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Pre-service teachers' views of mathematicians within mobile devices: A personalization principle study

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Abstract

Several studies have observed that the presentation tasks in mobile devices in a conversational rather than a formal style may produce a personalization effect and benefit performance. Put another way, students' cognitive structures tend to function better when they are involved in personalized contexts. However, little attention has been paid to the personalization principle from mathematics contexts, particularly in the southern hemisphere. Framed by the personalization principle, this mixed methods study investigated the effects of presentation mode in a task involving explicitly laying out the theories and obtaining results through logical proofs, ensuring no ambiguity, which entangles the practice of mathematicians. To this end, this mixed methods study selected a convenience sample of 162 pre-service teachers (PSTs) enrolled in an advanced mathematics module in a large public university located in south-eastern South Africa. Following random assignment, eighty-five (n_1 = 85) PSTs were presented with material in conversational tone and seventy-seven (n_2 = 77) PSTs were presented with material in formal tone. Quantitative analysis revealed, among other things, a significant difference in the responses by the two groups of PSTs, $t(160) = 4.83$, $p < .001$, and $d = .16$. In addition, qualitative analysis of what PSTs say about the functions of pure mathematicians in response to the presentation of the prompt in different contexts showed that personalized contexts foster performance. Considering the limitations of this study, a discussion of the consequences the results of this paper might have on the direction of future mathematics education research is provided.

Keywords: context, mathematicians, personalization principle, pre-service teachers

INTRODUCTION

Pre-service teachers (PSTs) are increasingly using smartphones–which of course have become "powerful learning devices" and gradually replacing the post office and land lines (US Department of Education, 2017, p. 76)–to connect with instructors for communication and facilitation of mathematics pedagogy. A PST working from a smartphone is alone but with the texts, narrations, feedback and cues, and is provided with a conversation. Communication is presented on a personal level, including predicting information in which the PST is interested almost correctly. This technology can be maximized by designing mathematical problems using a conversational rather than a formal style that PSTs can easily process (Brom et al., 2017). Thus, the infusion of technology into teaching and learning has considerably altered pedagogy, understanding in particular. According to Mayer (2005), people learn better through presentations in which the words are in a conversational style rather than in a formal style. Thus, mobile learning has ushered in a transformative era, compelling educational institutions to reimagine their pedagogical approaches and increasingly integrate it into traditional education (Dahri et al., 2024). It is therefore interesting to understand how PSTs perform on a task about mathematicians for whom proof is considered to be central to their practice.

As Mayer (2005) points out, there are two ways in which a conversational style can be formed:

(1) to use I and you instead of a third person and

(2) to include direct comments in the instructional content with which students are required to work.

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Contribution to the literature

- This article contributes to the literature on the personalization principle in undesratnding the functions of mathematicians, particularly in the southern hemisphere.
- The findings of this study are relevant for educators involved in initial teacher education in that PSTs perform better in personalised contexts than in non-personalised context.
- There is a need to engage in efforts intended to improve PSTs' knowledge about the actual work of mathematicians in their training courses.

It is my experience that the instructional content in mathematics is primarily conducted through the formal style. However, findings on the effect of these two ways of presenting instructional material have presented inconsistent results (Schrader et al., 2018). Additional to the discrepancies in the results, the effect of the personalization principle in the context of smartphones in mathematics pedagogy has not received sufficient attention. In fact, to the best of my knowledge, no previous study has addressed whether the presentation style of instructional material has an effect on PSTs performance in advanced mathematics modules, particularly from the southern hemisphere. By advanced mathematics module is meant here pure mathematics module for PSTs with a focus on theory (proofs) instead of computations (Paoletti et al., 2018).

The importance of conversational tones for PSTs contributes strongly to enhancing teachers' engagement, influencing teachers' satisfaction and performance, enhancing content knowledge, pedagogical skills, professional dispositions, and yielding improved learning outcomes, fostering understanding of proofs (Dahri et al., 2024). However, while tangible interfaces have played an important role in mathematics teachers' development for decades, employing these tangible objects together with smartphones in the classroom has been rarely explored yet (Reinschlüssel et al., 2018). Thus, the purpose of this study was to investigate this gap in research to contribute to the research base on increasing PSTs' interest and understanding of the nature of the mathematics discipline. To do this, the study investigated the effect of presenting prompts to PSTs in two different contexts: personalized (e.g., list five reasons for which you can hire a pure mathematician) and non-personalized (list five reasons for which they can hire a pure mathematician). Specifically, the following research questions were addressed:

1. To what degree does the personalization principle affect PSTs' responses to the prompts?
2. What do PSTs say about the functions of pure mathematicians in response to the presentation of prompts in different contexts?

The remainder of the paper is structured as follows: In the first section I review literature related to the personalization principle and mathematicians; then I present the theoretical perspectives framing the study before providing a discussion of the methods used to answer the two research questions; next I present analyses of the results; in the discussion section I integrate the results with prior research and consider the limitations of the study and suggest directions for future research; I end the paper with conclusions about the implications of the results.

REVIEW OF RELATED LITERATURE

Previous Studies on the Personalization Principle

In a transdisciplinary research project with computer scientists, mathematics educators and a textbook writers who were also teachers, Reinschlüssel et al. (2018) investigated the potentials of using tangible user interfaces for algebra learning, developed and evaluated a scalable system for different use cases in grade 9, while using the personalization principle. In presenting their results, they found that when focusing on specific concepts smart smartphones can enrich the interaction equipped with dynamic constraints. Dahri et al. (2024) conducted a quantitative study using a research framework and collected data from 563 schoolteachers through an online survey. These respondents were actively engaged in mobile-based training courses at a teacher training institute during their mandatory training programs in the academic year 2022-23. They used structural equation modeling to analyze their hypotheses on the personalization principle. The study's findings unveiled a robust and significant nexus between several critical factors and educators' experiences when utilizing mobile learning for training. Specifically, content quality, information quality, system quality, prior experiences, and mobile self-efficacy contributed strongly to task technology, ultimately enhancing teachers' engagement, and yielding improved outcomes.

Acknowledging that primary school students may face difficulties in acquiring mathematical competence, possibly because teaching is generally based on formal lessons with little opportunity to exploit more multisensory-based activities within the classroom, Cuturi et al. (2022) conducted a study in which they the designed a novel multisensory learning environment for teaching mathematical concepts based on meaningful inputs from primary school teachers. First, they developed and administered a questionnaire to 101 PSTs asking them to rate, based on their experience, the learning difficulty for specific arithmetical and geometrical concepts encountered by primary school students. Additionally, they reported that the questionnaire investigated the feasibility of using multisensory information to teach mathematical concepts. Results show that challenging concepts differ depending on students' school level, thus providing guidance to improve teaching strategies and the design of new and emerging learning technologies accordingly. Second, they obtained specific and practical design inputs with workshops involving PSTs and students.

Mayer et al. (2004) examined the performances of 62 psychology students enrolled at the University of California, Santa Barbara. Twenty-nine participants served in the personalized group, and 33 served in the non-personalized group. These groups were exposed to a narrated animation explaining how the human respiratory system works. Specifically, the narration for the non-personalized version was in formal style, whereas the narration for the personalized version was in conversational style in which "the" was changed to "your." Having conducted 3 experiments in this context, they found that the students in the personalized group were significantly more successful in transfer tests (i.e., tests involving solving novel problems using the presented material) than those in the non-personalized group. More specifically, they found had a large effect on students' subsequent performance on tests of transfer–yielding effect sizes of .65, 1.07, and .72 across the three experiments. Son and Goldstone (2009) experimented with 73 undergraduates at Indiana University who participated for credit. A computer program randomly assigned participants to two groups. Participants were asked to quickly read the text presented in the experiment. The task featured a medical doctor trying to diagnose patients with leukemia by examining blood cell distortion levels. They found that the personalized group learned less about medicine content than the non-personalized group.

In contrast, Yeung et al. (2009) set out to test the personalization hypothesis in the domain of chemistry under e-learning environments over 2 semesters. Using retention tests (i.e., asking for recall of what was presented in a lesson) and transfer tests immediately after students had completed the pre-laboratory work. Approximately 600 students took part in the project in semester 2, about 800 participated in semester 1. They found that the personalized group does not perform significantly differently in general from the non-personalized group. Specifically, however, the results suggested that the different performance of personalized or non-personalized groups is dependent on participants' prior knowledge; if prior knowledge was weak, significant improvements were found for personalized over non-personalized instruction. Doolittle (2010) randomly assigned 365 students to a control, segmented, or personalized multimedia group and found no personalization effects on learning historical inquiry content within computer-based material.

As Son and Goldstone (2009) suggest, personalized contexts "may have an effect on the content that is actually learned" (p. 53). Thus, the tone in which material is presented seem to matter. The study reported in this paper was framed by the Mayer et al.'s (2004) cognitive theory of multimedia learning which posits that personalization causes students to actively process the incoming material. The theory is based on the notion that the brain does not interpret a multimedia presentation of words, pictures, and auditory information in a mutually exclusive fashion; rather, these elements are selected and organized dynamically to produce logical mental constructs. Cognitive load occurs when extraneous information completes for the processing capabilities of the working memory and therefore interferes with the learning process (Wouters et al., 2008).

Mayer et al. (2004) and Moreno and Mayer (2004) conducted a series of experiments that focused on learning and ways technology can be used to enhance learning. Seven important principles–which are organized around a cognitive theory of multimedia learning (Mayer, 2005) which itself is considered the most comprehensive theory about learning with instructional multimedia (Wouters et al., 2008)–were uncovered. The principles are: coherence principle (extraneous words, sounds, and pictures); modality principle (presenting words as narration rather than as on-screen text), spatial contiguity principle (placing on-screen text near rather than far from corresponding pictures), temporal contiguity principle (presenting narrative simultaneously with corresponding animation rather than successively); voice principle (using a human voice rather than a machine voice; segmenting and pretraining principle (managing complexity by breaking a lesson into parts); and, personalization principle (using words in a conversational style rather than a formal style).

The Mathematicians' Practice

PSTs' views about the practices of mathematicians influence their attitude towards mathematics (Aguilar et al., 2016). In acknowledgement of the importance of understanding the practices of mathematicians, several researchers (e.g., Livingston, 1999; Picker & Berry, 2000, Rock & Shaw, 2000) conducted investigations into the constructs that characterize the work of mathematicians. Most studies reporting on the activities of mathematicians tend to associate mathematicians with proving theorems (Giaquinto, 2005). Hersh (1997) is convinced that one unrecognized cause of students' failure in mathematics is the misconception of the nature of mathematics. Thus, holding informed conceptions of mathematicians' work can have profound effects on the learning of mathematics. Given students' limited view on the practice of research mathematicians, it is unsurprising that some sections of the general public think of mathematicians as people that can help in doing arithmetic exercises (Picker & Berry, 2000).

The work of mathematicians is primarily that of constructing proof; thus, their work is described in terms of what they do. Simply put, a mathematician creates mathematics; this can mean creating new mathematical theorems and results (Latterell & Wilson, 2012). However, the concept of proof evokes various meanings to different people. For some PSTs, proof is viewed from everyday language to mean evidence (Knuth, 2002). In the discipline a litany of meanings is ascribed to concept of proof, on the basis of its role in mathematics. According to de Villiers (1990), proof is seen as a means of verifying the truth of a mathematical statement; explaining why a mathematical statement is true; communicating the results to others; discovering results whether those results are known to the PST or not and systematizing by organising accepted principles of previously proven results to apply the principles of logic to create a deductive argument.

THE THEORETICAL FRAMEWORK

The Personalization Principle

In the present study, the effect of one of these principles, the personalization principle, is examined in the context of understanding the practice of research (pure) mathematicians. The personalization principle is premised on the notion that learning increases when the content is presented in a conversational tone (e.g., I and you), that is, personalized style, rather than in a formal tone (e.g., he, she, and it). The theoretical explanation the personalization principle is that using the self as a reference point increases the student's interest, which in turn encourages him or her to deploy "available cognitive capacity for active cognitive processing of the incoming information during learning" (Mayer et al., 2004, p. 391). Personalized information tends to reinforce references to the communicated information for the student, unlike information referring to other frames of reference (Schrader et al., 2018). When students feel that the material talks to them, they see the material as a speaking partner; the material says. For instance, changing the to your, has a significant effect on students' learning of personalized science content in computer-based multimedia presentations (Dunsworth, 2005).

According to Mayer and Moreno (2003), the "major challenge for instructional designers is that meaningful learning can require a heavy amount of essential cognitive processing, […]. Therefore, multimedia instruction should be designed in ways that minimize any unnecessary cognitive load" (p. 50). Cognitive load is a phenomenon that occurs when extraneous information completes for the processing capabilities of the working memory and therefore interferes with the learning process (Wirth et al., 2020). The principle is also viewed as one of the techniques to reduce cognitive load (Wouters et al., 2008).

Proving and Validation in Mathematics

In reviewing the literature on the practice of mathematicians, perhaps it is important to provide an answer to this question, "What is mathematics, really?" Answers to this question vary considerably given the variety of fields in the discipline of mathematics and the complexities created by school mathematics. That notwithstanding, doing mathematics "often involves establishing mathematical truths by checking conjectures, and deciding whether to reject or accept them" (Zaslavsky, 2005, p. 316). In defining what mathematics is, Hersh (1979) concludes that it entails discovering of the properties of ideas through the construction of proof and searching for counterexamples. Watson (2008) provides a comprehensive description of what it means to do mathematics from the perspective of research mathematicians:

> Doing mathematics' is predominantly about empirical exploration, logical deduction, seeking variance and invariance, selecting or devising representations, exemplification, observing extreme cases, conjecturing, seeking relationships, verification, reification, formalization, locating isomorphisms, reflecting on answers as raw material for further conjecture, comparing argumentations for accuracy, validity, insight, efficiency and power. It is also about reworking to find errors in technical accuracy, and errors in argument, and looking actively for counterexamples and refutations (p. 4).

It is widely recognized that proving–defined here as a mental act of establishing mathematical knowledge using a range of cognitive processes generally referred to as mathematical reasoning, namely, patterning, conjecturing, exemplifying, generalizing; and, justifying–is the core of mathematical practice (Lannin et al., 2011). Most studies reporting on the activities of mathematicians tend to associate mathematicians with proving theorems (Giaquinto, 2005). However, this is not entirely correct. For Steinbring (2005), the practice of mathematicians entails communication and construction and justification of mathematical knowledge. Research mathematicians (hereinafter mathematicians) engage in activities well beyond just proving. An understanding of these practices is important if the participation of students in mathematics were to increase.

The concept of validating entails checking the correctness of a mathematical proposition or simply verification. In validating, all that is required is to examine if a prover logically connected axioms to arrive at a conclusion regardless of its form or aesthetic appeal (Hanna, 2007). Verification denotes the removal of uncertainty by seeking, in the vocabulary of Harel and Sowder (1998), to "convince" or "persuade" someone or oneself about the validity of a conjecture. Harel (2013) takes this idea of certainty further and claims that the 'need for certainty is the natural human desire to know whether a conjecture is true–whether it is a fact' (p. 124). That feeling of certainty is really powerful, for patterns and trends can be deceptive. All mathematicians have their favorite examples of patterns that look like they ought to hold but fail, or of conjectures that are true for the first n tries but then fail (Schoenfeld, 1994).

Mathematicians use "formal reasoning and the construction of rigorous proofs, informal deductive reasoning, and example-based reasoning" in validating proofs (Weber, 2008, p. 431). By formal reasoning and the construction of rigorous proofs is meant checking which assumptions or proof methods (e.g., direct proof) are used in the argument prior to line-by-line checking or constructing a sub proof with logical references and a valid proof technique during line-by-line checking (Weber, 2008). Informal deductive reasoning means justifying the truth and falsity of each claim using informal explanations (Weber, 2008). Example-based reasoning means that mathematicians use one or more examples to determine the validity of each line shown in the argument (Weber, 2008). On the contrary, PSTs tend to begin with a line-by-line check of the argument (Alcock & Weber, 2005) or use line-by-line checking with examples thus relying on empirically-based evidence to determine the validity of each claim (Selden & Selden, 2003).

METHODS

Design

The present study is underpinned by a pragmatic paradigm using a concurrent transformative mixed methods design to gather both numerical and verbal data in line with Creswell and Plano Clark's (2011) guidelines. Mixed methods studies present an innovative combination of different research perspectives that promise additional insight, which might not be accessible with a single methodological research approach (Buchholtz, 2019). Although a pilot study was conducted prior to the main study, its main focus was on refining methodological issues rather than demonstrating statistically significant findings.

This design was appropriate given the qualitative and quantitative evidence needed to explore the personalization principle among two groups of PSTs. As Holm and Kajander (2012) note, "[o]nly when the beliefs and knowledge of the teacher are both considered, can changes in mathematics teaching have real and lasting effects on future generations of students" (p. 13). Specifically, this study adopted two designs:

(1) a causal-comparative design to determine whether the personalization principle (independent variable) affected PSTs performance in the prompt (dependent variable) by comparing two groups of participants and

(2) a case study to seek insight into what PSTs say about the practice of mathematicians.

Research Context

The participants

The participants were a convenience sample of 162 PSTs recruited from a large public university in south-eastern South Africa, over three years. The longitudinal aggregation was chosen because it allowed data from multiple points in time to be combined for their ability to reveal patterns and trends in change over time about the views of mathematicians that participants may hold. This sample of PSTs was drawn from the target population of mathematics education students ($N = 824$), some of whom were in their third or fourth year of their Bachelor of Education (BEd) program. Specifically, eighty-five ($n_1 = 85$) PSTs were presented with material in conversational tone, that is, they served in the personalized group and seventy-seven ($n_2 = 77$) PSTs who served in the non-personalized group. These participants were chosen because they may have a different perspective on views of mathematicians compared to those who attended high school in the early 2000s, due to the change in the curriculum, which made geometry proofs compulsory for the learning of mathematics in high school.

The mean age was 21.8 years for the personalized group and 21.4 years for the non-personalized group. As is typical in schools of education and in the teaching profession in general (Correa et al., 2015), the majority of the participants were women; the personalized group contained 63% women, and the non-personalized group contained 61% women. The rationale for purposively selecting these two groups of participants was not only that they were representative of the population of PSTs registered for the module and easily accessible to the researcher, but primarily that they were appropriate in capturing the major variations in their knowledge of the work of mathematicians which could not be obtained from other choices (Maxwell, 2013).

The setting

The PST were enrolled, among others, in an advanced mathematics module as part of their BEd program. The curriculum includes both methods and content modules (courses). The assessment in tests and examinations of the advanced mathematics module comprises important theory content which involves reconstruction "ab initio" of proofs of major theorems. The textbook for the course was Bartle and Sherbert's (2011) Introduction to real analysis and the module included all the appendices. The book was chosen on the basis that it is intended to help develop PSTs ability to think deductively, analyze mathematical situations and extend ideas to new contexts. Topics covered in the module included sets, functions, properties of the real number system, proof by induction, limits of functions and sequences, the topology of the real line, limits of functions, continuity, uniform continuity, and the generalized Riemann ("gauge") integral. The book also provides brief biographical sketches of some famous mathematicians to enrich its historical perspective. The module lectures took place for 75 minutes twice a week over the course of a 9-week semester.

Data Collection

Survey prompt items

Using their mobile devices, PSTs responded to the personalized prompt, "If you have a leaky tap, you need to hire a plumber; if you break your leg, you need the services of a doctor. List 5 reasons for which you can hire a pure mathematician," or to the non-personalized prompt, "if someone has a leaky tap, they need to hire a plumber; if they break their leg, they need the services of a doctor. List 5 reasons for which they can hire a pure mathematician" (adapted from Picker & Berry, 2000, p. 71). The single problem was given on the basis of the multimedia learning theory's idea that when using multimedia, it is important to reduce cognitive load for the purpose of improving the information processing capabilities of students' memory. I take as characterization of a problem the as the following: "a mathematical question whose solution is not immediately accessible to the solver, because he does not have an algorithm for relating the data with the conclusion" (Callejo & Vila, 2009, p. 112). The participants took approximately 10 minutes to complete the task.

Data Analysis

The main purposes of the analyses of the data from the prompt were twofold: to explore the differences in responses to the prompt in the context of the principle and to describe PSTs' views of what mathematicians do. To this end, inferential and descriptive statistics based on the t-test and frequency tables were produced. I analyzed responses from PSTs over a period of three years (2018-2020), comparing their performance in the same prompt throughout. The concepts of personalization, proving, and validating provided a lens for interpreting the data.

Quantitative data

To answer the first research question, PSTs scores were analyzed by applying the test for independent means to answer the first research question. The data was subjected to SPSS. Initially, the data were imported from Excel spreadsheets. Next, the data were cleaned by handling missing values and outliers, prior to determining the appropriate statistical test based on the research question. Then, descriptive statistics was used to determine measures like means, standard deviations, and skewness. Last, an analysis was run, using the t-test to make inferences about populations based on sample data.

Responses which were consistent with the contemporary views of the work of pure mathematicians were categorized as "informed = correct" and misconceptions as "naïve = incorrect." Whether the data approximated a normal distribution was verified by using two tests: skewness and kurtosis z-value (ratio with standard error). Data obtained from the SPSS was used to calculate the effect size (d).

Qualitative data

For the second research question, the data were analyzed using a predetermined coding scheme to categorize what PSTs say about the functions of pure mathematicians in response to the presentation of the prompt in different contexts. Three mathematics professionals with varying educational backgrounds were purposively selected to assess intercoder reliability on the PSTs' responses to the prompts. One of the coders held a doctorate in secondary-focused mathematics education, one in pure mathematics, and one was an associate mathematics education professor with teaching experience in secondary school mathematics.

Thus, sampling here was consistent with Shadish et al.'s (2002) argument that when the characteristics and qualifications of the population are defined, purposeful sampling is a credible sampling technique. Each response was coded according to references to proving (patterning, conjecturing, exemplifying, generalizing and justifying) and validating as described in the theoretical perspectives section (**Table 1**). Initial coding involved sixteen categories.

However, because some codes appeared very infrequently, these codes were subsequently simplified into five categories: patterning (code 9); conjecturing (codes 1 and 10); exemplifying (code 11); generalizing (codes 5, 12, and 13); proof function (codes 3, 6, 7, 8, and 14); other (codes 0, 2, 4, and 15). Any response which mentioned several reasons for hiring a mathematician received multiple codes.

Table 1. Categorization of PSTs responses to the prompts

Response relating to:	Code	Response	Code
Blank	0	Discovering	8
Guessing	1	Looking for patterns/structure	9
Computing	2	Conjecturing	10
Validating	3	Examples/informal deductive reasoning	11
Help PST with assignment/homework	4	Generalizing	12
Prove	5	Justifying/formal reasoning	13
Communicating new results	6	Explaining	14
Verifying (truth)	7	Other	15

Table 2. Descriptives and normality tests of personalization principle

	Group	Measure	Statistics	Standard error
Prompt score	Personalized	Mean	3.22	.76
		Standard deviation	1.43	.16
		Skewness	.52	.40
		Kurtosis	–.97	.78
	Non-personalized	Mean	2.11	.72
		Standard deviation	1.63	.19
		Skewness	.17	.28
		Kurtosis	–1.12	.55

RESULTS

Quantitative Analysis

The test for independent means was used to analyze survey data. Preliminary statistical results showed that there were no outliers or missing data, and the Shapiro-Wilk test for normality showed that data of both samples approximated a normal distribution, namely, data values were between -1.96 and +1.96. The result of Levene's test for equality of variances showed that the variances of the two populations are the same. Put another way, a confidence interval with a 95% confidence level, showed that 95 out of 100 times the estimate fell between the upper and lower values specified by the confidence interval. Thus, the nonsignificant result (.405 is not below .05) suggested that there was no reason to question the assumption of equal population variances; that is, there was confidence in the conclusions drawn from the t-test results. These results, taken collectively, suggested the scores of the two groups were suitable for the t-test (Salkind, 2010). Descriptive statistics such as the means, standard deviations, and measures of skewness and kurtosis are presented in **Table 2**.

The results of the independent-samples t-test analysis conducted to explore if there is a difference in the performance of PST in relation to the personalization context in which the prompt presented showed a statistically significant difference in the scores for personalized: $t(160) = 4.83$, $p < .001$, and $d = .16$. Put another way, the results showed that the difference in performance between the two groups was not only statistically significant but also–on the basis of the very large Cohen's d–of practical significance.

Qualitative Analysis

Information about the second research question, "What do PSTs say about the functions of pure mathematicians in response to the presentation of the prompt in different contexts?" was sourced from PST responses to the prompts. Intercoder reliability, particularly intraclass correlation coefficient (ICC), which accounts for chance agreement, is crucial for ensuring the consistency and accuracy of qualitative data analysis. The reliability procedures followed were developing the codebook, which outlined all categories, subcategories, and their definitions to help coders understand what to look for and how to apply the codes consistently. The coders were trained to understand the codebook, coding procedures, and how to apply the codes consistently. This involved practice coding, feedback sessions, and discussions about disagreements.

The coders raised merely clarity-seeking questions prior to the scoring. The limited time available for the project constrained the provision of formal training on the use of the codes, simulating its probable future uses. However, this lack of training did not contribute to inconsistent coding, which suggested that the coding schemes can be administered uniformly and consistently in different contexts. All coders scored the same set of ten PSTs' responses independently. Then, they were asked to rate the responses on a 5-point Likert scale, with response options ranging from 1 (= very weakly represents mathematicians' work) to 5 (= very strongly represents mathematicians' work).

The result of this process was a set of categorizations grounded in literature. ICC was used. Whereas ICC is an index that reflects both degree of correlation and agreement between measurements, the term "class" is

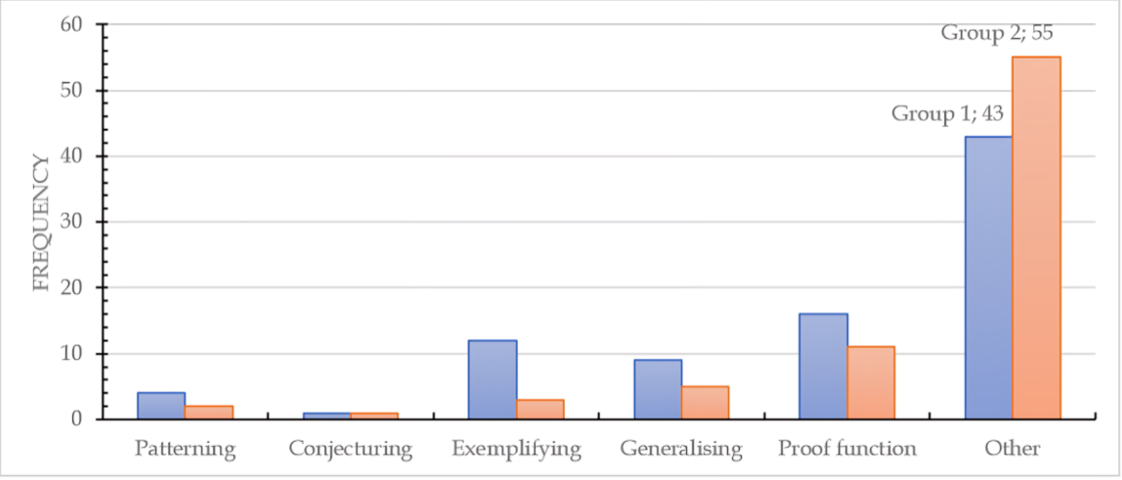

Figure 1. Distribution of PSTs' responses to prompts by the 2 groups (Source: Authors' own elaboration, using SPSS V30)

used to refer to "the test takers, persons, families, or other entities that serve as objects of measurement in a correlational analysis" (McGraw & Wong, 1996, p. 30). Thus, the ICC was used to assess the degree that coders were consistent in their coding of PSTs' responses.

Based on Koo and Li's (2016) ICC estimates, values less than .50, between .50 and .75, between .75 and .90, and greater than .90 were indicative of poor, moderate, good, and excellent reliability, respectively. For this analysis, the resulting single-measure ICCs for the prompts were within the "good" range (.83). This value suggested a high degree of agreement among coders, despite the lack of training, practice, or discussion among some of them. Put another way, these high ICCs suggested that the independent coders, with no training, introduced only a small amount of measurement error. In **Figure 1**, I provide a distribution of PSTs' responses according to the reasons for which they would hire a mathematician, gleaned from their answers to the prompts.

Although **Figure 1** shows that the most common responses suggest that PSTs view mathematicians as engaging in practices coded as "other" than in proving and validating, functions mentioned by a little over 51%, fewer PSTs held in the personalized group hold the "other" view about what mathematicians do. Specifically, the majority of PSTs responded with answers that either made little sense or gave no response at all, irrespective of the context in which the prompt was presented. More PSTs in the personalized group regarded mathematicians as people who engage in verifying, communicating mathematical results, explaining why a proposition is true, systematize mathematical results into a deductive system of axioms, and invent new mathematical results, all coded as proof function. That mathematicians formulate conjectures was almost equally mentioned by both groups while responses suggesting some kind of pattern observation or seeking by mathematicians, coded as patterning, were very rare for both groups, referred to by only less than 5% of PSTs.

DISCUSSION

The discussion that follows is organized around the two research questions:

1. To what degree does the personalization principle affect PSTs responses to the prompt?
2. What do PSTs say about the functions of pure mathematicians in response to the presentation of the prompt in different contexts?

This project aimed to investigate the personalization principle's effectiveness on the performance of PSTs in a prompt about the practice of mathematicians.

Quantitative analysis showed that the personalization principle significantly affected the performance of the group of PSTs who were presented with a formal format. This finding was parallel to the findings of Mayer et al.'s (2004) experiments and Dunsworth's (2005) study. Mayer et al.'s (2004) study found similar results. However, it was inconsistent with the findings of Son and Goldstone (2009), Yeung et al. (2009), and Doolittle (2010) who found a non-significant difference between personalized and non-personalized groups. Noteworthy is that the results of these previous studies were all in nonmathematical contexts.

The results in this study need not be construed as suggesting that personalized contexts must be a feature of mathematical practice because "if all learning is tied to specific contexts, the possibility of transfer across domains and phenomena comes into question" (Son & Goldstone, 2009, p. 53). My point is that although knowledge must be decontextualized and abstracted from particulars in order to be transferred to novel situations, learning in a personalized context, whenever practical, needs to be pursued. The findings in this study lend support to this stance. In fact, Son and Goldstone (2009) argue that when only a limited exposure to personalized contexts is available, strategic decontextualization, if successfully employed, can allow students to function across contexts and extend prior learning to solve new problems.

The qualitative results seem to be consistent with the finding that PSTs in personalized contexts tend to perform better than those in non-personalized contexts. In addition, these results revealed that a sizeable majority of PSTs had no clear idea of what mathematicians actually do. This finding is similar to Picker and Berry's (2000) who found that mathematicians are thought of as people that can help in doing arithmetic exercises. Thus, setting a personalized question tends to lead to a surprising array of valid but unexpected responses. Surprising because, in contrast to Son and Goldstone (2009) suggestion the personalized context had an effect on the content (i.e., what mathematicians do) that has not even been previously learnt. The key findings of this study extend our insight into PSTs' understanding of the functions of mathematicians and the effect of the personalization principle when responding to the prompt via smartphones.

There is no manuscript without some limitations. First, the study reported in this paper did not investigate PSTs reasons for the responses they provided. For example, understanding what they meant by "Examples." Future studies must conduct open-ended interviews to further shed light into this principle. Second, although the study's participants were representative samples, the results should be confined to contexts similar to this study given the small sample size. Future research may need to conduct randomized experiments to enable the generalization of results to other contexts.

The "novelty effect" in the context of mobile surveys, that is, the initial positive response and engagement participants demonstrate when using smartphones for the first time, seemed to diminish as they became accustomed to using them. This was observed in various aspects of survey participation during the longitudinal attrition. In particular, the novelty effect was observed in the response rates, the length and detail of responses, and overall satisfaction with the survey experience. The novelty effect could have been diminished by providing participating PSTs with a clear explanation of the research's purpose, ensuring it was easy to use, and making the survey itself engaging and interactive. Thus, this longitudinal study captured the full impact of the survey on participant engagement.

CONCLUSIONS

By focusing on the personalization principle, the mixed methods study reported in this paper investigated whether two different prompt presentation formats on the practice of mathematicians influenced PSTs performance. The results showed that there were more positive effects on the performance in the conversational presentation format than in the formal format. Further, qualitative results suggested that PSTs know very little about mathematicians' practice. If PSTs experience difficulty in describing the work of mathematicians, it should not come as a surprise that learners also have similar problems. The finding that PSTs have a limited understanding of mathematicians has educational implications. First, the implication for PSTs is that they will continue to struggle with understanding of the mathematical practice unless efforts are geared towards improving their knowledge about the actual work of mathematicians in their training courses. Second, the implication is that PSTs can take it upon themselves to learn what actually mathematics is all about. It is during such their own effort that they can pick it up about the work of mathematicians, especially when they learn to prove theorems. Additionally, PSTs can plan and facilitate mathematics lessons that focus on the practice of mathematicians. These results underscore the necessity to consider the format in which tasks are presented to PSTs.

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