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Heutagogy in action: Unveiling the transformative power of virtual "air campus" experiences of mathematics trainee teachers

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Abstract

The fourth industrial revolution has brought about significant changes in various fields including the education sector. It is increasingly essential for individuals, particularly student teachers, to embrace lifelong learning and acquire the know-how and skills required to grow into autonomous and critical thinkers. In this paper, we examine the virtual "air campus" experiences of 39 first-year student teachers of mathematics at a rural university in South Africa's Eastern Cape Province. The heutagogical approach served as a lens for trainee teachers' virtual "air campus" explorations. An exploratory qualitative case study design was employed to provide answers to two main questions that guided the inquiry. Findings of the study show that trainee teachers had varied experiences regarding what they learned from their virtual "air campus" visits. These include what constitutes effective teaching and how students learn as well as correction of common misconceptions regarding specific concepts in school mathematics. Through virtual lesson observations on the "air campus" of their choice, trainee teachers were also able to create their professional identities in terms of their future goals, ideal teacher traits, and desired teaching and learning environments. These findings demonstrate that integrating virtual learning environments into teacher education curricula and assessment has practical implications for enhancing trainee teachers' self-directed learning, critical thinking, and professional identity development.

Keywords: heutagogy, mathematics trainee teachers, professional identity, virtual "air campus"

INTRODUCTION

Mathematics is seen as a human activity that involves identifying, simulating, and analyzing qualitative relationships in physical and social phenomena (Department of Basic Education, 2011). Despite being a major component of the school curriculum, many students from different settings around the world have found mathematics to be difficult. Although the situation may be better in some East Asian countries, students from sub-Saharan Africa and other regions of the world have had challenges meeting the international benchmarks set by Program for International Students' Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) (Bethell, 2016; Mullis et al., 2012; 2020; OECD, 2019).

In the context of sub-Saharan Africa, the recruitment and retention of highly qualified mathematics teachers who possess both subject matter and pedagogical knowledge is one strategy for resolving this issue (Adelabu & Alex, 2022; Alex, 2019; Luneta, 2022b; Mukuka et al., 2023; Mukuka & Alex, 2024). According to Peressini et al. (2004), the development of fundamental teaching skills among preservice teachers takes place in a variety of settings, including mathematics content and mathematics education courses, school-based experiences, and school teaching practice. Preservice teachers would inevitably learn what and how to teach mathematics through their engagement with these academic activities.

In many settings including the South African context, first-year Bachelor of Education (BEd) student teachers specializing in mathematics education are required to go for school-based experience, which enables them to understand the connections between the what, the why, and the how of mathematics education. In year 2 and year 3, they are expected to physically go to schools and practice the teaching of mathematics in real classrooms.

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Contribution to the literature

- This study contributes to the literature on heutagogy and virtual learning environments in initial mathematics teacher training.
- The study also has practical implications for enhancing trainee teachers' self-directed learning, critical thinking, and professional identity development.
- Furthermore, this paper provides policy recommendations for integrating virtual learning environments into teacher education curricula and assessment.

However, teacher preparation activities including school-based experience and school teaching practice suffered as a result of the global school closures brought on by the coronavirus disease 2019 (COVID-19) pandemic. Many schools, colleges, and universities were compelled to switch to online learning during the COVID-19 pandemic environments (Kamal et al., 2023; Mukuka et al., 2021a, 2021b).

Research shows that most teachers and learners of mathematics at different levels of education had to adapt to online teaching and learning for the first time with very limited resources, expertise, and support (Engelbrecht et al., 2020a, 2020b; Olivier, 2020). Amidst such limitations, the COVID-19 outbreak provided mathematics educators with a challenge that inspired them to come up with innovative ways to keep their students engaged with their studies (Bakker & Wagner, 2020). In this paper, we analyze the virtual "air campus" experiences of mathematics trainee teachers at a rural university in the Eastern Cape Province of South Africa. The heutagogical approach served as the foundation for preservice teachers' virtual campus explorations. This project was launched through the Mathematics Education and Research Center during the COVID-19 school closure and has been running since then. The founding of the Mathematics Education and Research Center was based on supporting the professional development of mathematics teachers (both in- and pre-service), research, and community outreach. Moreover, the findings from a study by Korucu-Kis (2021), which highlighted the supportive role of a virtual learning environment in improving teaching skills for trainee teachers during remote practicum experiences, greatly influenced and inspired our research.

Heutagogical Approach

A need for knowledge-led economies globally demands a highly skilled and competent labor force. As such, educators at all levels need to ensure that current students and future generations gain the knowledge and skills necessary to develop into independent and critical thinkers. To some (e.g., Blaschke & Hase, 2015; Thakur, 2013), pedagogical and andragogical techniques in which teachers decide what students will learn and how they will acquire it, may not result in the production of independent critical thinkers. This is because such methods force students to memorize content in the order they are delivered and place an undue reliance on the instructors. Heutagogy may therefore be a useful alternative because it enables students to come up with their own problems and questions to address.

According to Blaschke and Hase (2015), heutagogy is a self-determined learning technique, where students are given more freedom to manage their own learning. This method of instruction draws inspiration from constructivism, humanism, and andragogy (Hase & Kenyon, 2000). Heutagogy calls for an instructor to facilitate learning by offering direction and resources, much like the andragogical approach (self-directed learning). However, heutagogy requires that ownership of meaning creation is entirely transferred to the learner, who negotiates and decides what will be learned and how it will be learned (Blaschke, 2012; Lock et al., 2021). These students look for areas of doubt and complexity in the things they study rather than merely performing the tasks instructors set. Teachers, on the other hand, simply assist by giving students' learning context and presenting opportunities for them to thoroughly investigate issues of interest.

In their conceptualization of the "pedagogy-andragogy-heutagogy" continuum, Jones et al. (2019) and Moore (2020) concur that heutagogy may not be considered as a replacement for pedagogy and andragogy but rather as a shift towards granting students a high degree of autonomy in regulating their own learning. As such, heutagogy requires the most student maturity since instructor control is quite low. While andragogy (self-directed learning) rates higher than pedagogy in terms of leaner autonomy (**Figure 1**), it has been argued that andragogy is still content driven while heutagogy is more of process directed (Links, 2018). Heutagogy, as portrayed in **Figure 1**, embodies minimal instructor control and maximal learner autonomy. This visual depiction delineates the spectrum of activities in which learners actively engage within the Heutagogical framework (**Figure 2**). On the other hand, pedagogy, which is characterized by a chalk-and-talk style, has the highest degree of instructor control (Blaschke, 2019).

Although heutagogy affords learners autonomy in managing their own learning, a review of literature by Moore (2020) highlights some challenges particularly the lack of empirical evidence on its effectiveness, difficulties in assessing learners, and incompatible

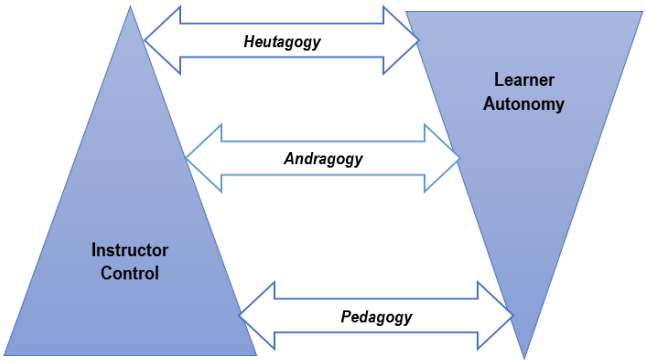

Figure 1. Levels of learner autonomy (Adapted from Blaschke, 2019; Moore, 2020)

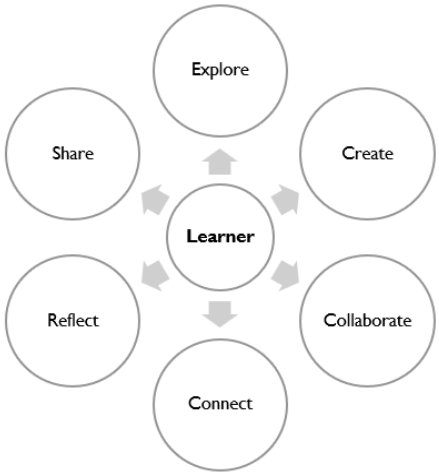

Figure 2. Heutagogical design elements (Blaschke & Hase, 2015)

institutional policies, among others. These may be some of the obstacles to heutagogy's adoption in conventional educational settings and environments with limited resources. However, based on lessons learned during the COVID-19 outbreak, when teachers had little to no physical touch with their students, heutagogy has grown even more obvious. As such, educators at all levels could explore various ways to incorporate heutagogical methods into their teaching strategies. This inevitably affords educators an opportunity to provide students with the skills they need for lifelong learning (Blaschke, 2018; Lock et al., 2021).

Current Study

The purpose of this study was to highlight mathematics trainee teachers' virtual "air campus" experiences. As stated earlier, this study was conducted at a rural university in the Eastern Cape Province of South Africa. First-year trainee teachers are required to observe actual classes for two weeks before they are introduced to lesson planning and actual teaching practice in schools. However, due to COVID-19 school closures, trainee teachers were unable to visit schools physically. As a result, the idea of "observing classes online" came up. First-year trainee teachers were

1. What were three main things I learned from this Campus?
2. What did I previously think was true, but now know to be wrong?
3. What was new or surprising to me?
4. One thing I learned in this visit that I may be able to use in future is…
5. I am still unsure about…
6. Issues that interested me a lot, and that I would like to study in more detail…
7. Ideas for action, based on this campus…
8. What I most liked about this campus was…
9. What I most disliked about this campus was…
10. Miscellaneous interesting facts I learned in this campus…

Figure 3. Guiding questions/items (Source: Authors' own elaboration)

requested to visit a variety of virtual campus sites to discover how each of the observed lessons were taught, how students learned, and the tactics they employed. The authors of this paper called this experience an "air campus" experience. The program has continued to run even after the COVID-19 pandemic because it was found quite useful in supplementing the support given to student teachers in their regular classes.

The virtual "air campus" concept was founded on the heutagogical approach's tenets, which requires students to create their own objectives for what to look out for in terms of learning outcomes and assessments. Consistent with the heutagogical approach, this initiative allowed first-year trainee teachers to observe and learn what they thought was best to boost their skills.

There was "no limit" to their learning, which is why the program suits its name and purpose. Student teachers were given five virtual campus links (which are provided in **Appendix A**) and asked to select one site to report on in accordance with the guiding questions displayed in **Figure 3**. According to Maher et al. (1999), "a virtual campus can be anything from a collection of web pages describing courses to a 3-D virtual reality environment for learning" (p. 320). The emphasis is on viewing a virtual environment as one in which learning takes place as opposed to teaching, which is consistent with the notion of heutagogy. In the context of this study, "air campus" is the term used for having the experience of observing school mathematics lessons that are freely available online.

Unlike the traditional school-based experience, the virtual "air campus" initiative puts no barriers to knowing, and the skills required to be an effective learner. With the heutagogical approach, student teachers were intended to transition from being passive recipients of the information they virtually saw to active analysts and synthesizers of those lessons. In a future, where knowledge management–or curation–is more valuable than access, it is believed that the initiative would provide them some of the most valued skills. Double-loop learning is a key idea in heutagogy (Blaschke & Hase, 2015; Moore, 2020; Thakur, 2013). In line with the activities displayed in **Figure 2**, trainee teachers were required to reflect on both the steps taken

to solve a problem and the problem-solving process itself. It was believed that these experiences would eventually give them (student teachers) a chance to get a better understanding of what and how they would teach once they were professionally ready. Heutagogy gives student teachers the tools they need to succeed in their future profession (in schools), with an emphasis on creating a learner-centered atmosphere that supports them in charting their own learning paths.

Research Questions

Based on the above-highlighted context, this study sought to address the following research questions:

1. What new things did trainee teachers pick up from the mathematics lessons they saw being taught at their preferred virtual "air campus"?
2. How did trainee teachers' perspectives on their professional development change following the virtual "air campus" visits?

METHODS

Research Design

This study employed a qualitative case study design to address the two stated research questions. Among different qualitative case study designs documented by Creswell (2014), this research adopted an exploratory case study design. Consistent with the heutagogical learning perspective, the intent of the study was to document trainee teachers' experiences with the observed virtual mathematics lessons. This design enabled the researchers to provide answers to the two stated questions that guided the inquiry.

Study Participants & Setting

The study targeted first year preservice teachers of mathematics from a rural university in the Eastern Cape Province of South Africa. The students are enrolled in a four-year BEd program with a focus on teaching mathematics and science to South African students in grade 8 to grade 12. Student teachers are required to spend two weeks observing the teaching of mathematics and science at the schools of their choice during their first year of study. However, considering the COVID-19 pandemic's disruption of learning, the university's Mathematics Education and Research Center took the initiative to expose student teachers to virtual "air campus" lesson observations prior to their scheduled in-person visits to the schools of their choice. As a result, first-year student teachers were given links to five virtual air campuses that hold various mathematics lesson videos. In keeping with the heutagogical tenets student teachers were required to visit a campus of their choice, observe a lesson of their choice, compile, and submit a report on their experiences. Student teachers were instructed to match their written observations to the 10 questions shown in **Figure 3** as a guide. However, because student teachers were allowed to add additional items, the list was not exhaustive.

Table 1. Mathematics lessons observed

Lesson observed	n	%
Geometry (fundamental properties of angles)	20	38.5
Border tiles	15	28.9
Comparing linear functions	2	3.85
Quadratic functions	3	5.77
Pythagorean theorem	7	13.5
Geometry (properties of quadrilaterals)	2	3.85
Modelling with systems of equations	1	1.92
Linear regression	1	1.92
High school algebra	1	1.92
Total	52	100

Typically, lesson observations were open-ended in the sense that observers (participants) were allowed to freely provide their views about every observed lesson. A total of 51 submissions were received from first-year student teachers. Of this number, only 39 were considered for analysis as the other 12 submissions did not specify either the air campus visited, or the specific lesson(s) observed. Without this information, it was difficult to link a particular student's written observations to a specific lesson observed especially that all the five air campuses have more than one lesson. Of the 39 submissions that were considered for analysis, 22 had visited air campus 1 while 14 visited air campus 2 and only three visited air campus 5. This means that none of the observers had visited either air campus 3 or air campus 4. **Table 1** illustrates the frequency with which each lesson was observed. The frequency with which each lesson was observed is displayed in **Table 1**. Since some participants observed more than one lesson, it is important to note that the total number of observations exceeded 39, as shown in **Table 1**.

Context of Lessons Observed

Air campus 1

This campus consists of two lesson videos on geometry grade 8-grade 9 and border tiles. The geometry lesson focuses on fundamental properties of angels including vertical angles, supplementary angles, and the right angle. The lesson was taken from a 1995 video study of TIMSS. The duration of the extracted lesson is 4 minutes 17 seconds in which a teacher mainly utilized "question and answer" technique, with learners seated in a tradition row-column arrangement.

The border tiles lesson, on the other hand, is an excerpt from middle school video tutorials by Boaler and Humphreys (2005) that are meant to enhance the teaching and learning of mathematical connections. In this excerpt, the session lasts for five minutes and 59 seconds. The students are placed in groups of roughly three and are asked to answer a question that requires

them to determine the number of colored squares in the border. According to Boaler and Humphreys (2005), the generalized computations can be articulated verbally, geometrically, symbolically, and graphically, and the arithmetic that results from the border's geometry can be applied when the size of the grid changes.

Air campus 2

This campus consisted of several lesson videos ranging from kindergarten to 12th grade mathematics. However, the focus of the submissions from student teachers is on four topics namely, comparing linear functions, quadratic functions, Pythagorean theorem, and geometry grade 11 (properties of quadrilaterals).

Students in grade 8 received the lesson on comparing linear functions for seven minutes and 51 seconds. The usual row-column seating arrangement is used, although discussion in pairs of two is prioritized. The class starts with a review of the pre-assessment that the students completed the day before, which involved verbally explaining and compiling data into a table to ascertain when three DVD rental plans would have the same cost. On their separate tables, students are then asked to describe how they got started. Students are assigned the lesson's goal for the day after discussing their tactics with partners. The lesson's main objective is to examine various tabular forms for students to pinpoint the times when the three different DVD plans have the same price and compare the tables. To make the session engaging for all students, the teacher chose student work that built on the work of the previous student to convey the mathematical story about cost analysis.

For eight minutes and 34 seconds, eighth graders are given a lesson on the Pythagorean theorem. The lesson aims to improve students' comprehension of the Pythagorean theorem in relation the connections between the three sides of the right-angled triangle (as shown in **Figure 4**). The intention is not to promote formula memorization but to develop deeper understanding of the formula $a^2 + b^2 = c^2$.

A lesson on quadratic functions focuses on students' practice with intercepts. Students work in cooperative groups for the five minutes and 20 seconds of the retrieved footage. The quadratic formula and the zero-product condition are currently being used by students to factor expressions and solve quadratic equations. Students are currently using their new tools to sketch the graphs of parabolas by locating their x- and y-intercepts and vertex.

Kites are the main topic of the lesson on quadrilateral properties. Students conduct their investigations in groups during the eight minutes and 12 seconds of the video extract. The lesson is introduced by explaining the students' roles and responsibilities to carry out the investigation. For the tinkering phase of the investigation, the teacher provides examples of ways to obtain information. She additionally discusses the topic in relation to a kite production company. She establishes a goal for investigating the crucial elements (length, intersection point, and angle location) that determine a quadrilateral's shape. The teacher presents manipulatives (differing and similar length strips with holes and a brad) and shows how the placement of the diagonals can affect the shape of a quadrilateral. She gives an example of how to draw a trapezium with stick.

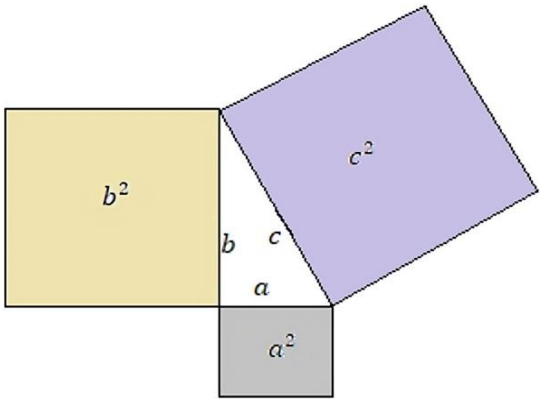

Figure 4. Connections among three sides of a right-angled triangle (Source: Authors' own elaboration)

Air campus 5

Six high school mathematics lesson videos are available on this site, and three student teachers observed three separate sessions, including modelling with systems of equations (32 minutes), linear regression in 11th-grade mathematics (28 minutes), and high school algebra (nine minutes 11 seconds). In the session on modelling using systems of equations, a teacher starts by giving out worksheets with a question that is framed in the context of a real-world event. She then gets students involved in understanding the scenario. After that, the teacher divides the class into groups at which point students interact with one another while working cooperatively in their assigned groups.

In the linear regression lesson, the teacher begins by sharing a real-life scenario with students. After giving out the datasets, the teacher instructs the students to create scatter plots and fit the regression line in their respective groups. A regression line is fitted to the provided data through discussions between the students (in their separate groups) and the teacher, and the teacher then inquires of the students as to the application of the regression model obtained. One of the students suggests that a model like this might be used to make predictions. The teacher then instructs the class to make predictions with different values. After that, the teacher asks the students to name any professions or fields in which the concept of regression might be used.

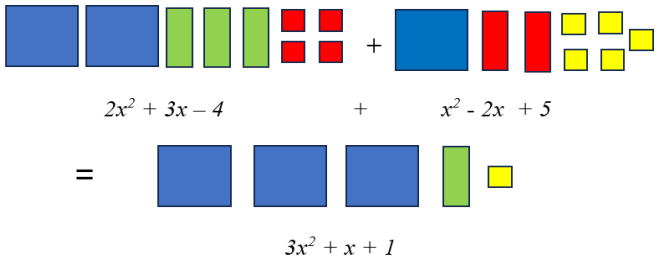

Figure 5. Simplification of algebraic expressions using algebra tiles (Source: Authors' own elaboration)

Lastly, the high school algebra lesson focuses on representing algebraic expressions using algebra tiles. The focus of the lesson is on the development students' understanding of representing algebraic expressions using algebra tiles. For instance, if a smaller yellow tile represents a unit, a green rectangular tile represents x while a blue square tile represents x^2 with red color symbolizing a negation, then the sum of the expressions $2x^2 + 3x - 4$ and $x^2 - 2x + 5$ could be modelled, as shown in **Figure 5**.

Data Analysis Procedures

To analyze the data and find the answers to the two research questions, thematic analysis was applied. The purpose was to identify recurring themes in the data collected in relation to the study's objectives. Through self-reflection and metacognition, trainee teachers were able to compare what they were learning from their virtual campus visits to their previous experiences. Like other existing studies, our analysis followed the procedure recommended by Braun and Clarke (2006). After receiving 51 submissions from student teachers, we read and re-read the submissions to become familiar with the data. We were then able to recognize the 12 incomplete submissions, leaving us with 39. Following that, initial codes were formulated and adopted by the two researchers. Based on their relationships to one another under each research question, the codes were then grouped into themes. Each theme was named following a thorough assessment in consultation with previously published works (Conner & Marchant, 2022). Based on this process, the data for the first research question revealed one main theme, whereas the data for the second research question revealed two major themes. **Table 2** lists the specific themes that emerged along with their corresponding descriptions.

Roles of Researchers

This research is a product of the trainee teacher development activities carried out by the Mathematics Education and Research Center. During the data gathering phase, the two researchers served as instructors. Analysis of data and manuscript development were also carried out by the two authors.

Ethical Clearance

Ethical clearance was sought and granted by the Directorate of Research and Innovation at the university, where research participants were enrolled as trainee teachers. This ethical clearance carters for all the intervention programs in the Mathematics Education and Research Center. After explaining the purpose of the study, all participants provided their consent to participate in the study, have their submissions recorded, and published, where possible. The participants' information has been kept confidential with assurance that the contents and findings of this research will not harm them in any kind, but will instead, contribute to knowledge advancement regarding "learning how to teach mathematics".

RESULTS & DISCUSSION

For each of the two research questions, we offer the study's findings in accordance with the themes derived from the data (as shown in **Table 2**). The results of the current study are further examined in relation to prior works in literature.

Student Teachers' Acquired Knowledge

The first research question aimed at gaining an understanding of the new things that student teachers picked up from the virtual mathematics lessons they observed at their preferred "air campus". Results show that student teachers had varied experiences regarding what they learned from their virtual air campus visits.

First, student teachers either acquired new information or had some misconceptions about certain mathematical concepts clarified. This is supported by the following quotes from selected participants:

> **Participant #2**: I thought that angles on the straight line are complementary but now I learned that angles on the straight line are supplementary.

> **Participant #14**: I previously thought that supplementary angles are equal but now I know that when they are added they make 180 degrees, which is what make them supplementary to each other and the fact that when angles are complementary form a right angle, which is equal to 90 degrees.

> **Participant #19**: After visiting campus 1, I have understood how to deal with supplementary and vertical angles. I also previously thought supplementary angles are angles of a triangle, but now I know that they are formed from a straight line.

> **Participant #20**: I've learned the relationship between straight-line, right-angle, and vertical

Table 2. Description of themes generated from data

Themes generated	Description
Student teachers' acquired knowledge (Research question 1)	This theme aimed at the understanding of the new things that student teachers learnt from their visit in terms of instructional approaches employed (including classroom management), assessment strategies, and newly acquired knowledge of school mathematical concepts.
Student teachers' beliefs (Research question 2)	Focus of this theme was on what student teachers considered essential for effective teaching and learning of mathematics based on their prior experiences and perspectives on their future careers. The intent was to learn more about how student teachers' visits to their preferred air campus affected their prior knowledge of the teaching process, how students learn, how to assess students' learning, and their knowledge of various concepts in school mathematics.
Student teachers' professional identity (Research question 2)	Their professional identity theme included how the knowledge gained from their virtual campus tours affected their ideas about their future career aspirations, ideal characteristics of a good mathematics teacher, and ideal teaching and learning environment.

> opposite angles such as straight line add up to 180° and right-angle add up to 90°. I've also learnt how to apply geometric reasoning and proof to justify mathematics statements and arguments.

The submissions above show that some trainee teachers were able to clear up their misconceptions about some basic features of angles as a result of the virtual air campus visit, while others were able to comprehend ideas that they had difficulty grasping in school. Similarly, Korucu-Kis (2021) found that the virtual practicum-based experience enhanced student teachers' domain-specific knowledge and skills. These findings show that teacher training institutions ought not to assume that student teachers are already familiar with school mathematics and should instead focus solely on university mathematics. Results from related studies (Alex, 2019; Malambo et al., 2018; Taylor, 2019) have also cast doubt on this theory, highlighting that prospective teachers should be exposed to the subject matter they would be required to teach during their initial teacher training. Similarly, studies by Niyukuri et al (2020) and Sunzuma and Maharaj (2019) have emphasized the need for teacher training programs to sufficiently prepare trainee teachers to teach geometry for them to avoid doing it in the same manner they were taught during their school days.

Second, findings demonstrate that student teachers gained fresh perspectives on various strategies for involving learners in order to assure their full engagement and productive learning. Some student teachers who were observing a virtual session on "border tiles" found that when given the chance to reflect and then explain their thinking to others, learners can uncover mathematical links in a variety of ways. Student teachers discovered that one way a teacher can both maximize the learning opportunities for his or her pupils and keep them actively engaged throughout the class is through group discussion. Two participants' quotes, which are included below, illustrate this viewpoint:

> **Participant #4**: Group work exposed students to different aspects of attempting questions

> **Participant #7**: I liked learner participation, and the way teachers made a good relationship with their students. Teachers did not use a few students to dominate the conversation they gave them all chance.

These results are in line with the literature that has already been published about the cooperative learning approach's contribution to improving student learning outcomes in mathematics classrooms (Goos, 2004; Mukuka et al., 2019; Slavin, 2015). Similarly, Brodie (2010) found that allowing students to engage together on mathematical activities will help them begin to see mathematics as a valuable human endeavor.

Third, student teachers' submissions reflect that they gained a new understanding of certain principles that constitute effective teaching. After observing a lesson on Pythagorean theorem, participant #33 realized that "the interest of the child in a lesson depends on how the teacher's teaching strategy is and that it is essential to make use of teaching principles, such as starting with what the learners know to maximize their focus and linking the information to the outside world or making it be more general". This observation is consistent with the submission made by participant #39 on teaching algebra using algebra tiles. This participant emphasized the importance of establishing a safe and supportive learning environment, where learners can feel free to participate in the lesson. The participant further indicated that he found it a little easier for learners to understand algebra when it is taught in a practical way (such as using algebra tiles) rather than just using numbers and variables. These observations align with the recommended methods suggested in the literature. For instance, Ross and Willson (2012) observed that learners' procedural and conceptual knowledge of mathematics was greatly improved using symbolic and active representations along with shared meanings and relevant feedback. Similarly, use of multiple representations, mathematical modelling, analysis of mathematical structures, and collaboration are all identified in a recent paper by Mukuka et al. (2023), as essential practices for the development of students' mathematical reasoning skills.

Fourth, trainee teachers discovered that to accommodate learner diversity in the classroom, a teacher must be patient and employ a variety of teaching techniques. The following statements from a few of the submissions illustrate this viewpoint:

> **Participant #6**: The lesson I learned from this visit (campus 1) was that as a teacher you should be patient with your leaners, have a self-confidence to make your leaners trust you, have forces that drive you to always push for the best, make learning fun and to always have things that motivate you to enjoy your work.

> **Participant #16**: I learned that the teacher must be the one who is leading the class. The teacher must have more knowledge than the learners. The teacher must also accommodate all learners during the class even those who are slow to learn.

> **Participant #27:** As a teacher allows learners to interact this helps more than when you are telling them what to think and speak. I have also learned that placing charts around the classroom helps the learners in retaining knowledge.

> **Participant #28:** At campus 2 (Pythagorean theorem lesson), I observed that teachers create small groups of students and get them to work together to study and solve problems faster. I also learnt that I must have patience. Some students are slow learners so teachers must understand what students go through to learn and help them complete that journey successfully.

> **Participant #39:** At campus 2 in the algebra class, students were quite different from each other; racially; age difference, and levels of understanding. This made me to realize that each student will have their own way of learning, and that it is your duty as the teacher to discover those ways of learning, for the good of the students.

These submissions show that student teachers realized that accepting learner diversity in the classroom and being patient with students are two ways to motivate them to learn. According to a study by Ukobizaba et al. (2021), among the factors that contribute to students disliking mathematics include a teacher's lack of tolerance and roughness. This shows that students can find mathematical connections in a variety of ways if their teachers offer them the chance to reflect and discuss their ideas with others.

Finally, trainee teachers recognized how in-service teachers in virtual classrooms evaluated their pupils' comprehension of various mathematical concepts. After watching the mathematics lesson at campus 2, participant #39 observed that both the teacher and the students valued feedback. Both participants #30 and 32 had the view that real-world scenarios and the use of manipulatives were necessary for an effective assessment of student learning after watching a presentation on the properties of quadrilaterals in which students were instructed to construct a kite with sticks for the diagonals. Additionally, there is sufficient evidence in the existing body of literature to suggest that using both virtual and physical manipulatives contribute to students' increased grasp of mathematical concepts, particularly in settings, where learner abilities range widely (Satsangi et al., 2016). Another study by Satsangi and Miller (2017) found that both virtual and physical manipulatives give students flexible learning options, encourage learner autonomy, and give teachers more options for teaching various kinds of students.

Beliefs About Effective Mathematics Teaching

Research shows that a person's beliefs about teaching have an influence on the classroom practices they adopt and the way in which they put those methods into reality (Conner & Marchant, 2022; Conner & Singletary, 2021). As such, the present study sought to understand the influence of preservice teachers' virtual classroom observations on their beliefs of what constitutes effective teaching of mathematics. Results reveal that student teachers' beliefs about the teaching process and how students learn have been influenced by their virtual campus visits. For instance, participant #1 watched two lessons (geometry and border tiles) and concluded that "teaching is not simply telling theories to students; it is about engaging with learners to create a healthy learning environment". This resonates well with the radical constructivist view of learning; "knowledge is not passively constructed but actively built up by the cognizing subject" (Thompson, 2020). Additionally, participant #10 previously believed that learners always tend to misbehave and never pay attention in class (especially those who sit at the back). After watching a lesson on geometry, this student teacher came to the realization that what matters most is the interest and energy that the teacher displays as learners would give back the same attitude.

Second, the virtual campus visits helped to dispel certain negative beliefs that student teachers had previously displayed. The following statements made by trainee teachers provide convincing evidence of how such trips changed their perspectives on the teaching of mathematics.

> **Participant #17:** Based on how people describe it, I used to think mathematics was the most difficult subject to teach, but now I realize there are many ways to make it simple.

> **Participant #18:** I thought allowing learners to work in groups was a bad idea and just a waste of

> time but now I have seen how learners gained confidence after their discussion, the way they feel free to even go in front and explain to their classmates.
>
> **Participant #32**: I previously thought that teaching is only about providing information to the students but now I know it is also about motivating students and improving self-esteem for those who are nervous to speak in the classroom.

Arising from the submissions above, it is worth noting that such beliefs are equally held by experienced mathematics teachers. During a focus group interview conducted by Mukuka et al. (2019) in exploring the barriers to effective cooperative learning implementation in mathematics classrooms, teachers reported that they avoided this instructional approach as it demanded more preparation and implementation time – making it difficult for them to complete the bulky syllabus on time.

Third, findings reveal that the knowledge gained from virtual campus visits had an impact on student teachers' perceptions about instructional and assessment approaches. The comments made by student teachers are shown below and represent this viewpoint:

> **Participant #33**: From my previous life experiences I've believed that the teacher from the start introduces the topic, write down notes on the chalkboard or white board and explains everything from there, ask a few questions and skip to the next topic without wasting time but here only the opposite occurred, the teacher spent most of her time doing review, allowed the learners to discuss, made use of their discussions and noted answers and tried to correct them by considering the pupils' comments. The teacher's gestures also revealed that the learners' opinions mattered most, she barely used some of the visual materials that were present in the classroom and wanted to make sure that all the learners participate fully by moving around in the classroom.
>
> **Participant #36**: I used to think that standing in front of learners and give them answers was the only way to teach, but I realize that learners also have information that I do not know meaning I may stand and give information, but I also have to give them an opportunity to explain themselves, for example opening discussion in the classroom to the question that I'll propose.
>
> **Participant #38**: I thought that if you give students something to do in groups there will be no need for you to assist, but now I saw an instructor moving around and assisting students with the task she gave them.

The submissions stated above show that student teachers have begun to recognize the importance of incorporating prior knowledge into lessons in accordance with constructivist tenets of learning (Thompson, 2020), the level of scaffolding that should be provided to students during cooperative group discussions (Lahann & Lambdin, 2020; Slavin, 2015), and the need to withdraw from the "hear lecture-do problems-get feedback" instructional approach (Mukuka et al., 2020).

Professional Identity

According to Conner and Marchant (2022), prospective teachers create their own view of teaching through their practicum experiences or by mimicking what they learned from their teachers during high school. As a result, these experiences may influence how one develops their professional identity and enable them to create an ideal model of teaching qualities they may desire to portray in future. Findings of the present study reflect that the virtual air campus visit influenced preservice teachers' professional identity in three ways: goals for the future, desired teacher qualities, and the 'ideal' teaching/learning environment.

Regarding professional goals for the future, student teachers expressed their desire to implement certain practices they thought would bring about meaningful learning. Below are some quotes from student teachers that reflect this perspective:

> **Participant #3**: Teaching geometry is not as difficult as I previously thought. I found it quite interesting to see a geometry class flowing like that. In fact, I intend to make use of those examples in my future geometry classes.
>
> **Participant #7**: One thing I learned on this visit that I may be able to use in the future is that every time I get in class, I will always do a quick review to remind my students on what I previously taught them. Being supportive will help students improve their mental health.
>
> **Participant #10**: What I may be able to use in future from this visit is to have courage when standing in front of learners, be sure of what I am teaching them and to be prepared for any kind of questions they may ask me.
>
> **Participant #15**: I previously thought that teaching is all about a teacher supplying knowledge to his students but no I was wrong. Teaching is all about students and their teacher sharing ideas. I would start with the strategy of

> allowing students to tell me what they think they know about the lesson.
>
> **Participant #20**: What I like about this campus (referring to campus 1) is that the teacher asks an open-ended question that encouraged learners to think critically and to share their ideas. This way learners were shown to have much confidence to participate to share their knowledge with the teacher.

Again, these submissions demonstrate that student teachers are already identifying themselves with certain practices they feel are quite effective, particularly the constructivist view of learning. Being supportive to students and providing opportunities for learners to share ideas are some of the practices that have been found useful in existing research. For instance, Mukuka et al. (2023) concurs with Goos (2004) that learners should be provided with opportunities to share their reasoning with peers for them to engage with mathematics at a deeper and thought-provoking intellectual level. Allowing students to share their prior knowledge about a certain concept provides opportunities for a teacher to spot their misconceptions and ride on those misconceptions to provide the necessary support. Previous studies have established that prior knowledge not only benefits individual and collaborative learning in complicated tasks but also predicts students' curiosity and overall learning outcomes (Wade & Kidd, 2019; Zambrano et al., 2019). Student teachers' submission also reflect that teachers need to display complex ideas in simpler ways to convey deeper levels of comprehension among students. Providing opportunities for gifted students to share their knowledge with peers during cooperative group discussions benefits both the more knowledgeable and less knowledgeable students (Slavin, 2015).

In terms of the qualities of a teacher they desired to become in future, student teachers submitted that the ideal teacher of mathematics ought to be patient with learners, self-confident, caring, someone who uses appropriate language in class to suit the level of his/her learners, and someone who is caring. Commitment to duty and creativity were also mentioned as qualities of a good mathematics teacher.

Regarding the preferred teaching and learning environment, student teachers were of the view that availability of the necessary teaching and learning materials would enhance student learning outcomes. It was also indicated that the teacher's ability to utilize available resources also matters. Student teachers also desire to be that teacher who treats all learners equally without segregation especially in contexts with learners of differing aptitude, gender, race, and age, among others.

CONCLUSIONS & IMPLICATIONS

This study has implications for theory, practice, and policy. First, the study has shown that the heutagogical approach has the ability to motivate trainee teachers to investigate numerous cutting-edge approaches to teaching and learning mathematics. This will surely have a beneficial impact on their future professional goals since it opens the door to independent learning that lasts a lifetime (Ahiakpa et al., 2023; Blaschke & Hase, 2015; Lock et al., 2021). Consequently, teacher educators and teacher training institutions must give trainee teachers more opportunities to explore different options and identify or associate themselves with good teaching practices within the community if they are to develop essential teaching skills.

Second, this study emphasizes how critical it is for trainee teachers to acquire digital literacy skills, particularly in the age of the fourth industrial revolution, when technologies like cloud computing, artificial intelligence, and machine learning have become usual (Ahiakpa et al., 2023; Luneta, 2022a; Traore, 2021). The fact that many university students, including those from low-resource contexts, do own a smart phone is ample evidence that using mobile technologies (such smartphones) has made things easier (Chimpololo, 2021). This is true even though the limited availability to digital technology (Luneta, 2022b; Mukuka et al., 2021b) may have had an impact on the student teachers' virtual air campus visits.

Third, this study has shown that there were misconceptions among student teachers concerning some school mathematics ideas. This demonstrates clearly that if these trainee teachers' initial training did not address their preconceptions, they would return to the classroom with the same misconceptions. Due to this, numerous academics within the field have emphasized the importance of ensuring that prospective teachers have a solid understanding of the subject matter they will be expected to teach once they have obtained their teaching credentials (Bethell, 2016; Buchbinder & McCrone, 2020; Malambo et al., 2018; Venkat, 2019).

Despite all the advantages of student teachers visiting campuses virtually, we are mindful of the study's limitations. For instance, not all students were willing to participate in the study because it required some amount of resource sacrifice, especially for those who would have opted not to utilize the university computer lab. It is also important to keep in mind that giving students a high level of autonomy necessitates an elevated degree of maturity on their part because instructor influence is quite little. Additionally, adopting a heutagogical approach in most traditional learning environments may prove to be challenging due to the lack of resources and inadequate digital capabilities. Nonetheless, we stress the enduring relevance of heutagogy as a robust instructional approach, persisting

even beyond the pandemic. As teacher trainers, we ardently champion the need for these opportunities to enhance the educational path of student teachers. We strongly urge their integration as a valuable enhancement to the established "observation" module in teacher education programs. Furthermore, we implore fellow educators in other teacher training institutions and the mathematics research community to explore diverse avenues for integrating heutagogical methods into their mathematics teacher training programs.

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APPENDIX A: LINKS

The virtual "air campus" links given to student teachers are, as follows:

1. *Campus 1:* https://www.mathnic.org/tools/09_observing.html
2. *Campus 2:* https://www.insidemathematics.org/classroom-videos
3. *Campus 3:* https://www.bing.com/videos/search?q=School+mathematics+virtual+lessons&qpvt=School+mathematics+virtual+lessons&FORM=VDRE
4. *Campus 4:* https://www.cimt.org.uk/papers/lessonstudy.pdf
5. *Campus 5:* http://www.doe.mass.edu/edeval/resources/calibration/videos.html