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Moving Parallel and Transversal Lines with Touches on Smartphones: A Look through Screenrecording

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Abstract: This article illustrates how videos generated through capturing touches on screens (screenrecording) can assist in analyses related to manipulation and reasoning by primary education learners in solving geometry tasks. We are presenting two protocols as ways to elucidate the use of application *AZ Screen Recorder* in learning about parallel lines intersected by a transversal line. In the first protocol, the interactions and the ways adopted by the subjects when analyzing the relation between corresponding angles are highlighted. In the second protocol, the relevant aspects are related to the particularities of the atmosphere of dynamic geometry used and the strategies adopted by the learners in the study of corresponding angles and collateral internal angles. The screen recording allowed us to (re)view the students' touches in two simultaneous sources (audio and interactions on screen), using the same application. The analyses point to the fact that screenrecording made it possible to identify interactions on screen, especially through synchronicity, which contributed to track learning processes and to reformulate a research planning.

Keywords: Interactions; Mobile device; Touchscreen; Screenrecorder; Contributions.

Introduction

Brazilian production in mathematics education with Digital Technologies has concentrated on research in five main fields: involving humans among them, and with their extensions and physical resources; reorganizing mathematical thinking, collaborative thinking and integrating resources of information and communication technologies; developing various digital resources; teacher training and digital technologies for cyber education; and the integration of mobile devices with touchscreen (MDwT) – smartphones and tablets – in the teaching and learning processes (Rosa, Bairral, Gitirana, & Borba, 2018).

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Although there is already a research agenda in Brazil on MDwT to analyze epistemic changes (Assis & Bairral, 2019), and/or changes of cognitive and didactic nature (Bairral & Carvalho, 2019; M. A. Bairral & Henrique, 2020), we have also seen studies focused on epistemic and epistemological implications at an international level (Arzarello, Bairral, & Dané, 2014; Sinclair & de Freitas, 2014). Still, those studies still have a predominant didactic outlook, or partake of a more cognitive nature (Calder, Larkin, & Sinclair, 2018). From a didactic point of view, they include outlooks on the way teachers communicate with their students when mobile devices come into play (Chao, Murray, & Star, 2016).

This article is the result of a research project[4] interested in the ways of manipulation of tablets and smartphones, and how the ways of manipulation can enrich cognition and multimodality of communication in geometry using touchscreen devices. We are presenting results that foster the use of mobile devices with touchscreen in the production of data in research on mathematics education. Specifically, we are illustrating how the video generated through the capture of touches on screen can be of help in the analyses regarding ways and manipulations done by primary education learners when solving tasks on parallel lines intercepted by a transversal line. The challenge in each instance is to show what happens behind the scenes, or the screens, as is the case.

MDwT, embodied cognition and touching domains

All technological evolution modifies the way in which we interact and learn (Borba & Villarreal, 2005). Humans, environment and technologies live in constant synergy (Moore-Russo & Viglietti, 2014). The architecture of new learning environments and their different mediating artifacts (tasks, pictorial resources, gestures, speech, touchscreen devices) contribute to the construction of mathematic concepts. When people communicate over objects and relationships, these objects and relationships get dynamic through different representations and varied ways of writing, orality and gestures (Bairral & Powell, 2015). Furthermore, educational decision taking has to be based on real learners' learning in their actual training environment from constant revisiting and refinements of knowledge in a phase of construction (Visnovska & Cobb, 2013).

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Just as humans develop with the advancement of technologies, technologies also recreate themselves with humans and, in this symbiosis; they transform their way to interact, to exist and to constitute themselves in the world. The touchscreen devices, interfaces that expand our memory and the physical dimension of our bodies, are also transforming our cognition and our ways to interact and to communicate[5]. In the semiotic package (Arzarello, Paola, Robutti, & Sabena, 2009), the different kinds of touches (simple, double, drag, zoom, etc.) directly on the screen, screen touching on, with and from the screen arise as one more way of the materialization of mathematics thinking of the subject (Bairral, 2020).

Mobile devices, such as smartphones and tablets, constitute a physical extension of our bodies (Bairral, 2020) and, as such, reassess our ways to think and interact (Arzarello et al., 2014; Borba & Villarreal, 2005). We understand that such devices are part of the process and they cannot be conceived as mere resources that help teaching, as they also alter the process in which knowledge is built (Bairral, 2020). Therefore, a mobile device is a part of the learning scenario, which modifies the ways of thinking and decision taking in both the proposal and the resolution of a task.

Smartphones and tablets have brought about possibilities of change to the teaching and learning processes. They can also contribute to research, specially enhancing the ways in which data are obtained and analyzed. Brazilian research in mathematics education using digital technologies as a source of analysis still lacks innovating and systematic ways in the creation of data collecting procedures in which the technology itself is used as support, especially because touches on screen belong to a new field of bodily cognition (Bairral, 2019).

Touches on the screen can be like a gathering of inputs and outputs that make it possible to have synchronic responses on the device screen (Arzarello et al., 2014). Touchscreen also occurs as the result of simulated action and sensory perception, which are the bases of mental imagery and language production (Hostetteer & Alibali, 2008). As for the performance, i.e., the speed of the response from the device, when we execute manipulations on MDwT only as touches on screen, it

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[5] Whenever the word “communication” appears in this paper, it should be read as *commognition*, that is, a phenomenon that combines both individual cognition and interpersonal communication (Sfard, 2008).

depends on three factors (Bairral, 2020): space, that is the area on which the touch is being performed or can be performed; sustained action of movement, with possible combinations of different types of touches; and simultaneous movement of several elements on the screen (Assis; Bairral, 2019).

According to M. Bairral, Arzarello, and Assis (2017), and Assis (2020), cognitive processes with dynamic geometric devices with touchscreen could be seen in two interrelated domains of handling: constructive and relational. In a constructive domain, students basically refer to tap and hold which are the basic or isolated ways of constructing geometric objects (point, line, circle, shape, etc.) with a touch interface. The relational domain is a combination of this construction and the performed touchscreen that includes drag (free or to approach), flick, free or rotate. Even though in the relational domain students also construct geometric objects, it is in this particular realm where they show more interacting and reflecting about the construction. In the relational domain the drag-approach appears as a powerful way of touchscreen improving geometric thinking. In this type of touch, students can use one or more than one finger.

While in the construction domain students act as discrete observers (focused on some specific construction or constructed object or even doing some touch on the screen) in the relational realm their touches seemed more focused on their questioning, conceptual understanding and other emerging demands concerning their touchscreen as a whole construction. Touches on the constructive domain seem focused on only predetermined motions, although motion through relational touchscreen provides motion open in a sense that they can generate more unpredictable processes. In both domains, touches are not simple acts upon geometric objects, they express reasoning strategies and they move dialectically in both domains.

In the same way that simultaneous touches of points on the screen bring about implications of an epistemological order, it also makes our cognitive structures more complex, for example, through the simultaneous motion of various elements (e.g., angles, sides, area, etc.) in a figure. Let's see what happens when we deal with concepts related with parallel lines intersected by a transversal.

Video data analysis in research on learning development

Doing research is not an isolated collection of actions and predetermined interpretations rigidly united by a list of procedures built in advance. Nor is it a neutral activity. Producing knowledge through multiple forms of data collection fosters new methods to evaluate aspects in the reasoning of subjects.

The use of (conventional) filming as an integral part of methodological procedures in teaching experiments is permeated by technical and human interests: the ideal amount of cameras to be used, the need for assessment concerning the shooting of the film, analyses procedures, need for transcriptions, adequate focus, adequate selection of technologies, etc., as pointed out by Derry et al., (2010) and Powell, Francisco, & Maher, (2003). Powell & Silva (2015, p. 27), point out that "[...] video recording enables the observation not only of the evolution of individual psychological processes, but also of classroom contexts". The authors underline that video recording makes it possible to revisit and identify different situations that can contribute to the analysis of the mutation of individuals' discourse, possible interactions and bodily manifestations. Powell et al., (2003) observe that the recording on video allows for a revisiting of the didactic situations which, when being reviewed, can generate insights that contribute to a deeper analysis, for instance, regarding some aspects that influence the mathematics learning, the process of construction of meaning, argumentations and suggestions of demonstrations imbued in the subjects' discourse.

According to Bottorff (1994), videorecording allows for density (different registers of the data recorded by the filming camera) and permanence (revisiting the same episode several times, enabling different, more detailed analyses). Nowadays, smartphones and tablets have broadened possibilities for research in mathematics education by enabling the recording (video, sounds, images) moment after moment of the same phenomenon. This observation combined to the fact that the production of data on video allows the recording of several combined elements, as, for instance, image and audio, that can be associated during the process of analysis and identifying different situations that can contribute to the analysis of the changes in the discourse of the individuals, possible interactions and body expressions (Powell & Silva, 2015), may mean one more tool available to the researcher.

Researching is a creative, prospective action of collective learning, which goes far beyond acts following a list of procedures or attempting the confirmation of objectives validated beforehand and foreseen results. In our research project it is not just the company of the device that we are considering, but the whole process encompassing the preparation, the data gathering, the analysis, the relation of researcher-teachers-learners that our research team is going through.

In our design-based research, the process of elaboration and refinement of tasks is dynamic, prospective and cyclic, thus, the realization of adjustments and experiments is always necessary (Cobb et al., 2003). From Bottorff (1994), Derry et al. (2010) and Powell et al. (2003), chart 1 sums up the theoretical contributions that we grab hold of for the use of the screen recording and, from them, we weave contributions and particularities of this new way to produce data in research.

The term screenrecorder or screenrecording refers to the recording on a single file generated by a recording program set within the device itself, namely a smartphone or tablet, which captures a whole set of synchronic tracks: video, audio, touches on screen, some of them external –in the case of a camera focusing the user's hand movements and gestures –and some internal –in the case of a video generated from the movements performed on the screen of a touchscreen device (smartphone/tablet) involved in the activity (Chart 4, Figure 3).

Our research questions: What contributions do screen recordings bring to the production of data in mathematics education research? Particularly, how does the capturing of touches on screens help the analysis of the resolution of tasks on parallel lines intercepted by a transversal line?		
Challenges DERRY et al. (2010, p. 6)	**An important strategy for data analysis: critical events**	**Particularities and potential sources for research**
Selection. How does a researcher decide which elements of a complex environment should be recorded, or which aspects of an extensive video corpus should be sampled for further examination?	We say an event is critical when it shows a significant or contrasting change in relation to a previous comprehension, a conceptual leap in relation to some previous conception. Contrasting	**Density** allows the monitoring of simultaneous details, different from the developing behaviors. Screen recording captures, in real time, two flows of data: audio and visual.
Analysis. What analytical		

frameworks and practices are available, and which of these are scientifically valid and appropriate for given research problems?	meaningful /significant moments can be events that confirm or contradict research hypotheses. They can be cognitive victories, conflicting schemas or naïve generalizations. A critical event can also be any event that is somehow meaningful to the agenda of the research.	**Permanence** enables different observers to register behaviors in comparable ways. With videotapes, researchers can (re)view recorded events as often as they need and in flexible ways (real time, slow motion, one take at a time, forwards, backwards) and they can build and consolidate their interpretations.
Technology. What technological tools are available and which social tools must be developed and disseminated to support collecting, archiving, analyzing, reporting, and collaboratively sharing video?		
Ethics. How can research protocols encourage broad video sharing and reuse while adequately protecting the rights of the human subjects who are represented in such recordings?		

Chart 1: Research questions and theoretical basis for screen recording

As Derry et al. (2010), p.6), we hope our efforts not only inform researchers and funding agencies associated with the learning related sciences, but also encourage and facilitate data sharing and collaboration for knowledge building across projects, as well as speeding the learning curve for new researchers, and helping ensure that time, effort, and scarce resources are spent wisely.

In design based research focused on learning or instruction we may conduct teaching experiments. These types of design experiments have both a pragmatic bend — "engineering" particular forms of learning—and a theoretical orientation—developing domain specific theories by systematically studying those forms of learning and the means of supporting them (Cobb et al., 2003, p. 9).

The design of the experiments

The teaching experiments described in this article took place in the second author's classes in the years 2016 to 2018[6]. The total didactic sequence (using GeoGebra software or APP) comprised twenty tasks (Henrique & Bairral, 2019a). The two activities illustrated in this article completed 200 minutes (four 50 minute lessons). Our focus here is on the screenrecording with the aim to inventory the particularities in this process in relation to conventional filming. We are highlighting elements that pertain to both filming processes, conventional and screenrecording, since filming with a camera on a tripod, as shown in the picture below, is also an element that orients our work.

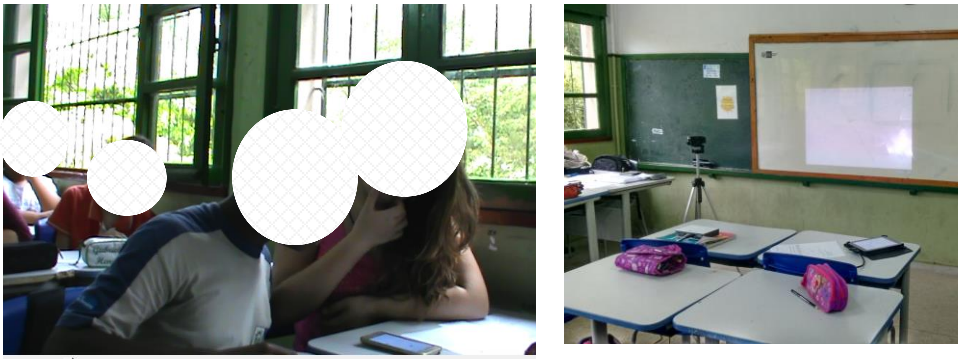


Figure 1: Conventional filming during protocol 1 for data production.
Source: Author's own

The information in each protocol with time spent on each intervention, critical event in each video, geometric relation studied and main sources for data collection are specified in Chart 2.

Protocol	Learners	Critical Event (time / video stretch)	Geometric Objectives	Device	Main Sources for Data Gathering
Protocol 1 (100 min)	E1 (13 years old) and E2 (14 years old)	09:40 – 11:10	Build and identify the relation between corresponding	GeoGebra APP	- AZ Screen Recorder[7], set in Android devices (Screen

[6] All the involved pupils' guardians authorize the pupils' participation and have signed corresponding terms of consent based on the view of the UFRRJ, process 23083.003202/2015-21.
[7] Available at: https://play.google.com/store/apps/details?id=com.hecorat.screenrecorder.free&hl=pt_BR. Access: March15 2020.

			angles		Capturing) -Conventional Film[8] shooting
Protocol 2 (100 min)	E3 (12 years old) and E4 (13 years old)	17minutes and 46 seconds	Discuss about the relation between angles (corresponding and collateral) on the same side in relation to the transversal straight line		-AZ Screen Recorder

Chart 2: Summary of protocols.
Source: Authors' own making.

Besides the instruments presented in Chart 2, triangulation was complemented with the researcher's field diary, application Evernote[9], written answer from learners, screen print.

We are illustrating two protocols of analysis in tasks performed with the GeoGebra application, set in the smartphones of pupils in their 8th year of Primary school, aged between 12 and 16. The first task (protocol 1) was proposed during the school year of 2016 and the second (protocol 2) during 2018. In Table 3 we are showing a summary of the tasks.

Task of protocol 1

1. Construct two parallel lines.

1.2. Construct one straight line transversal to the parallel lines.

1.3. With the selected tool **Angle** construct the eight angles that can be formed from the parallel lines with their transversal line.

1.4. Move freely, first the transversal line, and then the parallel lines.

1.5. What relations are there between the possible combinations of pairs of angles?

Task of protocol 2

[8] Process performed by means of a film camera with a tripod for the production of a video with audio (Figure 1b).

[9] Software with versions Application and Web, destined to the organization of personal information through notes, with the possibility to attach images, audios and videos. Available at: https://evernote.com/intl/pt-br/. Link tested on: July 2. 2020.

2. Research other relations between the pairs of angles that can be formed. As always, register your remarks and if necessary, make a drawing in order to clarify your discoveries. When you are done, print out and save the construction.

Chart 3: Summary of proposed tasks.
Source: Henrique & Bairral, 2019b

Let's see now the two situations listed in this article and some theoretical and cognitive considerations about them.

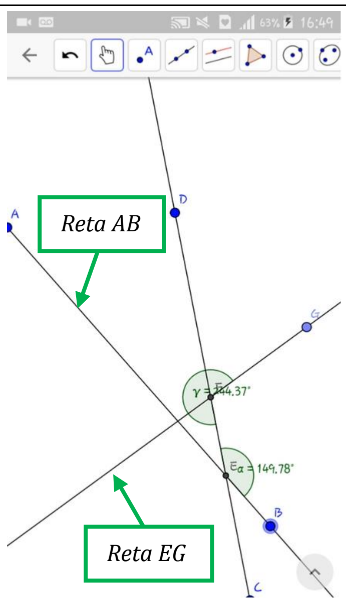
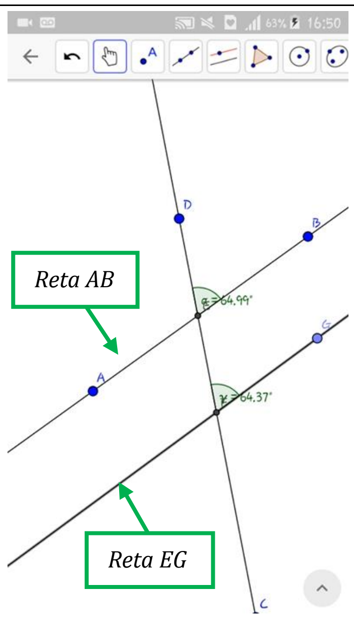
Protocol 1: Screenrecording paths in the analysis of relations between straight lines and angles.

For our analysis, we selected an event in the video (09:40 – 11:10) obtained from the capture of smartphone screen used by students E1 (13 years old) and E2 (14 years old). Table 4 portrays the actions of learners in their attempt to build and identify the relation between corresponding angles.

<table>
<tr><th colspan="2">Screen Print</th><th>Transcription</th></tr>
<tr><td>Instant: 10:00</td><td>Instant:10:32</td><td rowspan="2">10:13 – E2: we have to get sixty four. Lower, lower, down! A bit, there... thirty seven. Oh! No!

E1: Way too far!

E2: Go back! Thirty four. Oh!

10:32 – E2: Ninety nine.</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td colspan="2">Learners 1 and 2 moving and modifying a construction, aiming to identify the relation between corresponding angles.</td><td></td></tr>
</table>

Description

Chart 4: Students'actions while analyzing corresponding angles.
Source: Authors'own making.

The screenrecording of the learners' interaction fostered the identification of the paths they followed while attempting to build the angles corresponding and conjecturing. In a first moment, it was possible to perceive that the learners did not use the icon "straight parallel lines" from GeoGebra. With this, as the construction is modified the angles assume different values, and straight lines AB and EG are not parallel. It was also possible to infer the procedures adopted by the pair of learners.

We observed that they performed a contrary movement to establish a relation, that is, they tried to position the straight lines in a way that the corresponding angles would keep the same measures in order to guarantee that straight lines AB and EG would keep parallel. This fact can be confirmed through the transcription of the learners' speech from the moment the learners are trying to equal the decimal section of the values of the angles (chart 4, time 10:32)

We examined the actions performed by the learners through the interactions captured by screenrecording. This involved touches on screen, dialogues, a complicity between the learners when analyzing and manipulating geometric objects under study (parallelism of straight lines and congruence of corresponding angles). This reviewing was done thanks to putting together the recording of screen and audio. In this conjunction (screenshot + screenrecording + audio) it was possible to endorse the learners' looking for the equality of the angles from the initial adjustment of straight lines AB and EG, so that they would be parallel. Finally, we considered the position of straight lines and the congruence of the two corresponding angles in the analysis.

Protocol 2: Screenrecording paths in the analysis of collateral angles by dragging a straight line and making them supplementary

For the analysis of this activity, we selected events from a 17 minute 46 second long video obtained from screenrecording used by learners E3 (12 years old) and E4 (13 years old). In these excerpts, the learners discuss the relationship of the angles which are on the same side of the transversal line (corresponding and collateral) and the properties involved (congruent or supplementary). In Chart 5 we are presenting the registers obtained.

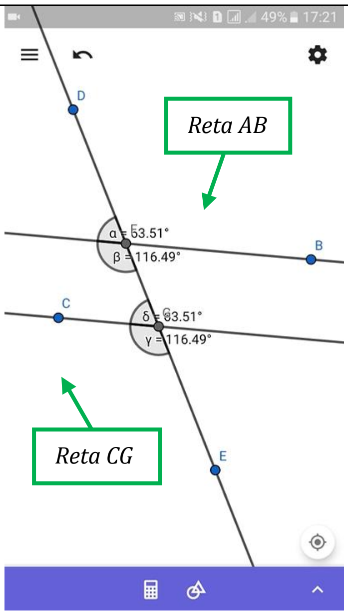
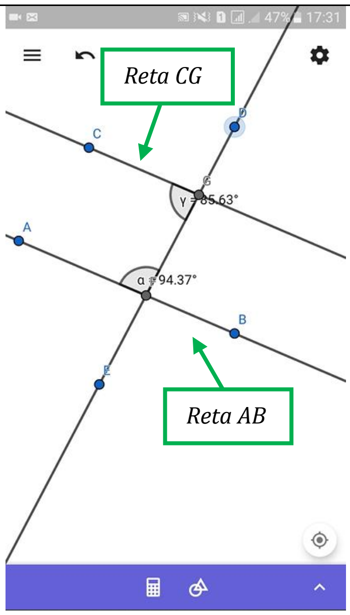
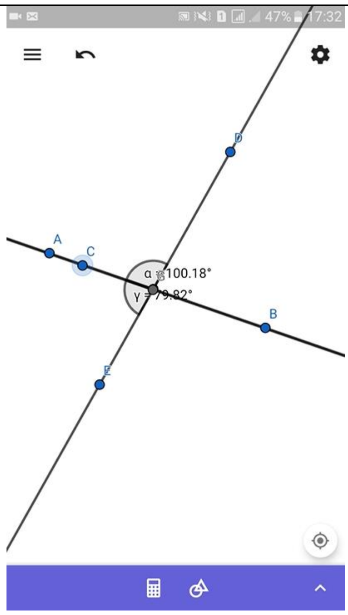
<table>
<tr><th colspan="3">Screen Prints</th></tr>
<tr><td>Instant: 16:25</td><td>Instant: 17:15</td><td>Instant:17:29</td></tr>
<tr><td>
</td><td>
</td><td>
</td></tr>
<tr><th colspan="3">Description</th></tr>
<tr><td colspan="3">Learners E3 and E4 talking about the relations between the angles.</td></tr>
</table>

Chart 5: Screens generated from screenrecording
Source: Authors' own making.

Through the screenrecording, we observed that the learners established a relation between corresponding angles from the congruence (instant 16:25, angle α = 53.51° and angle δ = 53.51°) and they used the possibility to drag with a double function: procedure and conjecture. Their first dragging action aimed to facilitate the analysis, and they therefore swapped lines CG and AB, which caused only straight lines and internal collateral angles to remain on the screen (instant 17:15, angles α and γ), and moved straight line CG in order for α and γ to become supplementary.

This dragging movement generated a new construction in which only the objects of analysis were present. In this way, corresponding to the second function attributed to the dragging, the learners formulated a conjecture about the relation between the angles (instant 17:29, anglesα and γ). Relating to this part of the episode, a brief dialogue preceding instant 17:15 helped us with the inference. E3 asks E4 about which angle is being taken as reference: “Is it AFD?” (angle α) and E4 declares: “I am using the straight line above as an example”, meaning that they are keeping straight line AB fixed, which includes angle α, and that they are moving CG in order to verify the relationship between the angles.

The learners could have established a conjecture through arithmetic analysis, adding angles α and γ in the field “Entry” in GeoGebra application. Nevertheless, it was from the screenrecording that we identified that the learners had borrowed a trait of a MDwT, in which the action of dragging involves some different purposes, such as formulating and validating conjectures, in order to establish a relation between α and γ, dragging the parallel lines, making them supplementary, that is, they established a visual conjecture to meet their purpose, which is a type of reasoning pertaining to the relational realm.

Results

The researcher’s interest will determine which events and which timescales a study should select (Derry et al., 2010). An appropriate selection strategy in this case might consist of identifying important critical events (Powell et al., 2003) related with the specific focus of the research. In a conventional recording, the identification and analysis of a critical event together with the density and the permanence allow for the detailed study of strategies adopted by the subjects in the resolution of a task. Nevertheless, such strategies alone may not be enough to analyze the solving of a mathematical task with a MDwT. The touches on screen, the gestures combined with the audio and other records allow us to re-build the paths followed by the learners in a net of information better articulated, chronologically.

Screenrecording differ from traditional filming in that they allow for the mapping of strategies and chronological follow up and articulation of the ways adopted in solving a task. This process, which we call synchronicity is the analytical process in which we can observe, in an articulate way, the various forms of communication (touches on screen, audio, constructions and manipulations on a figure, for example) and the simultaneous movements and manipulations of geometric objects (either in construction or under analysis) on the device. In this synchronic semiotic package (Arzarello et al.,

2009) it is possible to perceive the learners' representing and understanding the geometric object under study in more articulated and stable ways.

Synchronicity is also one more strategy to perceive the learners' reasoning on the movements between constructive and relational fields. Although GeoGebra App does not allow the construction by multitouches, it was through synchronicity that we could observe a shared action by the learners in simultaneous touches on screen.

Figure 2: Learners communicating to solve the task.
Source: Author's own making

The set of actions composed of gestures and other elements that we call screen capturing is done through a recording external (Figures 2 and 3) to the device which focuses on the touches on the screen and gestures. Nevertheless, in both protocols analyzed we articulated both capture of the screen and audio.

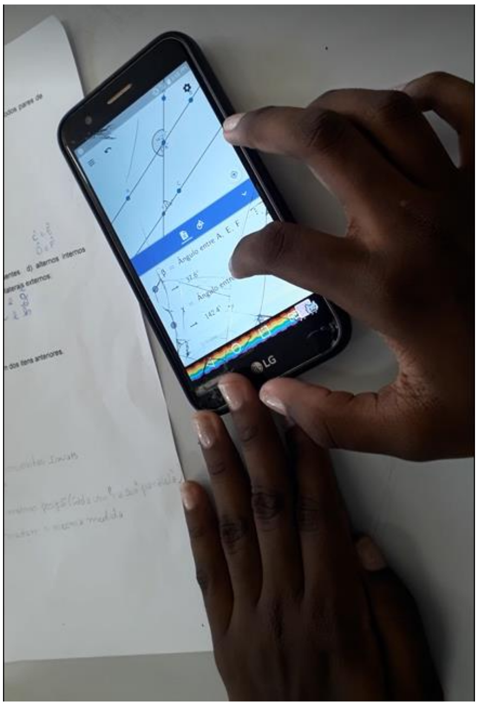


Figure 3: Recording gestures during the performance of an activity
Source: Author's own making

It is not our intention to point out that this process is better than the conventional one, but rather to stress the fact that its insertion into other procedures of data gathering can broaden possibilities for analysis. It is with this in mind that we present "singularities of each procedure":

- Cloud storage enables online and synchronous analysis
- Association with annotation applications that enables the storage images, audio, videos and text, Evernote, for example
- Captures details of hand gestures as synchronicity of movements
- Detailed identification of strategies adopted in the process of construction of the mathematical object and task solving
- Detailed look at an event with the communicative enrichment, besides talk and of gestures, touches and other handling on the Screen
- Allows the density and the permanence of gestures and dialogues of the subjects through direct handling of the geometric object
- Allows to observe more articulate and "stable" representational variation of movements
- Possibility of sharing and editing

- Allows the identification of the multiplicity and synchronicity of touches in a constructive or relational environment, and
- The students can generate and analyze their videos, expanding their discoveries by revisiting their videos.

Contrary to the research by Powell et al. (2003), who had a technical support for their filming, in our case it was the teacher on his own who organized the class for the filming and the screenrecording. The teacher had to rely on the help from learners, who recorded on their own cellphones and shared with the teacher at the end of each class. This is not the best in terms of technical or human organization. It would be advisable for at least one professional to help with the equipment, and the teacher would then be more available to pay attention to the learners in their task solving. But we had to make do with what we had, and it was what we could do. And we are grateful to count on the fact that screenrecording demands less equipment and human resource logistics.

Through screenrecording, it is possible to identify touches on screen, which suggests a cognitive-discursive conjunction of geometric objects with a dynamic of movements more detailed in terms of time and synchrony, which is not always possible with conventional recordings, where the generation of a video from external filming may not make it possible to observe the synchronicity and discursive integration, in addition to ascertain that the subjects did indeed perform every one of the particular manipulations or touches that they did. Capturing the screen with the Application set in each of the devices minimizes the missing out of details like gestures and touches on screen as well as facial expressions).

Regarding the recording with a conventional camera, usually fixed on a tripod, positioned so that it records the performance of the group, losses may occur in case a filming crewmember fails to focus on something significant. It is convenient to pay attention to the matter of storing capacity of the recording device (camera/smartphone), as there may be a loss of the recording. Another factor to be taken into account is the audio, of higher quality in screenrecording, as compared to conventional cameras, as learners are closer to the microphone when using the smartphone. Certainly, some of these problems may be overcome through the acquisition of professional sophisticated equipment for the capture of image and audio, but the idea for us is to share the possibilities of using applications that can be set free of charge in any device, when stressing the relevance of capturing touches on screens.

According to Henrique & Bairral (2019) the teaching experiments turned out to be stimulating, as it allowed students –through different ways of communication – an articulated observation of a set of elements (measurement or addition of angles, position of lines, etc.) and together with the handling of the DGE, the varied exploration of the construction of straight lines. The way in which the contents were approached enabled the students to have a wider vision of properties, as compared with learning without the use of smartphones. It is up to the teacher to reflect on whether to give priority to an excessive use of the naming jargon (adjacent, internal alternate, corresponding angles, etc.), which may complicate the process, or to aim valuing the understanding of identification and relation between angles and related properties. Based on this rich exploring process we defend instruction concerning parallel lines intersected by a transversal for favoring focus on angles relation and properties among the concepts and focusing less on memorizing names (corresponding angles, opposite by vertex etc.).The simultaneous analysis of several elements (angles, lines, intersections, etc.) and the need to take reference (line, angles and side) into account constitute a vast and stimulating field of geometrical exploration to widen the visual and representational range of geometrical objects. Therefore, it is important that the learners pay special attention to geometrical objects and relations that they aim to analyze. The mediation of the teacher is important, as the teacher can take on the functions of an observer and a constant propeller of ideas and interlocution with the learners.

The use of video recording may not be sufficient to analyze the development of geometric learning on MDwT, as it does not allow an analysis in minute detail of the constructions on the device, touches on screen and other handlings. In our experience, the possibility of putting together both sets of data (audio and touching) allowed us the reconstruction of the scenario for the research aiming the detailed look of strategies used by learners. Besides capturing the audio, the device enables to pause the recording and also offers resources for the edition of the generated video. The screenrecording allowed observing this joint variety of movements, to situate them chronologically in the development of the learning process, to allow the researchers to associate the movement to the type of screen touching, and even seeing whether it was an individual or a shared action.

Final remarks

Our research stresses the fact that mathematical thinking keeps developing –situated, integrated and in a synchronic way- with touches on screen, with gestures, with written or pictorial records, with remarks or constructions on screen, etc.. There cannot be a hierarchy in this communicative synchronicity. Although written records may be important in reviewing and reorganizing ideas, all forms should be seen as protagonists and equally important. According to the specificity of the interactive moment and the particularity of the geometric object that is analyzed, there may be one more convenient way to manifest discourse than another. In other words, there are moments when a drawing proves to be more convenient than a written justification and vice-versa.

This article promotes reflections on possibilities for the researchers in the synchronic refinement of their production of data. In a conventional film recording with a camera focused on the surface of the device, there is the possibility to register moments of interactions with, over, and on screen, although it is not always possible to identify interactions on screen and identify the elements in a specific construction that have been manipulated. Also, we cannot stress enough that the precision of devices, through filming with a camera, does not always seem to indicate the exact location of contact and selection, which is possible to identify through screenrecording. It is not a matter of passing judgment or hierarchy on the means to collect data, but the researcher needs to have a clear idea of what it is possible to achieve with each of the resources that are available.

In conventional filming there is the need for a big paraphernalia (tripods, cameras, etc.) and important human resources, besides the organization of space in order for the equipment to be available. In addition, if all the students (or groups) are not filmed, it is important to decide who is going to be filmed. If all the groups are going to be recorded, part of the room will have to be spared to allow for this.

Screenrecording also reduces the number of researchers needed, since the device itself records and the teacher has more freedom to circulate. Nevertheless, there is no doubt that it is important to have one more professional in the research environment, particularly with those of our projects which take place in the natural environment of the classroom.

The capture of the touch on the screen, drag, turn and speech intonation are examples of elements that can provide clues as to the underlying ability to observe and analyze possible task resolution patterns. It is worth emphasizing that this procedure is not characterized as something prescriptive, but can contribute to the customization of the task, either by inserting new resources or redesigning the task with other software, for example (Assis, 2020).

In relation to the study of mathematics relations present in the angles formed by the two parallel lines intercepted by a transversal line, screenrecording capturing allowed to show a particularity in the manipulation of straight lines for the formulation of estimates or conjectures: the concept and the focus on the idea of reference become important in the instruction of parallel lines cut by a transversal line (Henrique & Bairral, 2019).

Research in mathematics education has to continue using a variety of sources for the gathering of data. If we do research with digital technologies we also can to use various IT strategies instead of simply reproducing the usual traditional sources, like questionnaires and interviews. As a matter of fact, those old resources can be reconfigured to be used with new technologies, like Google forms. In fact, the analysis has to use information issued from various sources. The construction and use of innovating procedures of analysis, triangulation, meta-analysis and reproducibility are important aspects in the evaluation of cognitive research with MDwT.

MDwT –with their various App, including the ones with sharing and without connection – dispense with IT labs. The equipment can even be the students' own. For the Brazilian educational context that often displays infrastructural restrictions, this is a most welcome possibility. Therefore, transformations with the use of interfaces with touches on screen can occur so that practices can be elaborated in order to present new contributions to the learning and teaching processes.

In the current times of the COVID-19 pandemic, we have seen that teachers have found difficulties in the elaboration of activities or the sequence of tasks. Sometimes, a simple task can generate a variety of resources that the teachers themselves can use with their students. One of them can be screenrecording capturing. With them, students can analyze the performance of their own classmates while solving a task. They can describe what they do, they can construct narratives, they can generate a new task. Summing up, we can have a whole set of possibilities in which learners and their own mathematics thinking are the protagonists. There is clearly a potentiality in mathematics education with touchscreen devices.

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