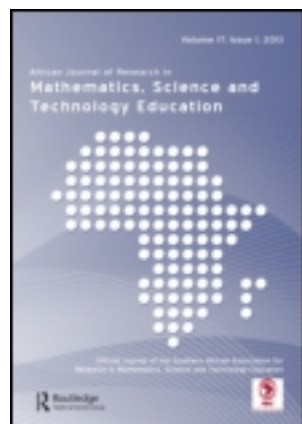


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Competencies in using Sketchpad in Geometry Teaching and Learning: Experiences of preservice teachers

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The subject of teacher competencies has been a key issue in mathematics education reform as the quality of an education system is fundamentally defined by the quality of its teachers. The study reported in this article attempted to identify and analyse displayed preservice teacher competencies and challenges encountered in early experiences with a *Sketchpad*-mediated learning of geometry. The instrumental approach to technology integration in the classroom as articulated by Trouche, Artigue and others was used as an analytical framework together with the van Hiele theory of geometrical thought development. A qualitative research approach was used to investigate preservice teachers' emerging competencies. Data were gathered through worksheet productions, lesson observations, open-ended questionnaires and an exit focus group interview. Twenty third-year mathematics major preservice teachers participated in workshop and microteaching sessions involving the use of the *Geometer's Sketchpad* dynamic geometry software in the teaching and learning of the geometry of quadrilaterals. The competencies displayed by the participants were described in terms of the instrumental theory for technology use and the van Hiele theory for geometric thought development. The competency levels showed that the preservice teachers had difficulties with computer hardware and software usage and the associated classroom organisation and management initially but gradually improved and gained confidence. The participants' own evaluations of their competencies affirmed that early experiences were unpleasant for many and barriers could be overcome by early exposure to computer environments. More computer resources need to be available for a day-to-day integration to be sustainable.

Keywords: Geometer's Sketchpad; instrumental approach; instrumental genesis competencies; instrumental orchestration competencies; van Hiele theory

Introduction

Much has been done to develop pedagogy for computer-based learning but much still remains to be done about a more theoretically grounded integration of (dynamic mathematics) technology into the classroom. Drijvers, Godino, Font, and Trouche (2013) remark that in an effort to address the core challenge of a deep understanding of students' learning processes, interest has grown in networking different theoretical frameworks. This appears more desirable in a context where some theories were proposed before computer-based mathematics instruction became widespread. This challenge is even greater for developing country scenarios where both preservice and practising teachers themselves have had very little or no prior experience with computers. Although it has been argued that

dynamic geometry environments (DGEs) have the potential to make mathematics learning more enjoyable for students (Jensen & Williams, 1992), much of the relevant research has been in developed country contexts. Even then, there has been evident need to develop teacher competencies to speed up the pace of integration of Information and Communication Technology (ICT) into mathematics classrooms. In a study involving 12 grade 7 students Hannafin, Buruss, and Little (2001), for example, examined teacher and student roles in, and reactions to, a student-centred instructional programme using the *Geometer's Sketchpad*. The study found that the teacher had difficulty relinquishing control of the learning environment even though she had agreed to do so. In examining opportunities to explore and integrate mathematics with the *Geometer's Sketchpad*, in the United States context, Olive (1998) presented examples from elementary, middle and high school scenarios where teachers had been using *Sketchpad*, and illustrated potential obstacles such as orchestration problems related to teachers' lack of experience with *Sketchpad*.

The development of geometry instructional strategies in a DGE environment has been explained in part by the Van Hiele (1986) theory of geometric levels of thought. The most obvious characteristic of this theory is the distinction of five discrete thought levels in respect to the development of students' understanding of geometry (De Villiers, 2012). The general characteristics of each of the first four levels can briefly be described as follows:

At Level 1 (*Recognition*) students visually recognise figures by their global appearance. They recognise triangles, squares, parallelograms, and so forth by their shape, but they do not explicitly identify the properties of these figures. At Level 2 (*Analysis*) students start analysing the properties of figures and learn the appropriate technical terminology for describing them, but they do not interrelate figures or properties of figures. At Level 3 (*Ordering*) students logically order the properties of figures by short chains of deductions and understand the interrelationships between figures (e.g. class inclusions). At Level 4 (*Deduction*) students start developing longer sequences of statements and begin to understand the significance of deduction, the role of axioms, theorems and proof.

Another feature of the van Hiele theory is that movement from one level to the next depends on instruction rather than age or biological maturation (Clements, 2004). To this end the theory postulates five phases of instruction (Van Hiele, 1986). In Phase 1 (VHP1) (*Information*) the teacher acquaints learners with the domain of investigation with the emphasis on learner's prior knowledge. In Phase 2 (VHP2) (*Directed orientation*) the teacher guides learners to explore tasks that permit only one solution. In Phase 3 (VHP3) (*Explicitation*) learners are encouraged to describe what they have learned about the topic while the teacher introduces technical terms. In Phase 4 (VHP4) (*Free Orientation*) learners are assigned tasks with multiple solutions. Finally, in Phase 5 (VHP5) (*Integration*) learners having achieved an overview of the topic may be asked to summarise the properties of a geometric shape. The viability of these instructional phases has been demonstrated by, among others, Atebe and Schäfer (2011) who have used them to analyse the nature of geometry instruction and observed learning outcomes in a non-technology intensive environment.

An instrumental approach (e.g. Trouche, 2004) is an analytical framework used in some recent research to explain teaching and learning in a technology-enhanced classroom. In the first part of this approach the process of *instrumental genesis* explains how learners may use the computer hardware and software to represent mathematical concepts, and hence can be linked to the van Hiele levels. In the second part of the approach *instrumental orchestration* is used to describe competencies related to didactic management of the computer environment and hence can be linked to the van Hiele phases of instruction.

The Instrumental Approach to a Technology-Enhanced Classroom

The instrumental approach articulated by researchers such as Trouche (2004) and Artigue (2002) acknowledges upfront the complexity of competencies or skills required of teachers when using technology within mathematics classrooms (Artigue, 2002). The skilful use of ICT for instructional purposes

is referred to as *instrumental orchestration* with the goal of facilitating *instrumental genesis* in learners. An *instrumental orchestration* is defined as the teacher's intentional and systematic organisation and use of the available artefacts in the instructional setting (Drijvers, Doorman, Boon, Reed, & Gravemeijer, 2010). Put differently, instrumental orchestration is a repertoire of teacher competencies in a technology-rich classroom. An artefact—in this case the computer and *Sketchpad* dynamic mathematics software—constitutes the given technological tool which the teacher can appropriate or integrate into his/her teaching of mathematics. When the artefact has been appropriated to facilitate learning it becomes an *instrument* which is a psychological construct (Verillon & Rabardel, 1995). This psychological perspective implies that the tool is used to aid concept development. The teacher's competency in using the instrument for mathematical concept development resonates with Shulman's (1986) conceptualisation of pedagogical content knowledge (PCK) as a prerequisite. In the instrumental approach Shulman's PCK is extended to technological pedagogical content knowledge (TPCK), to account for 'the phenomenon of teachers integrating technology into their pedagogy' (Mishra & Koehler, 2006, p. 1017). The conceptual development or connections facilitated by the teacher in learners by means of the instrument are the cognitive activity referred to as *instrumental genesis*.

Instrumental genesis, which is the goal of instrumental orchestration, depends crucially on the software constraints and affordances (constraints, enablements, affordances and potentialities), students' knowledge in the form of utilisation schemes (usage schemes, and instrumented action schemes) and the teacher's instrumental orchestrations alluded to above (Drijvers et al., 2010). Put differently, instrumental genesis comprises competencies (and consequences) of hands-on artefact usage for mathematical problem solving. It consists of two sub-processes (Trouche, 2004): an instrumentation process directed towards the user (student), and an instrumentalisation process directed towards the instrument (the computer and dynamic geometry software).

Instrumentation is the process by which the user is mastered by his artefact or by which the artefact prints its mark on the user by allowing him/her the competency to develop activities within some limits. Such limits include *constraints* which oblige the user in one way and impede in another, *enablements* which effectively make the user able to do something, and *potentialities* which virtually open up possibilities and *affordances* which favour particular gestures or movement sequences (Noss & Hoyles, 1996; Trouche, 2004).

Instrumentalisation, by contrast, is an instrument mastery process that can go through various stages including discovery and selection of relevant functions, personalisation and transformation of the artefact itself (Trouche, 2004). That is, the mastery and creativity in *usage schemes* (USs) which are oriented towards the management of the artefact (e.g. turning on a computer, adjusting the screen contrast, choosing a particular key, etc.) and *instrumented action schemes* (IASs) oriented towards the performance of specific mathematical tasks (e.g. computing a function's limit) (Trouche, 2004). Both teacher and student can progressively improve their instrumental genesis confidence enabling them to experiment and conjecture with greater competency and fluency. Understanding instrumental genesis sub-processes, therefore, is an essential repertoire of the (preservice or in-service) teacher's TPCK, their knowledge of curriculum (KoC) and subject matter knowledge (SMK) competencies in a technology-enhanced classroom.

In relation to TPCK, Drijvers et al. (2010) identify three elements of instrumental orchestration within a teacher's instructional activity: a didactic configuration, an exploitation mode and a didactic performance. A didactic configuration is a teacher competence that refers to the arrangement of artefacts/instruments in the classroom environment to facilitate learning in a particular manner. For instance computers can be arranged in a way that favours individual work, working in small groups and/or whole class teaching. An exploitation mode is a teacher competence that refers to the way the teacher decides to exploit a didactical configuration. For example a decision as to whether to let learners work in small groups, or individually, with worksheets or with instructions on the board or projected on a screen. It is a competence that also refers to how the teacher plans to introduce and let learners work through a task. A didactical performance is a teacher competence that refers to *ad hoc* decisions taken during the teaching process itself and may involve issues such as what question to pose, what

interruption(s) to make to draw learners' attention to a common obstacle or unexpected technological tool behaviour during task performance.

Purpose of the Study

As the notion of teacher competencies grows in topicality it is increasingly being recognised as a complex phenomenon (Cooney, 1999). In this article, we investigate competencies that preservice teachers displayed in their early efforts at instrumental genesis and instrumental orchestration in a Sketchpad-mediated DGE environment. Accordingly the study reported in this article is a contribution to enhanced understanding of Shulman's (1986) concepts of PCK, SMK and KoC in the form of competencies made more complex by the introduction of ICT tools. The following research questions guided the investigation:

- (1) What geometrical representation competencies were displayed by participants during their initial experience of *Sketchpad*?
- (2) What technology utilisation competencies were demonstrated by participants during their initial attempts to integrate *Sketchpad* into geometry teaching and learning?
- (3) How did the participants evaluate their early experiences with *Sketchpad* in the mathematics classroom?

Research Approach

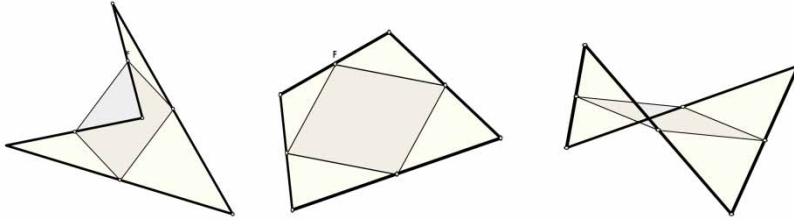
A qualitative research approach was adopted in which participants' *Sketchpad* productions, lesson observations, open-ended questionnaires and focus group interviews were used as data sources. The data gathering process was structured into three phases: namely (a) laboratory sessions to introduce participating preservice teachers to instrumental genesis affordances, constraints, enablements, and potentialities (ACEPs) of *Sketchpad* in the teaching and learning of geometry; (b) microteaching sessions and mini-presentation sketch preparations where volunteer participants could display their emerging instrumental orchestration competencies; and (c) responses to an open-ended questionnaire and an exit focus group interview to obtain feedback from participants about their early experiences of *Sketchpad*. The third phase took on a survey design driven by the assumption that the meanings which the respondents attribute to the questions are meanings which anyone conversant with the language would attribute (Pring, 2004). Each of these phases is briefly explained below.

Initial Instrumental Genesis Experiences with Experiences with Sketchpad

During the first phase of the study (five 2-hour sessions which lasted 5 weeks) a first group of 10¹ volunteer participants gained experience with computer hardware components, introductory *Geometer's Sketchpad* software by using worksheets with computer-based mathematical tasks. Berger (2011) refers to computer-based mathematical tasks as tasks that incorporate computers in their execution. The worksheets were analysed in terms of how the participants accomplished the tasks. Examples of workshop tasks follow.

Constructing a Square: Source(s) — Guided Tour 1 in Jackiw (2002) (VHP2 Activity)

In this introductory workshop session the preservice teachers used worksheets from which they learnt about *Sketchpad*'s basic tools and menu commands (usage schemes) of create and manage *Sketchpad* documents and how to backtrack the construction process using the 'undo' command. They were then introduced to instrumented action schemes of how to construct segments using the point and line tools and the segment tool on its own; how to construct circles using the compass tool or segment and compass tools; how to construct points at the intersection of two geometric objects; perpendicular and parallel lines. Some affordances, constraints, enablements and potentialities were



When the midpoints of the sides of a quadrilateral are connected, the resulting shape is always a.....

Figure 1: A theorem about quadrilaterals

demonstrated and practiced in the process such as how to perform an animation or how to drag objects.

A Theorem about Quadrilaterals Source: (Jackiw, 2002, pp. 21–24) (VHP2 Activity)

The *Sketchpad* objectives of this tour, illustrated on Figure 1, were to construct a polygon using the segment tool, to label a geometric object, measure lengths and angles, construct the mid-point of a line segment, and to create captions to accompany a sketch (i.e. application of appropriate usage schemes and selection of appropriate ACEPs to execute relevant instrumented action schemes).

Of didactical significance was that ‘discovering a theorem for themselves or actively exploring its consequences can make a huge difference in students’ level of recall’ (Jackiw, 2002). Participants were encouraged to record their conjectures in their work sheets for a paper trail of their instrumental genesis competencies.

Free Response Activity (VHP4)

Participants were asked to construct other quadrilaterals of their choice and to gain confidence in instrumentalising and instrumenting *Sketchpad*. Participants were again encouraged to record their construction steps in their work sheets for a paper trail of their instrumental genesis processes in this free orientation type (VHP4) activity.

Initial Instrumental Orchestration Experiences with *Sketchpad*

During the second phase of the investigation, which lasted a further 4 weeks, a second group of 10 participants joined the sessions as tutees while selected participants from the first group took turns to prepare and present lessons using *Sketchpad* to the combined group.

Participants’ performances were rated in terms of a lesson observation protocol consisting of a checklist informed by the descriptors of van Hiele Phases of instruction (e.g. see Atebe & Schäfer, 2011; Fuys, Geddes, & Tischler, 1988) and the instrumental theory as shown in Table 1. Participants were also encouraged to prepare mini-presentation sketches to gain confidence in preparing didactic materials, an exploitation mode aspect of instrumental orchestration and a free orientation van Hiele learning phase (VHP4) activity.

Evaluation of Early Experiences with *Sketchpad*

In the third phase of the study participants responded to a questionnaire to provide individual feedback on their *Sketchpad* competencies in respect of both instrumental genesis and instrumental orchestration. Participants ultimately attended an exit focus group interview session to provide collective feedback on their *Sketchpad* experiences.

Table 1: Checklist for lesson observations

VanHiele Phases (VHP)	Van Hiele Learning Phase Descriptors	Instrumental Theory Linkages
VHP 1: Information	Teacher anticipates and builds on learners' prior knowledge (e.g. geometry of triangles and quadrilaterals)	Relates to didactic performance/ didactic configuration
VHP 2 : Directed Orientation	Teacher condones informal terms, delays formal vocabulary (e.g. 'line' instead of 'line segment' or 'ray')	Relates to didactic performance
VHP 3: Explicitation	Teacher asks questions for learners to clarify informal terminology, gradually introduces formal terminology	Relates to didactic performance
	Teacher creates an interactive learning environment, encourages learners to negotiate meaning	Relates to didactic configuration
	Teacher asks questions to steer learners towards central idea (e.g. tessellations as repeated translations)	Relates to didactic performance
	Teacher asks learners to elaborate on their terminology or responses	Relates to both utilisation schemes and usage schemes
VHP 4: Free Orientation	Teacher uses open-ended questions or tasks and encourages learners' own solution strategies	Relates to both instrumentation and instrumentalisation processes
VHP 5: Integration	Teacher encourages learners to reflect, on refine or summarise (e.g. properties of shapes or construction procedures)	Can relate to the constraints imposed by the software.

Results and Discussion

Instrumental genesis competencies displayed by participants during their initial experience of Sketchpad

The Varignon theorem for quadrilaterals: Source—Jackiw (2002, pp. 21–24) (VHP 1 & 2)

Participants recorded their conjectures in worksheets and one of them, Rejoice, responded to this activity as shown on the transcription on [Figure 2](#). (NB: The preservice teachers' names are all pseudonyms).

She appeared to reason that because the opposite sides of the mid-point quadrilateral were always equal then it must be a parallelogram. This was a necessary and sufficient condition from which the equality of opposite angles and parallelism of opposite sides could be derived deductively. Dragging to form concave, convex and crossed quadrilaterals while observing measurements confirmed the inside quadrilateral to always be a parallelogram (Varignon Theorem). In a sense Rejoice

- | |
|--|
| <ol style="list-style-type: none"> 1. The opposite sides of the inside quadrilateral are equal 2. If a point (vertex) is dragged to form a concave quad the inside shape (quad) still has two opposites equal. 3. If the outside quad is dragged and formed into a crossed quadrilateral the two opposites sides remain equal 4. If it is dragged to form a convex the opposite sides remain equal. 5. Therefore the inside quadrilateral will be a parallelogram |
|--|

Figure 2: Rejoice's responses to the midpoint quadrilateral activity

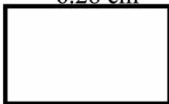
demonstrated sound geometrical or mathematical competencies which are indispensable for the productive use of technology in the classroom. However, an effective role played by technology itself was that the sketches could be constructed easily (an enablement of *Sketchpad*) and furthermore could be dynamically manipulated (a potentiality opening up possibilities unavailable in traditional paper and pencil environments) to provide a variety of idiosyncratic examples dependent on the user's choices. This was different from textbook-based examples which, by their static nature, invariably control the user rather than the other way round. That is, the students got the opportunity to master the artefact (instrumentalisation) suggesting that DGEs can provide learners with greater freedom and autonomy (a potentiality). DGEs thus potentially encourage and foster a democratic rather than authoritarian classroom discourse (which in turn calls for a flexible approach to curriculum design in the form of activity-oriented, learner-centred worksheets).

Free Response Activity to Construct Other Quadrilaterals (Van Hiele Phase 4 Activity)

In a free response activity to construct a rectangle, square and rhombus and to define them in terms of a parallelogram, Nathaniel presented the piece of work in [Figure 3](#). A closer analysis of the work showed that the preservice teacher 'drew' the quadrilaterals rather than construct them in *Sketchpad* using their properties. The drawings did not therefore pass the drag test because they separated when one part was dragged.

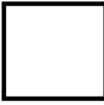
Starting with a parallelogram the student-teacher dragged it into a rectangle and this maintained parallelism and equality of opposite sides implying that a rectangle is a special case of a parallelogram (with all angles equal). Proceeding to the square, the preservice teacher manipulated the rectangle and adjusted it until it became a square of sides 4.03 cm and eventually concluded that a

1. Constructing a rectangle



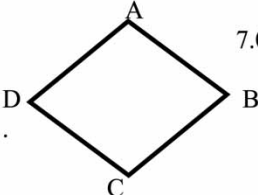
- opposite sides are equal
- all angles are 90°

2. Constructing a square



- all sides are equal
- all the angles are 90°

3. Constructing a rhombus



- all the sides are equal
- opposite angles are equal
- $\angle BAD = 103.77^\circ$, $\angle BCD = 103.77^\circ$
- $\angle CBA = \angle ADC = 76.23^\circ$

a) A **rectangle** is a *parallelogram* with all the angles at right angle 2 opposite sides equal

b) A **square** is a *parallelogram* with all sides and angles equal.

c) A **rhombus** is a *parallelogram* with all sides equal.

Figure 3: Nathaniel's reconstructed piece of work

square is a parallelogram with all sides and angles equal. Similarly, when using dynamic software a student can inadvertently create a special case by dragging (Sinclair, 2003, p. 300). This is an affordance of Sketchpad which is not possible with paper and pencil. The affordance, however, draws attention to the importance of the drag test which preservice or practising teachers can use for formative assessment (a KoC) to judge the effectiveness of the instrumental genesis process in their learners. An open-ended exploration in constructing rhombi ended without any of the teachers coming up with a single method. Coming up with different construction methods requires full van Hiele Level 3 understanding to see the inter-relationship between properties. As shown in Ndlovu (2004), most teachers in this study had not yet fully attained that van Hiele level of geometrical understanding. This demonstrated again that teachers' geometrical or mathematical competencies have an important role to play in the effective integration of technology into the mathematics classroom.

Instrumental orchestration competencies demonstrated by participants during their initial experience of Sketchpad

Micro-teaching sessions

The results of the evaluation of eight participants who prepared for and presented microteaching lessons are summarised in Table 1 where E, U, M and R were used to mainly classify observed instrumental orchestration or learning phase episodes. Presenter preparation was relatively adequate

Tatenda's microteaching presentation

Introduction: *Today we are going to construct and animate a Kaleidoscope in Sketchpad.*

On your desks you will find the worksheet with the instructions to guide you.

Ask your neighbour first if you experience problems with instructions or menu commands.

Development: Learners construct the Kaleidoscope step by step individually following instructions on worksheet (Worksheet available at: http://www.hpedsb.on.ca/ec/services/cst/elementary/math/documents/constructing_kaleidoscope.pdf)

Participants consult with their neighbouring peers to seek clarification of instructions or how to execute commands.

Tutor walks around checking tutees' progress and assists or interjects where necessary.

Participants who complete their constructions first are encouraged to raise their hands and to draw the tutor's attention to come and observe animation obtained as proof of completion.

Tutor congratulates successful participants as asks them to help those who are struggling.

Conclusion: Tutor asks learners to explain procedure and to indicate construction difficulties encountered and/or polygon properties and transformations used.

Gibson's presentation:

Introduction: Tutor revises meaning of tessellation and explains that different shapes can be tessellated.

Tutor directs participants' attention to the task of the session.

Development: Participants construct the tessellation using only translation beginning with a parallelogram following instructions on worksheets. (Worksheet available from Jackiw (2002, pp. 6–7) and at:...) Further development follows similar steps as for the previous lesson.

Conclusion: Tutor emphasises that tessellations can be done using a combination of transformations (e.g. translation and rotation for triangles).

Figure 4: Example lesson presentations

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(Mode of M). Participant activity in all lessons was relatively high both in terms of on-task activity and discussion with peers (M). This stresses the importance of creating a *Sketchpad* didactic configuration that enables learners to be active participants. Time was well managed (M), except for a few instances like the Kaleidoscope (Tatenda) and Tessellations (Gibson) lessons, where the construction processes were long but participants were eager to see the end results. The presenter had to be patient with the learners which is an important didactic performance. Presenting teachers felt more confident when they had previously succeeded in carrying out constructions as in the case of Tatenda (T), Bekithemba (B), Ian (I), and Gibson (G) who achieved levels of R. They were, however, less confident when the level of geometry involved was difficult or when a construction procedure was involved (U in the mastery of geometrical representations). Most presenters (5 out of 8) were not able to wrap up their lessons confidently (a weak didactic performance) due to lack of confidence in the geometrical (instrumentalisation) aspects (U). The overall ability to integrate skills was still weak due to the small number of opportunities for presentation.

Table 2 also shows the grading codes assigned. One participant performed at the elementary level, one at a unistructural and the rest (six) at multistructural levels of integration of instrumental orchestration and instrumental genesis competencies. No participant orchestrated at the relational level. The results showed that the teachers were only getting acquainted with the dynamic geometry software (instrumental genesis processes) and the related teaching approaches (instrumental orchestration processes). Mariotti (2001) found that the presence of the computer and the particular software represented a perturbation element in the internal context of the teacher. This suggests that participants should be given sufficient time to get used to the new technological environment through regular exposure.

Mini-project Presentation Sketches (VHP4 Task)

The purpose of the mini-projects was to offer the student teachers an opportunity to prepare their own sketches (PCK & KoC) as free response activities. This task gave the preservice teachers

Table 2: An evaluation of presenter instrumental orchestration performances

Criterion observed		Performance Code									Mode
		N	R	B	Q	T	A	G	I		
1	Level of preparation (didactic configurations & exploitation modes) and introduction(VHP3)	U	M	R	M	R	R	M	R		M
2	Control of <i>Sketchpad</i> usage schemes and instrumented action schemes (VHP5)	U	U	R	M	M	U	M	R		M
3	Tutor-tutee interaction (didactic configuration & exploitation modes) (VHP3)	U	U	M	M	U	M	M	M		M
4	Tutee-tutee interaction (exploitation mode) and VHP3	M	U	U	M	R	M	M	M		M
5	Whole class interventions (didactic performance) (VHP2)	U	P	U	M	M	M	M	M		M
6	Time management (exploitation mode) (VHP1)	M	M	R	M	U	R	U	M		M
7	Mastery of geometrical representations (instrumented action schemes) (VHP3/VHP4)	E	U	M	M	U	U	U	M		U
8	Monitoring of tutees' progress and interventions (didactic performances) (VHP3)	E	U	U	M	M	M	R	U		M
9	Conclusion (exploitation mode) (VHP5)	E	U	M	M	U	R	U	U		U
	Mode for overall performance	U	U	M	M	M	M	M	M		M

SCORE KEY:

E - Elementary understanding—evidence of little understanding of instrumental orchestration (IO)

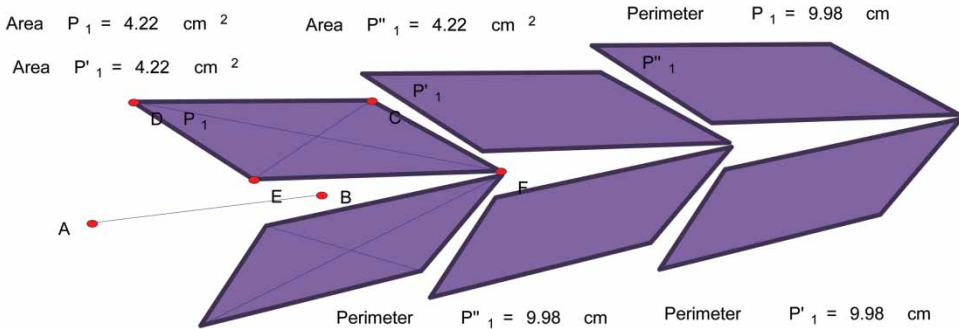
U - Unistructural Understanding—presenter focuses on one aspect of IO

M - Multistructural Understanding—presenter focuses on a number of aspects of IO

R - Relational Understanding—evidence of fluent execution of IO steps

KEY FOR PRESENTER INITIALS: N = Nathaniel; R = Rejoice; B = Bekithemba;

Q = Qhubekani; T = Tatenda; A = Andile; G = Gibson; I = Ian.



TRANSFORMATIONS: Construct any shape then reflect the shape using a mirror line. Then make the mirror line your translation vector to translate the shapes.

Figure 5: Tatenda’s saved sketch

opportunities to rationally adapt tasks to students’ level of geometric thought. *Sketchpad’s* capabilities afford the teacher the opportunity to produce his/her curriculum materials that support effective instrumental genesis, which can be extended to the students themselves to reduce over dependency on the teacher and the textbook. One of the preservice teachers, Tatenda, reported the construction of [Figure 5](#) as follows:

I started by constructing parallelogram CDEF. I then drew line segment AB and marked it both as a translation vector and mirror line. I performed two translations and followed them with a reflection command. I then dragged to produce the series of parallelograms in my sketch ([Figure 5](#)).

Participants’ Evaluation of their Early Experiences with Sketchpad

Selected Open-ended Questionnaire Responses

Fourteen participants responded to the open-ended questionnaire. Six out of 14 respondents (43%) described their early experiences with computers as having been: ‘a total nightmare’, ‘very complicated and confusing’, etc. This suggested that teacher educators and teacher professional development practitioners should anticipate the early difficulties with utilisation schemes competencies as basic as the usage schemes of simply turning on the computer, handling the mouse or operating the keyboard to be unsettling for beginner users. In turn, teachers should be patient with their learners in the early stages of introducing them to computers and mathematical software before these instruments can be appropriated more fluently via instrumented action schemes for geometrical representations, conjecturing and problem solving. In acknowledging the challenges that students face during their early encounters with technology, De Villiers (2007) advises that students do not necessarily need to know the software inside out before they can effectively use it to explore, learn, conceptualise, or conjecture. Instead these mathematical behaviours can easily be achieved by providing the learners with more or less ready-made sketches that only require dragging and/or animation.

Focus Group Exit Interview

Ten participants attended the focus group exit interview. Most of them reaffirmed that they took too long to master basic computer skills (usage schemes) and to execute appropriate commands (instrumented action schemes) because they had no previous exposure to computers as the following feedback showed.

Researcher: What do you consider to be the main reasons for the difficulties you met in these Sketchpad sessions?

Student 1: I do not have any previous experience with computers so it took me long to get used to the keyboard.

Student 2: I had real problems with handling the mouse at first.

Student 3: I did not know how to open or save a file and was helped by Nathaniel who has some knowledge about computers.

Student 4: I wish I had joined the sessions from the beginning then I would have learnt more computer skills.

Student 5: All student teachers must be exposed to computers during their training.

As already noted, Trouche (2004) distinguishes between two kinds of artefact utilisation schemes which can be a source of frustration in the early stages of technology integration: usage schemes oriented towards artefact management and instrumented action schemes oriented towards the performance of specific (mathematical) tasks. In response to how they would assist students in a computer laboratory situation (didactic performances) the following suggestions were cited:

Student 6: The problem is students work at different paces and so need specific individual assistance.

Student 7: Unless there is a problem common to all students, then the teacher can stop the class and make an explanation to the whole class.

Student 8: As I got used to Sketchpad it became more interesting to use to create my own sketches.

In spite of early difficulties some participants such as Student 8 appeared to have gained interest in using Sketchpad and therefore to have overcome the early challenges.

Conclusion

The first objective of this study was to identify (instrumental genesis) competencies displayed by pre-service teachers at two levels. At the first level it was in terms of familiarity with the operation of the hardware or what Trouche (2004) refers to as usage schemes directed towards the management of the hardware. At the second level it was in terms of familiarity with the software (syntax) or what Trouche (2004) refers to as instrumented action schemes/skills directed towards the performance of specific geometrical tasks. The second objective of the study sought to identify the (instrumental orchestration) competencies displayed by preservice teachers in their early experiences with *Sketchpad* integration into the teaching and learning of geometry and how these incorporated the van Hiele learning phases. The third and final objective was to record the preservice teachers' evaluation of their early experiences of *Sketchpad* as an ICT tool in the geometry classroom. The findings suggest that teachers who have no prior experiences with computers struggle to get used to the computer hardware components and let alone the getting used to the software to generate mathematical representations. Increased familiarity with the computer environment and the software, however, breeds confidence and creativity in its utilisation to explore mathematical/geometrical concepts in a more interactive (VHP3), creative (VHP4) and integrated (VHP5) way. An early introduction of teachers to ICT tools in initial teacher education as well as a vigorous introduction through in-service education could overcome the barriers and open up exciting possibilities for both teachers and learners alike. The young generation of learners of today have been born into an ICT ubiquitous society and an early introduction to ICT in the classroom can converge with their interests in the new tools and lead to more interesting mathematics learning environments. More resources should therefore be directed towards making computer laboratories more functional and more up-to-date in keeping with curriculum changes. More curriculum materials should be developed which suggest how the new ICTs can be instrumentally orchestrated to foster more effective instrumental genesis to scaffold learners to higher van Hiele levels of geometric thought.

Teachers working in professional learning communities can develop common identities and overcome their lack of confidence if they work collaboratively together and constantly engage in reflective practice. Wenger's (1998) communities of practice can therefore help to bridge the technological divide.

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Note

1. The computer laboratory had only 10 properly functioning computers out of 15 installed.

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