynamic geometry software, from a socio cultural perspective, is more than utilising a physical artifact. As students interact when tackling geometrical problems using a DGS in the social setting of the mathematics classroom, they talk the language of geometry even before being introduced to the technical terminology. In this way they "tune to the constraints and affordances by negotiating the situated environment established by the symbolic representation system. In doing so, they develop explanations of why objects behave in the way they do" (Resnick, Pontecorvo, and Samuel, 2014).

The Research Focus and Empirical Study

The focus of the research is on the following:

1. What are the mean achievement scores of male and female students in using dynamic geometry software and those in the control groups?
2. What is the impact of using dynamic geometry software on the interpretation that students give to geometrical objects encountered using the software.
3. How do learners learn to express explanations and verifications of geometrical theorems, properties and classifications.

In this paper the intention is to examine how the use of the dynamic geometry software both enables and constrains students who are learning to explain the relationships between the properties of quadrilaterals through tackling tasks using a particular DGS. The data comes from a case study of SS1 students carried out in Nasarawa State where the students, typically:

- know some of the properties of certain plane geometrical figures.
- have some experience of conjecturing and describing observations in open-ended problem situations.
- but have not been introduced to the formal aspects of proof and proving.

Research Hypotheses

1. There is no significant difference between the mean achievement scores of students taught using improvised instructional materials and those taught without improvised instructional materials.

Design choices were made with a view to the typicality of the setting. The school selected for the work was an urban comprehensive school whose results in mathematics at JSS3 were at the national average. The mathematics teachers in the school used a problem-based approach to teaching geometry and the students usually worked in pairs or small groups on geometrical problems and occasionally used computers. Throughout their geometry work the students were expected to be able to explain the geometry they were doing, either orally or in writing.

All the students in the class were tested using a van Hiele test at the start of the unit of work and on its completion. The teaching unit was prepared to form three phases, and designed to fit around other geometry work for the class. During each of the phases, the students worked in pairs.

Phase 1: Preliminary experience with *Cabri-géomètre* while working through a short series of tasks involving lines and circles.

Phase 2: A series of three tasks that involved constructing the following quadrilaterals: a rhombus, a square, and a kite.

Phase 3: A series of six tasks that involved relationships between various quadrilaterals

Data analysis

What are the mean achievement scores of male and female students in the experimental and control groups? The answer to this question is presented in table1

Table 1. Mean achievement scores and standard deviation of male and female students in the experimental and control groups

Pre-GAT					Post-GAT	
Variables	Sex	N	X	SD	X	SD
Experimental	Male	42	15.71	7.55	24.07	8.84
Group	Female	36	15.25	7.74	21.83	7.16
Control	Male	36	16.36	6.96	20.08	8.47
	Female	25	20.60	8.37	23.84	7.40
Total	139					

Table 1 indicates that both the male and female students in the experimental group improved upon their mean achievement scores in the post-GAT more than the male and female students in the control group even though they had higher mean achievement scores in the pre-GAT.

There is no significant difference between the mean achievement scores of students taught using improvised instructional materials and those taught without improvised instructional materials. The test of this hypothesis is presented in table2

Table 2. Two-way ANCOVA of the post-test achievement scores of students in geometry achievement test

Sources	Type III Sum of square		Df	Mean square	F_{cal}	F_{crit}
Corrected model	5366.29		2	2683.14	95.18	3.84
Intercept	1805.39		1	1805.39	64.05	3.84
Pretest	5297.70		1	5297.70	187.94	3.84
Group	412.12		1	412.12	14.62	3.84
Error	3833.51	136	28.6			
Total	79052.00	139				
Correct Total	9199.80	138				
$P \leq 0.05$						

From table 2, it could be seen that F_{cal} (1,138) = 14.62 $>F_{crit}$ (3.84) at $P \leq 0.05$ level of significance. Thus the hypothesis of no significant difference in mean achievement scores of students taught geometry using improvised instructional materials is rejected.

By the end of the teaching unit the students were reasonably competent with the hierarchical classification of quadrilaterals. The students accepted that particular quadrilaterals could be special cases of other quadrilaterals and could provide reasonable explanations of why this is the case. This is in some contrast to previous research that has found that many students have significant problems with the hierarchical classification of quadrilaterals (Fuys, 2012).

The qualitative development of the students' explanations can be summarised as follows:

- Initially, an emphasis on description rather than explanation. Some reliance on perception rather than mathematical reasoning. Lack of capability with precise mathematical language by both male and female students.
- At an interim stage, explanations become more mathematically precise but are influenced (mediated) by the nature of the dynamic geometry software.
- At the end of the teaching unit, explanations related entirely to the mathematical context.

CONCLUSIONS

Some of the value and function of the hierarchical classification of quadrilaterals, come from the following:

- It leads to more economical definitions of concepts and formulation of theorems by both male and female students.
- It simplifies the deductive systematisation and derivation of the properties of more special concepts by both male and female students.
- It often provides a useful conceptual schema during problem solving.
- It sometimes suggests alternative definitions and new propositions by both male and female students.
- It provides a useful global perspective for male and female students.

Given the significant problems mentioned above that many students have with the hierarchical classification of quadrilaterals, suggests that computer microworlds such as dynamic geometry software "offer great potential for conceptually enabling many children to see and accept the possibility of hierarchical inclusions". The evidence reported in this paper supports such a suggestion but documents the mediational impact of using such software. As documented by this study and other research, this mediational impact involves at least three aspects.

First, the students need to come to terms with the notion of a hierarchy of functional dependency within a figure. Secondly, the students need to gain an appreciation of the notion of the constraint of robustness of a figure under drag as a *mathematical* feature, rather than, say, as 'mechanical glue'. Thirdly, the 'dynamic' nature of the software influences the form of explanation given by the students.

Much previous research with dynamic geometry software has focused on students in upper secondary school where the students have received considerable teaching input in plane geometry, including the proving of elementary theorems, but are new to the particular software tool. The study reported in this paper focuses on students in Nasarawa State where students have quite limited experience of the formal aspects of geometry. The evidence shows that:

- When using dynamic geometry software, by both male and female students can make progress towards mathematical explanations, which, a range of research suggests, should provide a foundation on which to build further notions of deductive reasoning in mathematics.
- The 'dynamic' nature of the software influences the form of explanation given by the

students, particularly the male students.

- There is a vital role for the teacher in ensuring that students move from reasoning.

In the mathematics classroom, the practical issues of when and how to use dynamic geometry software are very important. Knowing more about the impact that the software has on student conceptions should help the software to be used in a more effective way.

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