

The PartoPen in Training and Clinical Use: *Two Preliminary Studies in Kenya*

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Keywords: Partograph : Digital Pen : ICTD : Health Informatics : Maternal Health

Abstract: This paper presents the findings from two studies of the PartoPen system – a digital pen software application that enhances the partograph, a paper-based labor-monitoring tool used extensively in developing regions. The PartoPen provides nurses with real-time decision support, instructions, and patient-specific reminders by playing short audio clips when a nurse records data on the existing paper partograph form. Previous studies have shown that correct use of the partograph significantly reduces pregnancy complications; however, the partograph is not always reliably or correctly completed due to resource and training challenges commonly found in developing world clinics. The PartoPen system addresses several significant barriers to correct partograph use in developing countries. The preliminary studies described in this paper examine how the PartoPen system affects classroom-based partograph training among nursing students at the University of Nairobi, and partograph completion and accuracy in actual labor and delivery situations by nurse-midwives at Kenyatta National Hospital in Nairobi, Kenya. The initial results of these studies indicate that using the PartoPen system enhances student performance on partograph worksheets, and that use of the PartoPen system in labor wards positively affects partograph completion rates and nurses' level of expertise using the partograph form.

1 INTRODUCTION

In 2010 the World Health Organization (WHO) estimated that 287,000 women die every year due to pregnancy related complications (WHO, 2010). The vast majority (99%) of annual maternal deaths occur in developing countries. Many of these deaths can be prevented with skilled care before, during, and after childbirth (WHO, 2010). In addition, the rate of maternal morbidities, which include fistula, uterine rupture and prolapse, and mental health concerns, is estimated to be between 15 and 20 million cases per year. Treatment for these complications, when available, costs an estimated \$6.8 billion per year (Stanton, 2010).

The WHO advocates the paper partograph as the single most effective tool for monitoring labor and reducing labor complications in developing countries. The partograph facilitates the tracking of maternal condition, fetal condition, and cervical dilation versus time during labor (Friedman, 1954). Used correctly, the partograph can serve as a tool for early detection of serious maternal and fetal

complications during labor. Early detection of pregnancy complications, especially in rural clinics, allows transport decisions to be made in time for a woman to reach a regional facility capable of performing emergency obstetric procedures. However, in order to be effective, the partograph must be used correctly. A recent study in Kenya reported that while 88.2% of the 1057 evaluated patient records contained a partograph, only 23.8% of the forms had been used correctly (Mugerwa et al. 2012). This is not unusual for developing countries where lack of training and continuing education, exacerbated by limited resources, represent serious barriers to effective partograph use (Lawn & Kerber, 2006; Levin, 2011; Lavender et al. 2011).

The goal of the PartoPen project is to increase the effectiveness of the partograph using an interactive digital pen with custom software, together with partograph forms printed with a background dot pattern that is recognized by the pen (Underwood 2011, Underwood et al. 2012). The digital pen uses internal handwriting recognition and paper-based location awareness to interpret the

measurements made on the partograph form. These interpreted measurements can then trigger alerts for attending health care providers when conditions arise that require additional observation or intervention. In addition, timers on the digital pen can be triggered when measurements are plotted in order to provide audio reminders to take routine patient measurements at specified time intervals. The PartoPen thus provides a low-cost, and intuitive solution that addresses several of the identified barriers to successful partograph use, including form complexity and data interpretation challenges.

This paper describes two preliminary studies that examined the PartoPen in use in Nairobi, Kenya from June 2012 – August 2012; the first was conducted with ninety-five third and fourth-year nursing students at the University of Nairobi School of Nursing Sciences, and the second, with nurse midwives in the labor wards of Kenyatta National Hospital (KNH) and Pumwani Maternity Hospital (PMH) over a period of one month. The principal findings of these two studies, reported in more detail below, are (1) the PartoPen improved the ability of nursing students to accurately complete partograph worksheets using synthetic maternal data, (2) use of the PartoPen during actual labor increases both the rate of partograph completion, and partograph accuracy, and (3) that the PartoPen was readily accepted and adopted by both students and practitioners.

2 RELATED WORK

There is a large body of research that examines the potential relationships between paper-based systems and digital tools, particularly mobile phones. Mobile phone tools have been designed to simplify data collection (Hartung et al. 2010), improve community health worker performance and effectiveness (Grameen Foundation, 2010; Parikh, 2005; Sherwani, 2007; Svoronos, 2010; Derenzi, 2008), and digitize data from paper forms (Dell et al, 2012; Ratan et al., 2010).

Digital pens offer the unique affordances of retaining the physical motion of natural writing, and simultaneous creation of a paper and digital record. Digital pens have been customized for context-specific research tools (Yeh et al., 2006; Cowan et al., 2011; Song et al., 2011; Landau et al., 2008) due to their programmability, portability, audio and note synchronization, and their ability to digitize sketches as well as handwritten notes for easy transmission via email. A specific example of how digital pens have been used in a healthcare setting is the

TraumaPen (Sarcevic, 2010). The TraumaPen integrates paper emergency patient intake forms with a digital display component in the exam room to reduce redundancy of verbal data transmission between health care practitioners.

Prior research on improving the paper partograph form includes the ePartogram device developed by Jhpiego (Jhpiego, 2011), and the partograph e-Learning tool created by the WHO (Mathai, 2010). Jhpiego is currently testing three ePartogram implementations, which include an Android tablet application, a digital clipboard system, and a custom hardware solution, but at this time, no data has been collected or analysed for any of these models. The WHO e-Learning tool is distributed to facilities like KNH via CD-ROM. However, the CD-ROMs are not given to every student or directly incorporated into the nursing curriculum. Single copies of the tool are often passed from student to student throughout the academic year, placing the primary responsibility for learning the material upon the students themselves. Less than half of the students who participated in the PartoPen study had used the eLearning tool.

To the best of our knowledge, the PartoPen system is the only standalone digital partograph solution that can be used interchangeably as a training tool *and* in active labor theaters without altering the currently paper-based system or requiring significant additional training for the technology itself.

3 THE PARTOPEN SYSTEM

The current implementation of the PartoPen system uses the Livescribe 2GB Echo digital pens, which can capture and synchronize audio and handwritten text, and digitize handwritten notes into searchable and printable PDF documents. These pens use an infrared camera in the tip of the pen that is triggered when a user presses the pen tip to a piece of paper. The camera captures a pre-printed unique dot pattern (see Figure 1) at a rate of 70 images per second.

Each printed dot contains location information, which the pen interprets and uses to perform location-specific functions, such as play an audio instruction prompt when an instruction button is tapped or trigger a decision-support prompt when a birth attendant plots a measurement indicating abnormal labor. The digital pens also include a speaker, a microphone, a 3.5mm audio headphone jack, up to 8GB of memory storage (approximately 800 hours of audio recording storage), an OLED display, a rechargeable lithium-ion battery, and a micro-USB connector for charging and data transfer

(Figure 2). Ink cartridges can be easily ordered and replaced.

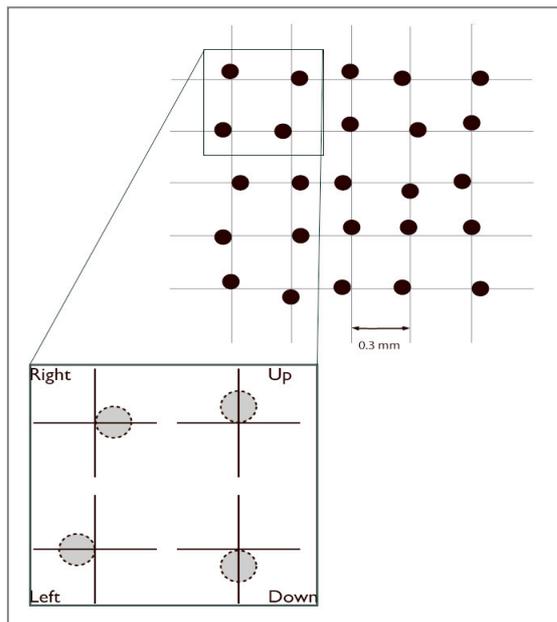


Figure 1. The Dot Positioning System (DPS) uses printed microdots, as seen above, arranged in specific patterns. The dot pattern allows the digital pen to determine where on the

The PartoPen provides partograph training instructions, task-oriented reminders, and context-specific audio feedback in real time. Tapping the pen in different areas on the partograph form provides audio instructions taken directly from the WHO partograph manual, which reinforces birth attendant training. The pen detects abnormal labor progression by analyzing data entered on the partograph form, and provides audio and text-based feedback to encourage birth-attendants to take appropriate action.



Figure 2. The digital pen used in the PartoPen system is depicted. The speaker, microphone, OLED display, USB connector, audio jack, memory storage, and replaceable ink tip are identified.

The PartoPen is appropriate for use in resource-challenged environments. It does not require network connectivity to operate, and uses a rechargeable lithium ion battery that can be charged using a standard cell phone charger. The dot pattern, printed on the partograph forms using a standard laser printer and printer paper, allows the pen to synchronize written text with recorded audio. Most importantly, the PartoPen is low cost, durable, consumes very little power, requires minimal training, and enhances – rather than replaces – the common paper tool in near-ubiquitous use in the developing world.

4 NURSING STUDENT STUDY

The nursing student study took place at the University of Nairobi (UoN) School of Nursing Sciences in Nairobi, Kenya. The university is closely affiliated with KNH, and the nursing students at UoN perform clinical rotations in the maternity wards at KNH. The goals of the nursing student study were to establish a baseline of common partograph errors based on the type of error (e.g., incorrect values, incorrect form location, or incorrect action based on entered data), determine if using the PartoPen decreases the number of common partograph errors in relation to the established baseline, and approximate the amount of training needed to use the PartoPen and access the majority of the built-in functionality.

4.1 Methodology

4.1.1 Participants

Ninety-five nursing students in their third and fourth years of study participated in the study. Local research assistants recruited participants from the population of 148 third and fourth year nursing students at the UoN. All students had previously been taught how to use the partograph to monitor labor during a 10-15 minutes in-class discussion as part of the nursing curriculum, and during their clinical rotations in the maternity wards.

The 95 student participants were separated by year (i.e., third or fourth year nursing students) and then randomly divided into three groups, resulting in six total groups. Group 1 was the control group, and Groups 2 and 3 were the intervention groups, which focused on the discoverability of the functionality, and the affect on partograph performance, respectively. Group 1 students completed a partograph worksheet task with a PartoPen in “silent logging mode,” and received no instructions on how

to use the technology. In the “silent logging mode” the digital pen records student answers, and logs when and where on the form student answers would have triggered feedback from a fully functional PartoPen. This control group provided a baseline for students’ performance on the partograph worksheet task.

Group 2 completed the same worksheet task, but used a fully functional PartoPen in “use” mode. The PartoPen software in “use” mode for the student pilot has two main components: instructions and decision support. For the nursing student study with nursing students completing a partograph worksheet, the reminders (enabled only for the maternity ward study) were disabled. In addition, playing pre-recorded spoken audio provided the decision support, in contrast to the maternity ward decision support, which was provided by scrolling text across the OLED display.

Group 2 received no training on how to use the technology. In “use” mode, the digital pen logs when errors are made on the form, which will be compared to the baseline results recorded from the first class of students. Students in this group will receive audio feedback from the pen when data is entered incorrectly on the form, and thus, corrected errors will also be recorded in this mode. The data collected from this group tested the discoverability and intuitiveness of the PartoPen functionality.

Group 3 received a fully functional PartoPen in “use” mode and a 15-minute introduction and demonstration of the PartoPen system before completing the partograph worksheet task. The digital pen will be recording errors, corrections, and all marks made on the partograph form. By comparing the results of Group 3 with the results of Group 2, researchers will determine the affect of providing a PartoPen tutorial on partograph performance. Groups 2 and 3 attempt to simulate PartoPen deployments in which students/nurses do

and do not receive training prior to using the device. Given that most of the PartoPen functionality is “pushed” to users just by normally completing a partograph form, researchers hypothesize that training on the PartoPen system should not significantly alter the results of participants with the same level of prior partograph knowledge – Groups 2 and 3 respectively.

4.1.2 Partograph Worksheet Grading

For all student groups, the partograph worksheets consisted of two patient case studies and two blank partograph forms printed with the dot pattern. The students were asked to record the patient data on the blank partograph forms as if they were actively monitoring that patient during labor.

The principal investigator created a grading scheme based on the partograph grading schemes currently used to evaluate nursing students during clinical rotations. Each measurement category on the partograph (e.g., fetal heart rate, contractions, pulse, etc.) was graded in five sub-categories out of a set number of points specific to the particular case study. The five sub-categories included “measurement present”, “mark accurate”, “correct symbol”, “plotted on correct time line”, and “correct spacing”. In the grading example shown in Figure 3, the partograph form sections are listed vertically in the far-left column, and the sub-categories and possible point totals run horizontally along the top of the spreadsheet. The cells that have been grayed-out represent categories that are not applicable to the specific case study.

Three research assistants graded all 95 worksheets according to the grading scheme described above, and each student was given an overall worksheet grade based on the total number of points possible for the two case studies they received.

	Marks are there? (possible)	Marks are accurate value? (possible)	Symbols correct? (possible)	Plotted on correct vertical line? (possible)	Spacing? (possible)
Patient Info	7	7	7	7	7
FH	9	9	9	9	8
Liquor	1	2	1	2	0
Moulding	0	2	0	2	0
Cervix	1	2	1	2	0
Descent	2	3	2	3	1
Time	1	5	0	5	0
Contractions	9	9	9	9	8
Oxytocin					
Drops/min					
Drugs given					
Pulse	9	9	9	9	8
BP	1	2	2	4	0
Temp	2	3	2	3	1
Protein	1	2	1	2	0
Acetone	1	2	1	2	0
Volume	1	2	1	2	0

Figure 3: An example of the grading spreadsheet used for grading the worksheets in the teaching and training study. Partograph form sections are listed vertically in the left hand column, grading sub-categories are listed horizontally across the top of the spreadsheet, and points possible for each category are listed in red. Grayed out cells indicate that these categories were not applicable to the case study being graded.

4.1.3 Focus Groups

After completing the worksheet task, 5-10 students from each group were randomly selected to participate in a focus group discussion. The goals of the focus group discussion were to gain an understanding of current partograph training programs used at the study site, determine students' perceptions about the partograph form as a labor monitoring tool, and to record students' perceptions of the PartoPen system as an in-class training and active labor monitoring tool. The focus group discussions took between 15 and 30 minutes, and student responses were audio recorded using a digital pen and later transcribed.

4.2 Preliminary Results

4.2.1 Quantitative Results

Using the grading scheme outlined in section 4.1.2, scores were calculated as a percentage of total points correct out of the total possible points. Researchers performed an unpaired t-test to determine any significant difference between groups, particularly if Groups 2 and 3 showed any improvement in performance over Group 1 – the control group. Due to time constraints and limited grading resources, only the data from fourth year students is presented here. Group 1 from year four, which used the PartoPen in silent logging mode to complete the worksheet had an average score of 58%, which means that on average students in this group correctly plotted 58% of the measurements from both case studies in the worksheet with the highest possible score being 100%. The average score for Group 2, which used the PartoPen in “use” mode but received no instructions, was 63%. And the average score for Group 3, which used the PartoPen in “use” mode and received instructions, was 66%. The difference in the average scores for the worksheet task suggest that use of and training on the PartoPen facilitated more accurate data recording on the partograph forms.

Table 1: Average scores on worksheet completion task for fourth year students divided by PartoPen functionality group number. This table illustrates an increase in student performance with increasing PartoPen functionality and training.

Group # and PartoPen Mode	Avg. Score
Group 1 – silent logging mode	58%
Group 2 – use mode, no training	63%
Group 3 – use mode, training	66%

In each worksheet, students received two patient case studies. All students received the “Mrs. B” case study, and either “Mrs. C” or “Mrs. A.” The three case studies represent three possible labor outcomes. Mrs. A’s data represents an uncomplicated, timely labor that progresses without medical intervention. Mrs. B’s data illustrates a case of prolonged or obstructed labor, which is addressed by the administration of oxytocin – a labor-inducing drug. Finally, Mrs. C’s labor progression data illustrates an increasing number of complications, including fetal distress, and ultimately results in a cesarean section. Thirty-four instructional audio prompts are available for all students and all patient case studies. However, only the Group 3 students were informed how to access the instruction prompts by tapping the pen on the text to the left of the graphs on the form. The average scores for each group based on patient case study are shown in Table 2. Using an unpaired t-test, the difference between Group 1 and Group 3 for the patient case study Mrs. C, was found to be significant (p-value = .0267). These data could suggest that for more challenging or complex labor cases, the availability and utilization of the instruction prompts promotes more accurate form completion.

Table 2: Average scores on worksheet completion task for fourth year students divided by patient case study and group number. This table illustrates a significant difference (p-value = .0267, between Group 1 and Group 3 for the most complex patient case study: Mrs. C.

	Mrs. A	Mrs. B	Mrs. C
Group 1	61.3%	58.6%	52.0%
Group 2	63.5%	62.9%	62.9%
Group 3	65.2%	62.7%	72.2%

4.2.2 Qualitative Results

Qualitative data from the focus groups examined three factors: students’ previous partograph training, students’ perceptions about the usefulness and effectiveness of the partograph as a labor monitoring tool, and students’ feedback on PartoPen usability.

Students explained that the in-class introduction of the partograph ranged from a 5-15 minute explanation by the lecturer. Lecturers reportedly demonstrated the partograph, but did not consistently fill one out completely in class. Students themselves did not practice filling out the partograph form. Students gained the majority of their experience using the partograph during their clinical rotations in the maternity wards. Individual experiences using the partograph in maternity wards fluctuated due to the number of nurses in the ward

available to facilitate partograph training and the number of patients per day in the ward requiring a partograph (i.e., in active labor).

Students expressed that recording the contractions is the most difficult part of the normal partograph form because of having to remember the different shading styles that indicate contraction duration. Students also experience challenges when plotting the descent of the fetal head, moulding, and liquor (i.e., amniotic fluid). All of the students who participated in the focus groups from Groups 2 and 3 expressed that the PartoPen significantly mitigated these challenges and made the difficult form sections easier to fill out. One student commented: “In a classroom setup, it would be good because it will really help when we are first learning [the partograph]. It solidifies the basic things we need to know.” Another student said: “At first, when you asked us what action to take when a measurement was made across the alert line, we were silent. But now, after we used it, we all know right away what to do.”

Students suggested several feature changes to improve the PartoPen for student use. The suggestions include modifying the form itself to make the boxes larger and thus easier for entering data into (the PartoPen system used the standard WHO partograph form), and developing a flexible instruction-creation platform so that instructions can be easily modified to keep up with changes to WHO and Kenya Ministry of Health protocols. Several students also voiced concern that one unintended consequence of the PartoPen might be a decrease in situational awareness, creating too great a reliance on the pen for instructions and decision support in an actual labor and delivery scenario. This was explored in the maternity ward study, and was not observed by researchers or stated by nurse participants.

The PartoPen study at the UoN suggests that using the PartoPen system in classrooms can improve students’ ability to correctly complete a partograph form. The study results also suggest that training on the PartoPen device does not significantly affect student performance on partograph completion tasks. The results of the teaching and training study support the hypothesis that a significant increase in partograph completion and accuracy can be achieved with little or no training on the device itself due to the intuitive design, push-based functionality, and enhancement – rather than replacement – of the current paper-based system.

5 MATERNITY WARD STUDY

The second PartoPen study took place at Kenyatta National Hospital (KNH) and Pumwani Maternity Hospital (PMH). The goals of this study were to evaluate the PartoPen for usability in labor wards, determine if PartoPen use impacts partograph completion, and to investigate the broader impacts of the PartoPen on patient care and maternal health outcomes.

5.1 Methodology

The maternity ward study evaluated partograph completion rates for the month immediately prior to the introduction of the PartoPen, and for the month when the PartoPen was in use. “Completion” was measured using a partograph completion rubric previously developed by KNH staff for hospital administrative purposes. According to this rubric, a complete partograph has measurements for all of the partograph form sections, and a complete labor summary. A research assistant scanned the 369 partograph forms completed in the month prior to PartoPen introduction. During the month of PartoPen use, 457 partograph forms were initiated.

There were three phases in the introduction of the PartoPen system at KNH and PMH: (1) training nurses how to use the PartoPen system, (2) introducing the PartoPen system for use during 2-3 shifts per day, and (3) establishing sustainable infrastructure and gradually reducing researcher supervision in the labor wards.

During the first phase, small groups of nurses received a 10-20 minute introduction to the project and were trained on how to effectively use the system during their shift. Nurses were given a demonstration of the PartoPen functionality to introduce them to features of the system (reminders, audio decision-support, and additional instruction access), as well as a brief tutorial on exchanging pens during shift changes.

In phase two, researchers introduced the PartoPen system in both KNH and PMH labor wards during the day shifts – approximately 7:30AM until 6:00PM. During the introduction week, the PartoPen functionality and the study design were adjusted to fit various environmental factors that had previously been unknown, such as modifying reminder sounds and text wording to account for noisy and busy environments, and simplifying the patient reminder ID system to allow nurses to create short, personalized identifiers for patients, rather than relying on the handwriting recognition in the pen to capture the patient’s full name.

Table 3: Survey questions that nurses were asked to answer after three weeks of using the PartoPen system.

Nurse Survey Questions
1) Before the PartoPen project, how would you rate your level of expertise using the partograph form (on a scale of 1 – 10)?
2) After the PartoPen project, how would you rate your level of expertise using the partograph form (on a scale of 1 – 10)?
3) On average , how many patients in active labor do you care for during one night shift? (Circle one of the ranges below)
4) On average , how many patients in active labor do you care for during one day shift? (Circle one of the ranges below)
5) Before the PartoPen project, for what percentage of your patients did you complete a partograph? (Circle one of the ranges below)
6) After the PartoPen project, for what percentage of your patients did you complete a partograph? (Circle one of the ranges below)
7) On a scale of 1 – 10 , rate your satisfaction with the PartoPen project in terms of usability (i.e., ease of use, functionality, instruction clarity, etc.)
8) On a scale of 1 – 10 , rate your satisfaction with the PartoPen project in terms of usefulness (i.e., level of patient care, level of job satisfaction, amount of time spent on tasks, etc.)

During the third phase, no changes were made to the code or the study design in order to keep study conditions consistent for data collection purposes. Quantitative data was collected using a back-end logging system on the digital pens, which was downloaded every day at the beginning of the morning shift. Data logged by the pens included the following time-stamped variables: when audio prompts were played, which audio prompts were played when measurements were made, how many times instruction buttons were tapped, when the partograph form was started and completed, and which pen completed the form. Qualitative observations were also recorded during the three weeks of PartoPen use.

At the end of the three-week use period, nurses were asked to complete a survey on their experience before and during the PartoPen project (see Table 3).

5.2 PartoPen Software Implementation

In the PartoPen implementations at KNH and PMH, half-hour and four-hour reminders were enabled and

activated by plotting a fetal heart rate measurement or a cervical dilation measurement, respectively. When a reminder would play, the patient’s name and the type of measurement needed would scroll five times across the OLED display.

Throughout the labor monitoring process, if a nurse plots a measurement indicating potential labor abnormality, the decision support functionality is activated, a sound is played, and text scrolls across the OLED display indicating the available options for the patient.

The number of audio instructions for the maternity ward implementation was reduced, because researchers discovered that nurses rarely used the audio instruction functionality, and the audio was unnecessarily taking up valuable space on the pen. The most common instance of nurses using the instruction buttons was to teach students doing their clinical rotations how to use the partograph. To better facilitate the process of nurses using the system to teach students, researchers added the full set of audio prompts back onto the pens during the first week of implementing the system in the labor wards. In the Appendix, the partograph that was used for the KNH maternity ward study is shown. The boxes (buttons) around the text on the left side of the form can be tapped repeatedly to access the use instructions mentioned above.

5.3 Preliminary Results

5.3.1 Quantitative Results

During the maternity ward study three types of quantitative data were collected: the 369 scored patient partographs collected prior to PartoPen introduction, scored patient partographs during the period of PartoPen use, and survey responses from nurses who had completed the three-week usage period. This paper focuses on the results of the surveys, as data analysis on the partograph forms is not yet complete.

After three weeks of using the PartoPen system consistently on every shift, nurses were asked to fill out a short survey that captured demographic information about the participant, and gathered before-and-after information about PartoPen use. The survey consisted of eight Likert scale questions, and six free-form response questions.

On average, nurses self-reported an improvement of +2, on a scale of 1 to 10, in partograph expertise during the PartoPen project, a 9 out of 10 for usability of the PartoPen, and a 9.2 out of 10 for usefulness. Nurses also reported that the number of partographs they completed during the PartoPen study was, on average, 25% more than they completed before the study. This increase in

partograph completion rates is supported by initial data analysis on the partograph forms, and by an internal report by the hospital administration. In addition to the functionality provided by the PartoPen, which encouraged higher rates of partograph completion, the general increase in conversation and interest in the partograph due to the PartoPen study was also a likely contributing factor to the improved partograph completion rates.

Overall, the quantitative data gathered from the surveys suggest an increase in partograph knowledge among nurses, an increase in the number of partographs completed, and strongly positive perceptions of the PartoPen's usability and usefulness.

5.3.2 Qualitative Observations

During the first week of the PartoPen implementation, researchers were present in the labor wards from 7:30AM until 6:00PM to answer questions, facilitate PartoPen handoffs during shift changes, and to observe usage of the PartoPens. The most significant observations fall into two categories: digital pen design and PartoPen functionality.

Digital Pen Design

The nurses emphasized the necessity of a functional cap for the pens to keep ink from getting on their uniforms. One nurse, after getting pen on her uniform, remarked "Here, take it back, I won't use it unless there is a cap - or I'll bring you my laundry!" Caps for the pens were distributed to the nurses, although the currently available cap for the Livescribe Echo pen was considered difficult to use. A makeshift lanyard system was created to allow nurses to wear the pens around their necks, but a shirt clip or similar way to attach the pen to a pocket would be preferred. Other pen design improvement suggestions included having different colors of ink available, and making the pen thinner and lighter.

PartoPen Functionality Observations & Changes

During the first week of the study (the implementation and training phase), researchers observed nurses getting reminders from the pen, shaking their heads, and dismissing the reminder. Upon further investigation, researchers realized that the reminders nurses were receiving were for patients who had already delivered or had received a cesarean section. New functionality was added to the PartoPen that enabled a reminder ID system and a reminder cancelation system. The reminder ID system (pictured in the Appendix under the

"Summary of Labor" section) was implemented to give nurses a way to create custom identifiers for patients that would scroll across the display when a reminder for that patient was triggered. Nurses write the identifier in one of the reminder ID boxes at the bottom of the form when a patient is admitted. The handwriting recognition engine in the pen interprets and stores this identifier and displays it for all future reminders for this patient. The reminder cancelation system addresses the issue of outstanding reminders for a patient that has already delivered or has been prescribed a cesarean section. A blue box at the top of the form (pictured in the Appendix in the top right-hand corner of the form) was created for nurses to sign their initials in once a patient has delivered or has been transferred for a cesarean section. The act of signing in the blue box cancels any existing reminders for that patient, and thus nurses will not receive unnecessary reminders.

The reminder and decision support functionality used in the maternity ward study relied on distinct pen tones and scrolling text on the pen. Nurses informed the researchers that while this implementation did reduce the distractions associated with long audio prompts, they were unable to look at the OLED display to see which patient needed an exam if they were in the middle of another delivery. The text displayed for both reminders and decision support prompts is only scrolled five times before the display returns to showing the current clock time. Several modifications could be made to address this problem including implementing a repeat button that will re-scroll the most recent text, continuing to scroll the text until the nurse uses the pen again, or implementing an audio based reminder system that uses an audio recording (made by the nurses themselves) of the patient's name, which is played back for that patient's reminders. The last solution is currently being developed, and will be tested in the next iteration of PartoPen studies.

Displaying the time on the OLED display on the pens proved to be one of the most important features of the PartoPen system. Because measurements and exams are time-based, and each observation is associated with the time it is taken, nurses often ask each other for the clock time. Nurses often use their mobile phones to get the time, but hospitals are increasingly restricting the use of personal phones during nurses' shifts to reduce distractions and increase nurses' involvement with the patients. Nurses therefore began using the PartoPen to determine the exact time measurements were taken, increasing the accuracy of recorded data.

6 CONCLUSIONS & FUTURE WORK

The preliminary results of the nursing student study indicate that student performance on a partograph worksheet completion task improves when using the fully functional PartoPen system. A significant finding of this study was that the PartoPen significantly improved student scores on the more complex patient case study, suggesting that reinforcement of existing knowledge, and real-time decision-making may be amplified and improved by using the PartoPen system. Based on the positive results from the student study at UoN, researchers are currently working with other Kenyan nursing schools to integrate the PartoPen into their existing nursing curricula. Additionally, the authors intend to examine how the PartoPen can be used to facilitate initial training on the partograph, and the transition from in-class partograph instruction to clinical use of the partograph form.

While the maternity ward study is on going, preliminary results suggest that using the PartoPen system increases partograph completion rates and increases nurses' accuracy when completing partographs. In addition, nurses were satisfied with both the usability and the usefulness of the PartoPen, suggesting that continued and sustainable use is possible in this environment.

After the three-week period of PartoPen use, twenty pens were left at KNH to continue being used by nurses in the labor wards. At the time of writing, these pens have been in use at KNH for a total of seven weeks, and data continues to be collected and analyzed by local researchers.

Future work on the PartoPen project will focus on expanding the number of study sites to include clinics at various levels of healthcare, including rural health clinics, dispensaries, and district level facilities. Future research will also expand on the nursing student study data described in this paper, and evaluating the impact of long-term PartoPen use in the classroom, and how this affects performance among students during clinical rotations and evaluations.

The next step in determining the impact of the PartoPen system is to expand the goals of the study from looking solely at completion rates to include how partograph completion (or incompleteness) affects patient outcomes. Currently researchers are collaborating with a larger maternal health project based at KNH to study the effects of PartoPen use on maternal and fetal outcomes.

ACKNOWLEDGEMENTS

This research is funded by a Gates Grand Challenge in Global Health grant, a National Science Foundation Graduate Research Fellowship, and by the ATLAS Institute at the University of Colorado Boulder. We would like to thank the leadership of KNH, PMH, and the UoN, particularly Dr. John Ong'ech and Dr. Grace Omoni, for their support and cooperation during the PartoPen studies, and all of the students, nurses, and staff who participated in the studies. Maya Appley, Addie Crawley, Sara Rosenblum, and Vincent Ochieng contributed significantly to this study.

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APPENDIX

PARTOGRAPH

Name: _____ Age: _____ Gravida: _____ Para: _____ IP No: _____

Date of admission: _____ Time of admission: _____ Ruptured membranes: _____ Hours on admission: _____

LABOUR PROGRESS

Y-axis: CERVICAL DILATATION (CM) PLOT A (0-10), Fetal Heart Rate (60-160), PULSE AND B.P. (60-120), TEMP RESP (36-42), URINE PROT ACT VOL

X-axis: Hours (0-24)

Phases: Latent Phase (0-8h), Active Phase (8-18h)

SUMMARY OF LABOUR

1st Stage: Induction labour: Yes/No, Duration: _____ Hrs, No. of VE: _____

2nd Stage: Mode of delivery: _____, Duration: _____ Mins, Oxytocin/Egometrine: Yes/No, IV/M: _____

3rd Stage: Baby Alive/SB: M/F, Apgarscore 1 Min: _____ 5Min: _____, Resuscitation: Yes/No, Duration: _____ Mins

Placenta complete/incomplete, Membranes complete/incomplete, Cord normal/Abnormal, Placenta Wt: _____

Blood loss: _____ Mls, Perineal tear/Episiotomy: Repair: Yes/No, Mother BP: _____ Pulse: _____ Temp: _____ Resp: _____

Baby Length: _____ Weight: _____ Gm, HC: _____ Cm, Drugs given: _____

Delivered by: _____ Time and Date of Delivery: _____

PartoPen Reminder IDs: _____