Learnings from the Use of Screencast Videography in Mathematics Education Research on Item-Writing

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Abstract: *This paper presents the viability of screencast videography (SCV) as a methodology in mathematics education research, particularly in the area of item-writing. Through the lead author's implementation of SCV in the pilot study of his dissertation project, the authors reflect on the affordances and challenges of utilizing SCV in mathematical item-writing research and its implications in mathematics education. With screencast display as its primary source of data, SCV may also utilize other sources of data, such as webcam footage and audio recording. The authors elaborate on the strengths and weaknesses of these data sources which collectively complement one another. They then share their introspections on the opportunities and limitations of SCV, and how these could be potentially addressed. In sum, SCV as a research methodology promotes corroboration and triangulation of data sources; when applied in mathematical item-writing research, it sheds light on the item-writing process and experience of mathematics teachers. This, in turn, may potentially inform the necessary support mathematics teachers need in designing assessment items that will ideally promote student learning and achievement.*

1. Item-Writing as a Field of Study

Research on item-writing (i.e., writing test items) for various purposes in assessment has been anchored on theories which are deeply rooted in the field of language and communication. Despite this, research on mathematical item-writing remains scant, especially with respect to the processes and experiences undergone by mathematical item-writers and their broader implications to mathematics teaching and learning. In this section, an overview of the progression of item-writing theories and models is discussed, and is then followed by a brief discussion on the knowledge gap in mathematical item-writing research.

1.1 Evolution of Item-writing Theories and Models

The seminal work by Flower and Hayes on the cognitive model of writing is a writer-oriented theory in which the writer and their activities related to writing are the focal point of the theory [1]. Their theory posits that writing consists of interrelated cognitive actions or thinking processes that enable the writer to navigate towards the attainment of their goal. To this, a more developed version of the model was proposed [2], which greatly differs from the former model. In this updated model, the writer and the writing processes are situated in two components: a task environment and the individual, in such a way that elements from each component interact with each other. Some of these elements are as follows: cognitive processes, working memory, long-term memory, motivation, physical environment, and social environment [3].

Further improving on the aforementioned, in [4], it is proposed that item-writing is a socio-cognitive process. In this model, the writer is positioned in a wider social context as they argue that item writing is not an isolated activity. Entities involved in the wider context are the *perceived readers* whose potential responses to the questions are considered during item-writing. The materials and resources used for item-writing, such as institutional documents (e.g., assessment framework), are considered as well. Likewise, there are efforts to further expound the field of item-writing. In [5] (as cited in [6]), item-writing was modeled as an activity consisting of three distinct phases, in which item-writing is viewed from a problem-solving perspective. These phases are as follows: initial representation phase, exploration phase, and solution phase. The initial representation phase is related to goal setting and defining the problem to be solved. Meanwhile, the exploration phase pertains to the writer's attempts to search for solutions to the problem defined previously in a purposeful approach. Lastly, in the solution phase, the writer moves towards the completion of the writing task by satisfying the constraints set for the item in the earlier phases.

In a subsequent study, item-writers were observed while going through item-writing tasks that were assigned to them by the researchers [6]. They attempted to dissect the cognitive processes of the item-writers during the task by recording and analyzing their verbal behaviors. [7] aimed to expand the model in [6] into a more comprehensive one, considering the contrast between expert and novice writers on top of their cognitive processes and knowledge structures. Such studies have been successful in pinpointing elements crucial to item-writing processes (e.g., schema activation, decomposition, and evaluation), especially duty-related item-writing activities of professionals in the academic setting (e.g., writing items for standardized assessments). Hence, such studies are necessary in advancing knowledge regarding item-writing activities, for these may provide theoretical and practical support in improving the assessment culture and practices of teachers and educators.

1.2 Research Gap in Mathematical Item-Writing

One notable research gap in the body of knowledge in item-writing is the absence of studies describing how the same cognitive processes apply and extend to mathematical items. The studies related to item-writing that were mentioned in the preceding sub-section discuss the production of items that mostly consist of text (e.g., a question that asks students to identify the thesis statement of a given passage). To this, minimal attention has been directed to mathematical items; an example of such is shown in Figure 1.1.

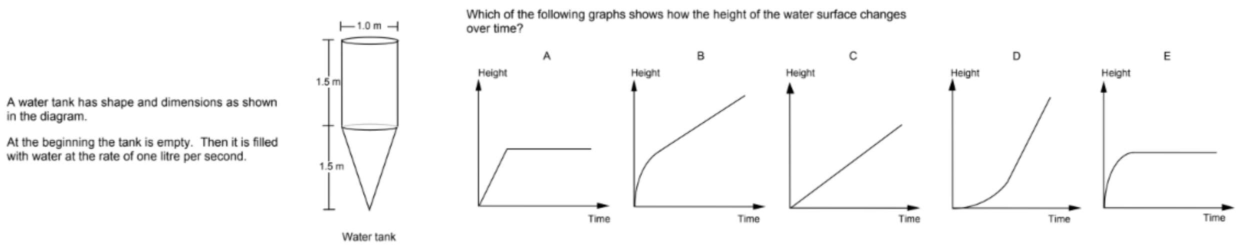

Figure 1.1 An Example of a PISA Mathematical Item [8]

Mathematical items not only use text, but also incorporate non-textual elements, such as symbolic, notational, graphical, or tabular information. A study that focuses on how item-writers develop test items in mathematics will be helpful in uncovering the processes undertaken by academic professionals who are directly involved in this endeavor, most specifically mathematics teachers. This is essential in order to better understand mathematics teachers and their needs, so that ample support may be given and extended to them. Although teachers receive support in the development and improvement of their tests in the form of feedback from peers and mentors within the same working environment, the process that they undertake in creating the items remains widely unexamined. This is crucial to their duties, considering that teachers could spend at least a third of their time on tasks directly related to assessment – which include designing, grading, and interpreting results [9] (as cited in [10]).

More importantly, research on mathematical item-writing connects to the broader conversation on several pertinent topics of interest in mathematics education, such as task design [11], problem posing [12], and international large-scale assessments (ILSAs), among others. More so, today's educational context challenges learners to harness data, utilize technology, and integrate mathematical concepts and methods to solve non-routine problems with a critical and discerning mind. To this, examining mathematical item-writing could be seen as a valuable endeavor in further improving the quality of assessments and problems posed by teachers. This has the potential to enhance the learning experience of students. However, in the Philippines, the educational landscape is shaped by socioeconomic issues [13], in addition to haphazard curriculum modification and implementation [14]. Nevertheless, there are efforts among stakeholders to improve the quality of education across the country (e.g., scholarship programs for capacity building of STEM teachers). In light of the abysmal mathematical performance of the Philippine learners in ILSAs such as PISA 2018 [15] and TIMSS 2019 [16], the authors argue for the investigation of Filipino teachers' mathematical item-writing process, as results from such research may provide the necessary groundwork to support their professional development. This, in turn, may ideally improve the mathematics learning and achievement of Filipino learners.

2. Screencast Videography

Proposed by Kawaf [17] in 2019, Screencast Videography (SCV) as a research methodology aims to produce data in the form of concrete actions performed in a visual digital environment. An example of such an environment is a digital word processor which is extensively used in and ideal for document creation. In her study, Kawaf posited that the philosophical principles underlying SCV are anchored on interpreting moving images. She illustrated its application in marketing and consumer research, in the form of consumer experiences in online fashion shopping. According to her, this methodology allows for analyzing digital experience and interactions by adopting a dynamic form of inquiry that is visual-based. Data in SCV primarily consists of on-screen activities via screencast recording; this, in turn, reveals detailed records of users' digital experiences or activities. Kawaf urged researchers venturing into the use of SCV as a research method to partake in reflecting on the following aspects of their study: context, intervention level, software to be used, mode in screencasting, timeframe, and obtrusiveness.

The context pertains to the research topic and the field or industry it applies to. Meanwhile, intervention level refers to the imposition of limits or constraints onto the item-writers, such as asking them to perform specific tasks during the observation, or making certain covert actions more explicit. On the other hand, the software to be used is any package or application to be utilized in capturing experience-related behavior throughout the observation. As for the mode in screencasting, it could be in full screen mode, or streaming only certain or required parts of the screen. In terms of timeframe, it is a timeline for the observation which has been determined by the researcher beforehand, or setting indicator behaviors that determine when the observation starts and stops completely. Lastly, obtrusiveness is an aspect which might inadvertently alter the writer's natural behavior, or their tendency to show the more desirable side of their activities, as a consequence of being aware that they are being observed.

Additionally, Kawaf enumerated important considerations for analysis and interpretation, given the tendency of the data to be multimodal. One of which is the possibility for the data to be analyzed through a multimodal lens. In such cases, the visual, audio, and spatial aspects are examined altogether, including the temporal relationships among them. Hence, the method subscribes to an existential phenomenology paradigm with an overarching idea of the whole being greater than the sum of its parts; thus, the transitive parts in the continuous stream of the participants' thoughts are deemed as important as the substantive parts.

In relation to mathematics, the construction of mathematics tests using technological hardware and software could be investigated through SCV, as these require very precise formatting to reduce or avoid ambiguities in the presentation of symbols which might inadvertently cause misinterpretations among test-takers. Moreover, the use of SCV in mathematics education provides a glimpse into the teachers' thought processes and choices of action as they embark on tasks specific to instruction and assessment; these are processes that are challenging to define and concretize. Processes related to the teaching-learning cycle, in addition to the affective and behavioral dimension of mathematical item-writing, are abstract in nature. Hence, the digitalization of a teacher's actions during item-writing allows for these actions, emotions, and gestures to be observable and thus can be subject to evaluation, thereby providing valuable input to the forms of support that could be accorded to mathematics teachers.

3. Sample Implementation of SCV in Mathematical Item-Writing

The lead author utilized SCV in his dissertation project's pilot study in examining the item-writing process of four mathematics teachers with respect to items that are parallel to those that follow the assessment frameworks of ILSAs, specifically PISA. This is because one of his research objectives is to describe in detail how mathematics teachers construct test items in relation to their assessment literacy. He aimed to simulate the observation of processes behind writing PISA-like mathematical items through this pilot study before the actual implementation of the main study. An investigation of such processes is warranted provided that studies about ILSAs focus on student-centered variables and not so much on teacher-related factors. The teacher-participants of the pilot study were four tertiary mathematics instructors from a Philippine state university in a Northern Mindanao province. They all have academic backgrounds related to mathematics education.

In the pilot study, the teacher-participants were first oriented on the Programme for International Student Assessment (PISA) framework [18], which consists of three domains: content (i.e., quantity, change and relationships, space and shape, uncertainty and data), process (i.e., formulating, employing, interpreting, reasoning), and context (i.e., personal, occupational, societal, scientific). On the same day, they were then given at most four hours to construct exactly four PISA-like items, i.e., each item must be classified using one of the four content categories, one of the four context categories, and one of the four process categories (e.g., an item is classified as space and shape–occupational–formulating). As this was an individual item-writing activity that was simultaneously conducted for several participants, the lead author used several devices to record the screencasts of the participants over separate calls in an online conferencing platform where one device is assigned to one participant. Thus, actions performed on a digital word processor and other digital tools were recorded per participant. Moreover, the observer turned off his camera in order to subdue the obtrusiveness inherent to the research method.

Hence, three types of data were simultaneously captured through the video recordings: (1) the screencast display, (2) the webcam footage, and (3) the audio input. Utilizing an online conferencing platform allowed for the recording of the teacher-participant's screencast, webcam footage, and audio during the item-writing task. To ensure more depth of the data captured, SCV was implemented with a full screen mode of recording as this mitigates any possible loss of potentially useful data, as opposed to limiting the screencast only to applications that are of direct use to the writer, such as the word processor. While there were only three data sources, there were four teacher-participants whose item-writing session lasted between 2.35 and 3.83 hours. Data analysis began with watching the screencast recordings first, followed by the webcam footage. For each of these data sources from each participant, possibly significant moments were taken note of along with their corresponding timestamp. It was then followed by the transcription of the audio recording, in which noteworthy moments were also timestamped. It proved to be a challenge on how to consolidate and find connections among the data sources given the sheer volume of data.

With regard to the screencast recording, the authors noted that the teacher-participants were able to design their own PISA-like items, mostly via dynamic mathematical software, spreadsheet software, online calculator, web search engine, and word processor software. Additionally, their actions mostly revolved on browsing the web, editing and formatting text, images, and tables. A sample of these actions is illustrated via screenshots as shown in Figure 3.1. Scrutinizing these, it could also be observed that the teacher-participants' actions related to item-writing were deliberate, as these processes consumed most of their time spent during the item-writing workshop. Examples of such were looking for and verifying information to be utilized in the item, be it from digital or non-digital reference materials. Additionally, the participants spent significant amount of effort in the composition of the textual part of the item, as well as the integration of the non-textual elements that are useful in the item (e.g., producing a data set in tabular form, selection of accompanying graphic element).

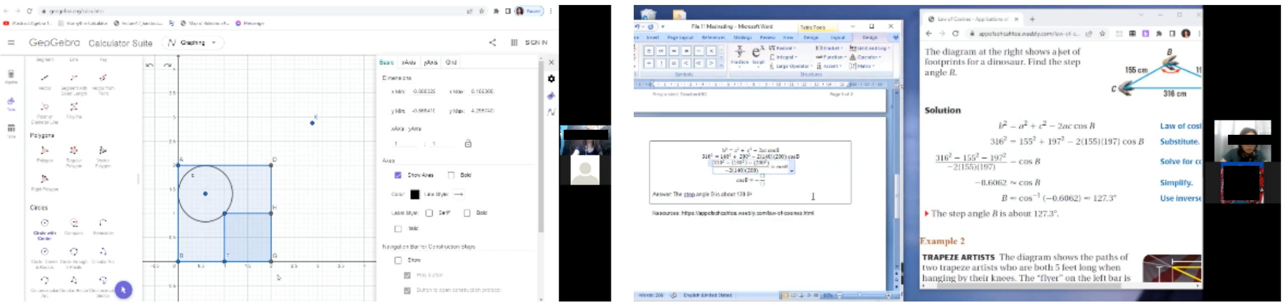

Figure 3.1 Screenshots from the Screencast Recordings of the Teacher-participants

In terms of the webcam footage, the facial expressions of the teacher-participants showed their silent struggles (e.g., fatigue) while partaking in the item-writing activities. These mostly showed that they engaged in deep thinking manifested in physical stances or bodily postures that denote serious contemplation but with a few occasional breaks. However, it should be noted that the webcam footage was not able to capture activities that went outside its field-of-view. Lastly, the audio recordings revealed that the teacher-participants were mostly silent during the task. This was perceived by the lead author as a manifestation of focusing on the task at hand; nevertheless, thought processes that could have been verbalized were a missed opportunity. Despite this, some of them were observed to be engaging on intermittent utterances, such as self-talk or rereading portions of the partially created item that were displayed on the screencast.

In sum, the pilot study showed how SCV could be a viable methodology in observing the mathematical item-writing process of teachers. It allowed the lead author to tap into several data sources while making sense of the cognitive, affective, and behavioral dimensions of the teacher-participants' experience during the given task.

4. Post Facto Introspections

This section discusses the insights gained by the lead author in his use of SCV as a research methodology for examining mathematics teachers' item-writing process, along with the strengths and weaknesses of each data source as observed during the pilot study. This is followed by a discussion of the authors' reflection on the affordances and challenges of SCV and its implications in mathematics education research on item-writing.

4.1 Screencast Display

This source of data showed teacher-participants' actuations that led to the production of the output required by the item-writing task. This allowed the researcher to identify not only the types of resources accessed by the teacher-participants (e.g., websites, software), but also their possible patterns of action (e.g., copying text from a web page before editing it in a word processor). Their recorded acts were not limited to their online activities; their desktop and file navigation, along with their use of other digital tools, such as word processor, internet search engine, spreadsheet application, and dynamic mathematical software, also contributed to the richness of data captured via their screencast display. While this allowed the researcher to observe the teacher-participants' computer activities and, to an extent, describe the cognitive processes they enacted during mathematical item-writing, the screencast display did not provide context about their circumstances. It did not inform the researcher of the background activities that the teacher-participants undertook that may have had an impact on their decisions related to the task, such as the participant's ability to focus on the writing task given the external distractions in the immediate physical environment.

4.2 Webcam Footage

An advantage of capturing webcam footage is that it showed the teacher-participants' facial expressions and bodily movements that might be indicative of certain emotions that have arisen during the task. An example of bodily movement that was noted is attention span. This manifested through the intensity and duration of the participant's gaze at the screen and the frequency of eye movements. In addition, participants exhibited distress in the form of deep or heavy sighs, facial expressions that suggest tiredness (e.g., droopy eyelids or partially closed eyes), and the height at which the participant's head is rested (e.g., a low hanging head as a sign of mental fatigue).

The webcam footage also gave a glimpse of the physical environment the teacher-participants were in; this may potentially inform users of SCV whether such an environment is conducive to accomplishing item-writing tasks. In the context of the pilot study, the environments that the participants were situated were not necessarily ideal as there were some notable distractions (e.g., talking to other people in the household). They were, at the very least, able to secure a devoted physical space that is conducive enough for them to perform the item-writing task. The aforementioned observations provided the researcher with insight on the characteristics of a conducive environment for mathematical item-writing, especially with that of fatigue and productivity. Data from timestamps vis-à-vis the teacher-participants' corresponding activity and expressions indicate that breaks are necessary, and that ergonomics must be prioritized as well.

However, a possible downside of the webcam footage stems from the camera hardware. As there was only a single camera for every teacher-participant, the view of their offscreen activities was limited. For instance, writing activities or processes that were needed for the task and were done on paper may not have been captured and recorded.

4.3 Audio Recording

The last source of data, audio recordings, reveals the teacher-participants' verbalized thoughts and emotions during the task. It includes, but is not limited to, self-talk, which is a vital element in cognitive activities. For instance, one of the participants' self-talk behaviors was related to rereading the item and reviewing it thoroughly. Another participant was also observed to be humming and singing which is indicative of a self-soothing behavior possibly mitigating or keeping stress at bay. However, it should be noted that most of the time during the item-writing task, the teacher-participants tended to be silent as they tried to possibly focus. This is a dilemma that the lead author identified upon reflecting on his SCV implementation.

4.4 Opportunities and Affordances of SCV

An amalgamation of the three sources influences the collective strengths and weaknesses of SCV as a whole, including the opportunities and challenges that come with the research method, especially in the context of social sciences and the field of mathematics education. It can be seen that one source's weakness is another's strength; the three sources complement each other by filling in the limitations posed by one. To elaborate, the webcam footage and the audio recording fills in the gap of the screencast display by providing rich information about the participant's circumstance, both physically and temporally. They add depth to the item-writing processes captured primarily by the screencast display. Moreover, the screencast display informs the researcher of the actual activity being done by the teacher-participant at the exact moment pertinent to a portion of the webcam footage and audio recording. Collectively, they are able to capture a broad perspective of writing at the teacher-participant's level which is ideal for case studies where the participant's writing activities comprise the unit of analysis.

An affordance that SCV brings in mathematical item-writing research is that it allows item-writing to be viewed and analyzed from different and/or combined perspectives. From a cognitive perspective, researchers may be able to observe the possible thought processes that underlie the actions and decisions carried out by the teacher-participants with respect to their item-writing outputs. As for the affective and psychological dimensions, SCV possibly allows researchers to gain an understanding of which elements and factors associated with the item-writing process affect the emotional and behavioral states of the teacher-participants. In turn, these may inform policy and practice concerning item-writing that considers the best interests of the teachers.

Moreover, different phenomena of interest to the researcher can be observed via SCV, such as participants' overall experiences, the challenges in using technological tools, processes essential to item-writing, and how the participants carried out reference consultations throughout the item-writing process. Another affordance is that the observation can also be done remotely, which expands the pool of potential participants given that their participation is limited by their availability. Additionally, the methodology is highly replicable, which can be subject to further iterations and hence more opportunities in developing and improving it.

4.5 Possible Challenges and Limitations of SCV

The two authors reflected on the lead author's implementation of SCV and have identified several challenges and limitations encountered. SCV methodology is most suitable for non-participant observation studies. In such studies, observations are conducted by the researcher in the natural setting of the research participant without the possible interference of the observer [19]. Just like in any observation methodology, data from SCV can only consist of those gathered from the three sources (i.e., screencast display, webcam footage, audio recording). As such, limited data may result from the teacher-participants not being sufficiently expressive of their thoughts and emotions. Teacher-participants may also be forced to work in isolation given that they are being recorded individually. Another possible limitation is when item-writing activities are situated in social settings (e.g., consulting peers for feedback); the interaction may not be captured using this methodology. Transcribing the data from all three data sources and integrating them into one transcript is perhaps the most challenging aspect in the methodology as it requires the observer to pay close attention to three media simultaneously. This could possibly entail rewatching the recording(s) multiple times to get a good grasp of the critical moments in the item-writing process of each participant.

Furthermore, inevitable instances unavoidably mar the quality of the data captured in SCV. These were some of the unfortunate circumstances experienced by the lead author during the study: unstable internet connection, technical problems in uploading and downloading the recording, and hardware problems (e.g., malfunctioning or glitching screens). The lead author's grave source of worry during the study was the possibility of a power interruption, which is not uncommon in a developing country such as the Philippines, most especially in rural or provincial areas.

In light of the challenges and limitations, the authors offer several circumventions to address these. In terms of the three data sources possibly not being able to capture background or off-screen activities, the research participants may be requested to document such activities (e.g., through a journal or logbook), whether they deem these activities having contributed to their item-writing process or not. As for possibly protracted periods of silence during the item-writing activity, researchers may choose to implement the think-aloud protocol wherein research participants are informed ahead of time that they should verbalize their thoughts as much as possible throughout the item-writing activity [20]. However, this may require some form of training so as to familiarize the participants with the protocol.

With regard to mathematical item-writing activities carried out in groups, software applications that are geared towards collaboration may be utilized, along with other sources of data for triangulation. Such collaborative item-writing endeavors may be implemented fully online, fully onsite, or in a hybrid manner. Regardless of modality, the authors envision that it may be necessary to have at least a camera and microphone dedicated to capturing the group dynamics. Meanwhile, individual cameras and microphones will still be in place for capturing more interpersonal (or personal) interactions. More importantly, each participant's screencast display should be recorded, whether they are working on an individual or a collaborative space.

In terms of the challenge of integrating data across the various sources, the authors noted how the use of spreadsheet software is a viable means to corroborate data and facilitate later analysis. Timestamps could be placed adjacent to particular and significant observation(s) from each source. This may aid the researcher in tracking moments across the sources efficiently and effectively. Table 3.1 shows a sample snapshot of data corroboration across various sources via a spreadsheet.

Table 3.1 Sample Data Corroboration from a Participant Recording

Timestamp	Screencast Display	Webcam Footage	Audio Recording
1:17:07	Started Item Q1, filled out the item specifications for Item Q1		"So, question number 1. Item format, MC"
1:17:21			"Context"
1:17:30			"Process"
1:17:41			"Process"

1:17:48		Motions his head to his right side	(sighs)
1:23:30		Returned his attention to the screen briefly, then motioned his head to his right side again	

Lastly, with respect to infrastructural issues such as power interruptions or loss of internet connectivity, the authors noted the importance of having contingency measures in place. Such plans should be designed with utmost caution and in consideration of the research participants. In the case of the lead author's SCV implementation, one contingency measure implemented was to invite a third-party observer as a meeting co-host. This is to ensure that in the event the lead author experiences any form of interruption, the continuity of recording ensues.

5. Conclusion

The present paper discussed the viability of screencast videography (SCV) as a methodology in mathematics education research. Tracing its roots from business research, the authors shared their reflections and insights on implementing SCV in mathematical item-writing research. The primary source of data in SCV is the recording of the screencast display, which records all the onscreen activities of the participant with respect to the task on hand. This is complemented by other sources of data, particularly webcam footage and audio recording. Triangulation amplifies the strengths accorded by each source through painting a better picture of the participant's item-writing process. Nevertheless, several limitations have been identified by the authors, to which they offered several possible workarounds. In all, the authors hope that through this paper, more research could be conducted on mathematical item-writing as it not only advances the knowledge pool in item-writing research, but may also ideally support teachers—the ones who are highly involved in the item-writing process for assessments in classroom use. Likewise, the authors envision more utilization of SCV in the field of educational research, given how the recent pandemic allowed us to embrace the opportunities accorded by technology. With remote non-participant observation becoming commonplace in conducting research via virtual means, SCV applies not only to activities that take place behind a teacher's day-to-day preparations for classes, but also to those that take place in the implementation of such planning (e.g., actual instruction in classroom settings). Further studies in mathematics education can focus due attention to the observation of such activities.

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