

ABSTRACT

AMEDU, JEROME ZEGAIGBE. Examining Mathematics Teachers' Perceptions of the Effects of Informal Learning on Teacher Knowledge and Practices: An Explanatory, Sequential Mixed-Methods Study (Under the direction of Dr. Karen Hollebrands and Dr. Ruby L. Ellis).

Although there is a growing research interest in teacher informal learning and an increasing acknowledgment of the important role it plays in teacher professional development (Jurasaitė-Harbison, 2008; Jacobs & Park, 2009; Lecat et al., 2020), the effects or outcomes of informal learning are difficult to measure and there are relatively fewer studies that focus on these outcomes (Kyndt et al., 2016). The purpose of this explanatory, sequential mixed methods study (quan → QUAL) was to investigate math teachers' perceptions of the effects of informal learning on teacher knowledge and practice.

Phase one of the study involved examining how math teachers' participation in four different informal learning activities (learning through media, colleague interaction, individual reflection, and stake-holder interaction) relate to their self-reported efficacy in select TPACK domains (technological knowledge (TK); content knowledge (CK); pedagogical knowledge (PK); and technological pedagogical content knowledge (TPACK)) and differed based on teacher career stage. The quantitative analysis was based on 258 cases with complete responses out of a total of 397 respondents who took the survey.

In phase two, two rounds of semi-structured interviews were conducted, and a mini survey capturing teachers' daily informal learning experiences was administered to examine math teachers' experiences and perceptions of informal learning and explain the quantitative results obtained in phase one of the study. The qualitative analysis was based on a multiple case study approach involving four purposefully selected cases from the first phase of the study, and 173 responses from two open-ended survey items on the main survey. The research questions

were answered based on meta-inferences obtained from both the quantitative and qualitative phases.

This study found positive correlations between math teachers' participation in informal learning and their self-reported efficacy in select TPACK domains (TK, CK, PK, TPACK). Furthermore, math teachers' media interaction, interaction with colleagues, and participation in individual reflection were all found to be significant predictors of their self-reported efficacy in at least one of the four informal learning activities this study focused on. No statistically significant differences were found in participation in informal learning activities based on teacher career stage.

Findings also revealed five distinct categories of informal learning activities that mathematics teachers engage in: consulting information sources, interaction and discussion with others, learning from others without interaction, practicing and testing, and reflection in and on action. Overall, reflecting on practice and using social media were the two most frequent informal learning activities that most math teachers reported engaging in. However, the case analysis suggested that referencing web-based resources and collaboration with colleagues may be the most prominent and useful informal learning activities in teachers' everyday practice.

Three categories or levels of factors that affect teachers' informal learning were also identified: personal, interpersonal, and school-level factors. An overwhelming majority (70.3% of survey quotes) of issues that affected math teachers' informal learning were school-level factors. Time and scheduling accounted for most of these (36.9% of survey quotes), making it the most influential issue affecting math teachers' informal learning. Overall, informal learning was found to contribute meaningfully to math teachers' content, pedagogical, and technological knowledge, as well as their motivation and emotional well-being. Most contributions or effects

of informal learning reported pertained to teachers' pedagogical knowledge. Teachers' TPACK self-efficacies in different domains mostly determined the areas of practice where they sought out informal learning opportunities. Although teachers found informal learning very useful for solving immediate or in-the-moment problems of practice, informal learning also contributed to changes of a more enduring nature in how teachers attended to equity and approached student engagement in their classrooms.

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Examining Mathematics Teachers' Perceptions of the Effects of Informal Learning on Teacher
Knowledge and Practices: An Explanatory, Sequential Mixed-Methods Study

by

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DEDICATION

This dissertation is dedicated to:

God Almighty, the source of all knowledge;

My parents and siblings who stick with me through thick and thin;

My spiritual and academic mentors whose support keep me focused; and

My biggest cheerleader and fiancée, the delectable Amour, who inspires me.

BIOGRAPHY

Jerome Zegaigbe Amedu was born on February 2, 1988, in Kano, a commercial town in Northern Nigeria. He is the last of eight children and a first-generation college student. Jerome had his elementary, secondary, and undergraduate education in Nigeria. He taught high school math and physics for 3 years after completing a bachelor's degree in mathematics education at the University of Maiduguri in 2011.

Even as a teen, Jerome loved assisting friends and kids of close family friends who struggled with math. This passion for teaching was later fueled by his favorite high school math teacher, Mr. Vincent, who made math enjoyable. Beyond completing a bachelor's degree in Mathematics Education, Jerome's passion saw him completing graduate programs in mathematical sciences at the African Institute for mathematical sciences (Tanzania) and Lappeenranta University of Technology (Finland) on fully funded scholarships. He soon realized that besides teaching math to struggling students, pursuing a career as a math educator will potentially increase his sphere of influence as far as improving students' math experience is concerned, albeit indirectly.

Consequently, he left Finland for the U.S in 2019 after gaining admission into the Ph.D. in teaching and learning in STEM (with a focus in Mathematics and Statistics Education) program at North Carolina State University. He was a beneficiary of the Graduate Student Support Plan (GSSP) and other forms of financial support. Jerome also taught different undergraduate and graduate methods courses while at NC State, worked with faculty on research projects, and presented at different national and international conferences. Jerome intends to take up a faculty position after completing his Ph.D. program; this will allow him to continue to teach, do research and mentor preservice and in-service teachers alike.

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Completing a Ph.D. is arguably one of the most challenging endeavors I have undertaken so far. I am glad that I have come this far; however, my story will be incomplete without acknowledging all the wonderful people that supported me on this journey. I want to thank friends and colleagues in my cohort who supported me, especially at the beginning of the program. Michael Hoyes and Josh Mannix were amazing! Special thanks to Dr. George Corliss, it won't be ought of place to describe you as my life coach at this stage.

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CHAPTER 1: INTRODUCTION

Background of the Study

Teacher professional development (PD) has been identified as one of the keys to improving school quality (Desimone, 2011). As a result, it has featured prominently in debates about school improvement, student learning, and teacher quality (Opfer & Pedder, 2011; Richter et al., 2014). Although teacher professional development has received considerable attention in both research and policy, for a long time, the focus was mostly on formal teacher learning opportunities which are classroom-based, institutionally funded, and take place within formal structures or learning environments (Richter et al., 2014; Macià & García, 2016).

Richter et al. (2014) noted that formal learning opportunities are based on the *traditional view* of teacher professional development: a professional development model which is based on the notion that teachers acquire skills and knowledge and update same by attending workshops and courses. Although specific formal professional development programs have been shown to improve student outcomes and teacher knowledge (Martin et al. 2010), they are limited in scale. Formal teacher professional development models continue to be associated with challenges such as teachers' disengagement, disinterest, dissatisfaction, and declining participation (Scribner, 1999; Sowder, 2007; Bill & Melinda Gates Foundation, 2014). Some researchers suggest that teacher apathy towards professional development is connected to the failure of traditional professional development efforts to truly meet teachers' needs (Ball & Cohen, 1999; Brooks & Gibson, 2012, as cited in Appova, 2009). There are also difficulties that come with the fact that formal professional development tends to hold within fixed times and geographical locations (Jones & Dexter, 2014). Furthermore, teachers are often not part of decisions about the content and format of formal professional development experiences, as they are dictated by people other

than them. As such, teacher voice is largely lacking in professional development planning, contributing to teacher dissatisfaction (Boston Consulting Group, 2014; Darling-Hammond, 2017; Anderson, 2019).

The inadequacies of formal professional development seem to have prompted calls to explore alternative approaches (Jones & Dexter, 2014; Slama et al., 2021). One such call specific to mathematics teacher professional learning is contained in a white paper by Slama et al. (2021). In their paper, Slama et al. (2021) noted that math teacher learning is in a “steady state” where support for educators in schools and districts is limited to three professional development approaches: professional learning communities (PLCs), instructional coaching, and professional learning workshops. They further noted that these approaches, which they described as tools of the steady state, are prevalent even though there is no strong evidence for their effectiveness or strong educator support for them. They went on to identify different teacher-led math initiatives (including those that are social media-based) that could support teacher learning and called on researchers to examine the impact of these teacher-led initiatives. Such teacher-led, non-formal learning experiences which occur “outside formally structured, institutionally sponsored, classroom-based activities” (Watkins & Marsick, 1992, p. 288, as cited in Macià & García, 2016) have been described as *informal learning*.

Due to the need or pressure to respond to change, a lot of teachers have turned to teacher-led informal learning spaces online (Trust, 2017). These “bottom-up online communities and networks are an important source of professional development” (Macià & García, 2016, p. 291). Teacher-led professional learning has also been shown to be positively linked to student outcomes (Akiba & Liang, 2016). Similarly, while effective PD is essential in teacher learning, teachers attribute a lot of their learning to everyday work experiences, including learning by

doing or trial and error (Kwakman, 2003; Lohman & Woolf, 2001). While there is a lot of learning that takes place online, it is important to note that teacher informal learning is not limited to online spaces (e.g., online communities and networks) only, as informal learning can also be self-directed (e.g., reading articles in professional journals), occur within schools (e.g., informal teacher interactions), in-person educator communities, unconferences, and so on (White et al., 2013; Jones & Dexter, 2014; Carpenter & Linton, 2016).

There is growing attention being paid to informal learning in the broader literature and an increasing acknowledgement of the important role it plays in teacher professional development (Marsick & Watkins, 1990; Eraut, 2004; Jurasaitė-Harbison, 2008; Jacobs & Park, 2009; Lecat et al., 2020). However, despite the amount of research that has focused on teacher informal learning, current gaps in the informal teacher learning literature call for concern. To start with, the effects or outcomes of informal learning are difficult to measure and there are relatively fewer studies that focus on these outcomes compared to other issues related to teacher informal learning (Kyndt et al., 2016). Eraut (2004) also noted that even though informal learning takes place in formal education settings, research on the outcomes of such learning is very limited. There are calls for research that focuses on the antecedents and consequences of informal learning (e.g., Tannenbaum et al., 2010; Kyndt et al., 2016; Lecat et al., 2020); yet the field still remains largely dominated by research that focuses on theory, model development, and descriptive studies (Noe et al., 2013). Besides current disproportionate focus on qualitative research methods, research in the field also tend to be exploratory and limited to understanding specific contexts or environments (Kyndt et al., 2016; Lecat et al., 2020).

More so, Kyndt et al. (2016) pointed out that studies which report the outcomes of informal learning are sometimes vague and lacking in detail; only a few of them specifically

focus on mathematics as well. Furthermore, studies of the impact of online communities and networks on teacher professional development reveal mixed findings (Macià & García, 2016). This study focused on secondary math teachers' perceptions of the effects of informal learning on their knowledge (content, pedagogical, and technological knowledge) and practice. These three knowledge types form the key knowledge domains of the TPACK framework. The TPACK framework suggests that successful implementation of technology in the classroom requires a knowledge of content, technology, and pedagogy (Koehler et al., 2012).

This study is important as it identified the types of informal learning activities that math teachers engage in as part of their continuous professional learning in the course of their daily work. Furthermore, it revealed teachers' perceptions of the effects of these informal learning activities in the areas of content, teaching practices, and technology integration in the classroom. Together, these findings contribute to a deeper understanding of math teachers' perceptions of informal learning and provide some insight into how informal learning can be supported. Studies of teacher informal learning have largely focused on specific contexts and small samples (Kyndt et al., 2016). This study is a shift away from this norm as it is based on a large number of math teacher participants drawn across multiple contexts within the United States.

Purpose Statement

The purpose of this study was to identify the types of informal learning that math teachers engage in during their daily work and examine their perceptions of the effects of informal learning as well as factors affecting it. Specifically, this study sought to: 1) Identify the types of informal learning activities that math teachers engage in as part of their continuous professional learning in the course of their daily work; (2) examine math teachers' perceptions of the factors that support or hinder their informal learning in the workplace; (3) examine math

teachers' perceptions of the effects of informal learning on their content, pedagogical, and technological knowledge and practice; and (4) explore how math teachers' participation in informal learning relate to their self-reported efficacy in select TPACK domains, as well as differ based on teacher career stage. The selected TPACK domains are content knowledge (CK), technological knowledge (TK), pedagogical knowledge (PK), and technological pedagogical content knowledge (TPACK).

Research Questions

This study was guided by the following research questions:

- 1) How do math teachers' participation in informal learning activities relate to their self-reported efficacy in select TPACK domains and differ based on teacher career stage?
 - a) Do relationships exist between math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) and their self-reported efficacy in select TPACK domains (CK, TK, PK, and TPACK)?
 - b) Do math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) differ based on teacher career stage?
- 2) What informal learning activities do math teachers engage in during their everyday practice?
- 3) What are math teachers' perceptions of the factors that affect their informal learning?
- 4) What are math teachers' perceptions of the effects of informal learning on their knowledge and practice?

Overview of Methods

To examine the four research questions, this study employed an explanatory sequential mixed methods design (quan → QUAL). This research design is made up of two distinct phases: the quantitative phase followed by the qualitative phase with the qualitative component having more emphasis in the research design (Morse, 2003; Johnson & Onwuegbuzie, 2004). The first phase involved the collection and analysis of quantitative data related to teachers' self-efficacy in select TPACK domains and their frequencies of participation in different informal learning activities through close-ended survey items; while the second phase involved collecting qualitative data through open-ended survey items, semi-structured interviews, and participants' survey-based journaling to further explain specific quantitative results. Findings from the first and second phases were summarized and combined to give a robust and holistic picture of math teachers' perceptions of the effects of informal learning. Neither of both approaches can give such robust perspectives as a stand-alone. See chapter 3 for a detailed description of the data collection and analysis for each of the components of the study.

Significance of the Study

Teaching is a dynamic profession that is constantly changing and there is a need for teachers to continuously develop in order to keep up with this change (Anderson, 2019). The challenge of helping teachers live up to the demand of the teaching profession warrants that research pays adequate attention to the sources of the different bodies or categories of knowledge (e.g., content knowledge, knowledge of curriculum) that teachers draw upon for teaching. In his seminal paper, Shulman (1987) describes four major sources of these bodies of knowledge (or knowledge bases as he called them): scholarship in content disciplines; the materials and settings of the institutionalized educational process (for example, curricula, textbooks, school

organizations and finance, and the structure of the teaching profession); research on schooling, social organizations, human learning, teaching and development, and the other social and cultural phenomena that affect what teachers can do; and the wisdom of practice itself (p.8).

Although sharing the wisdom of practice is a major part of teacher continuous learning; yet, Shulman (1987) noted that this knowledge source is underutilized while Anderson (2019) suggested that it is rarely captured by formal research and “largely left to be exchanged among teachers outside of formal learning opportunities, infrequently documented, and rarely analyzed” (p. 3). Both Shulman (1987) and Anderson (2019) speak to the untapped potential of informal learning in a way and suggest the need for more research that focuses on teacher informal learning in general.

Also, whereas recent trends in the literature suggest a growing interest in teacher informal learning (Kyndt, 2016; Jacobs & Park, 2009; Lecat et al., 2020); so far, relatively fewer studies have explored the effect or outcomes of teacher informal learning, especially as it relates to how informal learning contributes to teachers subject knowledge (Kyndt et al., 2016). Furthermore, studies that explore the effects of informal learning on teacher learning outcomes and professional development reveal mixed results, tend to be lacking in detail, and mostly employ qualitative methods (Kyndt et al., 2016; Lecat et al., 2020). This study contributes to narrowing gaps in the literature, especially in the context of mathematics as a subject area.

This study identified the types of informal learning that math teachers engage in during their daily work, and examines their perceptions of the effects of such learning as well as factors affecting it. The findings from this study contribute to the literature as they provide rich explanations on the extent to which math teachers find informal learning useful for improving their content, technological, and pedagogical knowledge as well as their practice in general. As

far as I know, this is probably the first study that will attempt to explore possible connections between participation in informal learning activities and math teachers' TPACK self-efficacies. As earlier mentioned, little is known about how informal learning contributes to teachers' content knowledge (Kyndt et al., 2016); hence, this study makes a meaningful contribution in that regard.

This study also revealed factors that support or hinder teacher informal learning in schools. Identifying contextual factors that affect teacher informal learning in the workplace provides insight into how best to support this type of learning. In addition, this study explored possible connections between participation in informal learning activities and teacher career stage. These findings contribute in narrowing possible gaps and strengthening or disproving existing findings about these connections. For example, Rolls and Plauborg (2009) found that few studies have focused on teachers in their mid-career stage while Appova (2009) and Richter et al. (2011) suggest that veteran and more experienced teachers do not learn as much as younger colleagues and they generally tend to be less motivated about learning in the course of their daily practice. This study touches on some of these issues and more.

This study also contributes methodologically to the teacher informal learning literature because it employed a mixed-methods approach in a research area that has been largely dominated by studies that use qualitative research methods. Kyndt et al. (2016) noted that these qualitative studies too, tend to be exploratory and suggest that the field is ready to advance beyond exploratory approaches to begin “building coherent theoretical models that are subsequently tested in larger samples to determine whether generalizations can be made” (p.1141) while at the same time paying attention to specific contexts and teacher biographies. They suggest that a mixed-methods approach is appropriate for such undertaking. Lecat et al.

(2020) corroborate Kyndt et al. (2016) when they stated, “Interviews and questionnaires can give a good overall view on teachers’ learning activities and what is important to them” (p. 10).

Subjectivity Statement

The role of the researcher in qualitative research (and by extension mixed methods research with a qualitative component) positions them as the primary data collection instrument, underscoring the need to identify assumptions, personal values, and biases that the researcher brings to the study (Creswell, 2016). Milner IV (2007) corroborated Creswell’s (2016) point when they noted that “In the process of conducting research, dangers can emerge when and if researchers do not engage in processes that can circumvent misinterpretations, misinformation, and misrepresentations of individuals, communities, institutions, and systems” (p. 1). It is in the light of these and similar voices that call for reflexivity in research that I attempt to describe how my personal experiences, social and demographic characteristics and related issues might influence my research inquiry into math teachers’ perceptions of the effects of informal learning on their knowledge and practice.

Considering the immense contributions of informal learning to my professional growth as a math teacher educator, researcher, and former high school math teacher; I have very strong personal views about teacher informal learning. Hence, this study is very personal to me and I am deeply invested in it. I believe that teachers learn a great deal from informal learning opportunities such as informal communications with colleagues, mentoring, observing other teachers, interacting with their students, and so on, than they do from formal learning opportunities. I believe this is largely the case, differences in teacher characteristics such as age, teaching experience, and grade level, notwithstanding. As such, I assume that a considerable

number of teachers have negative perceptions of formal professional learning opportunities (e.g., professional development workshops).

Another assumption that I bring into this study is the belief that most, if not all teachers use technology in their classrooms. I also assume that most teachers consciously engage with their colleagues both face-to-face and online largely to learn how to improve their practice rather than giving or receiving emotional and learning about issues that are not related to teaching. Additionally, although I have had opportunities to support teacher formal professional development efforts in the US and participated in professional development programs as a high school teacher, my experiences were largely outside the US context.

I acknowledge that some of the issues I have raised so far and certain demographic and social characteristics (e.g., my race, gender, and current position as a Ph.D. candidate) that I bring into this study may have impacted the research process. Specifically, they could have affected the kinds of questions I asked; especially during the interviews, participants' responses, and how I interpreted the data. However, I acknowledged my biases and continually reflected on my positionality throughout the research process.

CHAPTER 2: LITERATURE REVIEW

In this section, I reviewed key issues in the broader teacher professional development literature and made a case for more research that focuses on teacher informal learning. Next, I broadly discussed different conceptualizations of informal learning as well as features and types of informal learning activities based on extant literature. A discussion about the role of teacher informal learning on their professional development was also presented. I concluded the chapter by describing the theoretical underpinnings of the study.

An Overview of Key Issues in Teacher Professional Development

Support for Teacher Professional Development

Guskey (2000) defines professional development as “those processes and activities designed to enhance the professional knowledge, skills, and attitudes of educators so that they might, in turn, improve the learning of students” (p. 16). Thus, the need to attend to teacher professional development as part of efforts to improve teacher quality and student outcomes cannot be overstated. Teacher continuous professional learning is critical if educational reforms targeted at improving teaching practices and student learning must succeed (Cohen & Hill, 2001; Desimone, 2009). There seems to be a consensus regarding the importance of professional development for school improvement considering current efforts both in terms of research, policy, and funding invested in teacher professional development (Akiba, 2012; McCarthy, 2016). In the United States, this was not necessarily the case about three decades ago when Smylie (1996) noted that professional development as practiced then generally had an unfavorable reputation among scholars, policymakers, and educators.

Additionally, the need to support teacher professional development has over the years been acknowledged in national reports such as *A Nation at Risk of 1983*, *No Child Left Behind*

(NCLB) Act of 2002, Every Student Succeeds Act of 2016 and similar reports which call for improvements in student achievement (Eschler, 2016). Bredeson (2003) opines that research reports, policy statements, and legislative mandates in the United States and Europe are testaments to the fact that professional development is seen as crucial to efforts aimed at school improvement around the world. Teacher preparation efforts have also been supported financially. For example, the NCLB makes funds of up to 3 billion dollars aimed at improving teacher qualifications through various means available to states annually (Birman et al., 2009). Among other provisions meant to support teacher qualifications, Birman et al. (2009) noted that the NCLB also requires that ten percent of Title I allocations be channeled towards teacher professional development. Besides state, federal, and other stakeholder support for improving teacher quality, private organizations are also reported to play key roles in teacher preparation (Hightower et al., 2011). Organizations such as the Carnegie Corporation of New York, the Ford Foundation, and the Bill and Belinda Gates Foundation are known for grants that they award Universities and other nonprofit organizations (e.g., Teach for America) involved in different teacher-related research and training initiatives (Hightower et al., 2011; Bill & Melinda Gates Foundation, 2014).

These patterns appear similar on the international level. Based on an international review of the literature on teacher professional development, Villegas-Reimers (2003) noted a significant increase worldwide in both the level of interest in teachers and the support they receive in professional development. The researcher went on to identify various evidences that suggest an increasing interest in and support for teacher professional development: (1) Availability of an extensive body of literature on models and practices of professional development; (2) Acknowledgement of the importance of teacher professional development by

both international and national donor organizations, their commissioning of various studies aimed at exploring how to more effectively support professional development efforts, and their provision of support for implementing programs targeted at improving teachers' professional skills and knowledge; and (3) the inclusion teacher professional development as a key element in the design and/or implementation of most educational reforms.

Teacher Professional Development: Perceptions, Challenges, and Impact

Hightower et al. (2011) identified three key purposes that teacher professional development could potentially serve: “remediating weaknesses in the skills and knowledge of incoming teachers, keeping teachers up to date on emerging developments in the field, or addressing the needs of such specific student populations as English-language-learners or special education students” (p. 12). Whereas there is no doubt that teacher professional development in the United States has received considerable attention both in terms of research, policy, and funding; however, there are challenges that make it difficult to maximize the potentials of teacher PD. For example, U.S investments in teacher professional learning over the years tend to focus on short-term workshops which can hardly improve teaching practices and student achievement (Wei et al., 2009; Darling-Hammond et al., 2017). Although specific teacher PD programs have been shown to improve student outcomes and teacher knowledge, they are limited in scale (Martin et al. 2010). Several studies related to teachers' experiences of PD report challenges such as teachers' disengagement, disinterest, dissatisfaction, and declining participation (Scribner, 1999; Sowder, 2007; Bill & Melinda Gates Foundation, 2014). These studies suggest that many teachers may not have found some of their professional learning opportunities useful for their practice.

Furthermore, despite the amount of focus on teacher professional development, demonstrating how it affects student achievement is difficult even though the connection might seem intuitive (Yoon et al., 2007). Sleeter (2014) also reported this gap in the literature as they found, based on a review of 196 articles published in four leading teacher education journals, that only six percent of studies addressed how teacher education affects teacher practices and/or student learning. Yoon et al. (2007) give a glimpse of the extent of the paucity of research that addresses the impact of teacher professional development on student achievement in detail when they noted:

Of the more than 1,300 studies identified as potentially addressing the effect of teacher professional development on student achievement in three key content areas, nine meet What Works Clearinghouse evidence standards, attesting to the paucity of rigorous studies that directly examine this link. This report finds that teachers who receive substantial professional development—an average of 49 hours in the nine studies— can boost their students’ achievement by about 21 percentile points (p. 1)

The researchers also stated that high-quality professional development is hard to come by even though there have been calls for such programs over the years. This speaks, to some extent, as to why teachers in the United states do not find much of the professional development offered to them useful (Wei et al., 2009). In their report, Wei et al. (2009) noted that American teachers have fewer opportunities for effective sustained, collegial professional development compared to their counterparts in most high-achieving nations. Thus, Yoon et al.’s (2007) study begs the question: what counts as effective or high-quality teacher professional development?

In general, teacher professional development is geared toward improving teachers’ knowledge and skills with the hope of improving teaching practices and then student

achievement (McCarthy, 2016; Hightower et al., 2011). Opfer and Pedder (2011) describe this as the process–product conceptualization of causality and opine that it is the impetus upon which the concentrated attention on professional development in educational research and policy circles rests. They also noted that this straight-forward conceptualization of teacher professional development is dominant and has influenced a large body of research that focuses on the “processes and elements of *effective* professional development—that is, in identifying the features and forms of teacher learning activities that result in changes in teaching practice and, by extension, increases in student learning” (p. 384). Therefore, as a first step to understanding why the amount of attention on teacher professional development has largely not yielded commensurate improvement in teachers’ practices or gains in student achievement, it is helpful to examine the characteristics or features of high-quality teacher professional development. Examining these features are also useful for making sense of teachers’ dissatisfaction with PD reported in different studies (Scribner, 1999; Sowder, 2007; Bill & Melinda Gates Foundation, 2014; Boston Consulting Group, 2014).

Features of High-Quality Teacher Professional Development

Research has identified different characteristics or features of effective professional development- “structured professional learning that results in changes in teacher practices and improvements in student learning outcomes” (Darling-Hammond et al., 2017, p.v). Anderson (2019) suggests that formalizing these features has helped the field establish common standards for supporting teachers’ learning. Among other things, it has also provided a way of identifying benchmarks for addressing concerns about the quality, duration, and impact of teacher professional development, the model notwithstanding.

Whereas there are recent studies that address the quality of teacher professional development, the topic is not particularly new. About three decades ago, Smylie (1996), drawing from theories of adult learning, learning to teach, and “best practices” literature noted that teachers learn best through active learning, problem-oriented learning, and learning opportunities grounded in teacher daily practice, inquiry, experimentation and reflection. The researcher also suggested that teacher learning opportunities should be collaborative, coherent, intensive, and ongoing. Learning opportunities should also be linked, at least to some extent to broader goals for student learning and school improvement. In the same vein, Hightower et al. (2011) mentioned five criteria of teacher professional development that *No Child Left Behind* considers high quality:

- It is sustained, intensive, and content-focused
- It is aligned with and directly related to state academic content standards, student achievement standards, and assessments.
- It improves and increases teachers’ knowledge of the subjects they teach.
- It advances teachers’ understanding of effective instructional strategies founded on scientifically based research.
- It is regularly evaluated for effects on teacher effectiveness and student achievement (pp. 1-2).

Like Smylie (1996) and Hightower et al. (2011), there are numerous other studies that discuss the design features or elements that characterize effective teacher professional development (e.g., Villegas-Reimers, 2003; Borko, 2004; Darling-Hammond et al., 2017). One of the most cited of these studies is a report by Darling-Hammond et al. (2017) which is based on a review of 35 methodologically rigorous studies that showed a positive connection between

teacher professional development, teaching practices, and student outcomes. Darling-Hammond et al. (2017) identified seven commonly shared features of effective teacher professional development: content focus, active learning, collaboration, using models of effective practice, coaching and expert support, feedback and reflection, and sustained duration. The remaining paragraphs in this section briefly describe each of these features largely based on the study by Darling-Hammond et al. (2017).

According to Darling-Hammond et al. (2017), *content-focused* professional learning is discipline-specific, job-embedded, and is intentionally focused on the curriculum and priorities of the district or state where the professional development is conducted. Furthermore, Darling-Hammond et al. (2017) also suggest that the nature of content-focused professional development creates opportunities for teachers to analyze students' work, explore new curricula and specific components of pedagogy or student learning in a content area. With respect to student work, researchers suggest that meaningfully engaging teachers in looking at student work, especially collectively can offer great opportunities for teacher learning (Little et al., 2003; Silver & Suh, 2014).

Professional learning opportunities that incorporate *active learning* involve teachers' engagement with the same learning activities as their students as they design and try-out teaching practices (Darling-Hammond et al., 2017). In contrast to traditional PD models that tend to be lecture-based, this type of PD employs artefacts, activities that are interactive in nature, and other techniques to create professional learning experiences that are strongly rooted in teacher practice and classroom context. Besides content focus and active learning, PD which effectively incorporates a *collaborative* component as part of the model design so that teachers have opportunities to engage in problem-solving as a group while learning together can lead to gains

in student achievement. This collaboration could be one-to-one, based on small group interactions, schoolwide or involve professional collaboration that transcends school boundaries. 32 out of the 35 studies that Darling-Hammond et al. (2017) reviewed used one form of collaboration or the other to support teacher learning; it was not clear whether or not the remaining three had an element of collaboration.

Research has shown that the *use of models* (both curricular and instructional) of effective teacher practice and *modelling* of instruction foster teacher learning and support student achievement (Darling-Hammond et al., 2017). It can also assist teachers in developing a vision of practice that could direct or serve as a foundation for their learning and professional growth. Examples of modelling include lesson plans, peer observation, video and written cases of teaching, and curriculum materials (e.g., student work samples, sample assessments). Kennedy (2016) opined that more will be learnt from studies when research designs and PD models are tied more closely to underlying theories of teacher motivation and learning.

Expert scaffolding including coaching support teachers in effectively implementing new curricula, teaching strategies, and tools (Gallagher et al., 2017; Penuel et al., 2011; Roth et al., 2011, as cited in Darling-Hammond et al., 2017). Coaches and experts— who tend to be educators themselves— play important roles in guiding and facilitating context-based teacher learning. This includes sharing content expertise, evidence-based practices, modelling instructional practices, supporting group discussion and collaborative analysis of student work. Overall, 30 of the 35 studies reviewed by Darling-Hammond et al. (2017) provided coaching or expert support to educators.

The last two design features of effective PD that Darling-Hammond et al. (2017) described are feedback and reflection and sustained duration. Effective professional development

models often involve built-in time for teachers to reflect, receive feedback on, and make changes to their practice. Feedback and reflection are commonly engaged in mentoring and coaching teachers and have proved useful for moving them toward expert visions of practice learned or modelled in the course of PD. They are also important parts of adult learning theory.

Finally, yet importantly, time and quality implementation are critical in providing effective teacher professional development (Darling-Hammond et al., 2017). Whereas there is no clear evidence with regards to the duration of effective PD models, research has shown that short-term workshops hardly bring about meaningful changes in teacher practice. To capture this in Darling-Hammond et al.'s (2017) voice- “professional development that is sustained, offering multiple opportunities for teachers to engage in learning around a single set of concepts or practices, has a greater chance of transforming teaching practices and student learning” (p.15). It is important to note that all the PD initiatives described in Darling-Hammond et al. (2017) occurred over an extended period of time, none happened in a single encounter.

Consolidating Teacher Learning: Making a Case for Teacher Informal Learning Research

Formal teacher learning opportunities (or formal PD) are classroom-based, institutionally funded, and take place within formal structures or learning environments (Richter et al., 2014; Macià & García, 2016). Whereas there is no consensus in the field regarding the definition of informal learning (more on this shortly), key features of informal learning are well-known (Lecat et al., 2020; Huang et al, 2020). Informal learning tend to be teacher-led, non-formal learning experiences which occur “outside formally structured, institutionally sponsored, classroom-based activities” (Watkins & Marsick, 1992, p. 288, as cited in Macià & García, 2016). It is unstructured and unlike formal PD, especially in the U.S, it is non-mandated, and it does not follow a specified curriculum (Richter, 2014).

Researchers agree on the main characteristics that effective professional development models share in common; yet, formal teacher professional learning opportunities continue to be associated with challenges such as teachers' disengagement, disinterest, dissatisfaction, and declining participation (Scribner, 1999; Sowder, 2007; Bill & Melinda Gates Foundation, 2014; Anderson, 2019). Anderson (2019) opined that teacher dissatisfaction with PD provided by their schools may not be unconnected to the absence of teacher voice and made a case for teacher-directed learning. The researcher further pointed out the benefits (e.g., higher teacher satisfaction, gains in student achievement) when teachers guide their own learning and noted that most PD that take place in schools do not make room for teachers to influence their own learning (Boston Consulting Group, 2014; Darling-Hammond, 2017; as cited in Anderson, 2019).

In the same vein, whereas teacher PD has received considerable attention in both research and policy as earlier mentioned, for a long time, the focus was largely on formal teacher learning opportunities. These formal teacher learning opportunities are based on the *traditional view* of teacher PD- the notion that teachers acquire skills and knowledge and update the same by attending workshops and courses (Richter et al., 2014). Besides the fact that teachers rarely have a say about the content and format of formal PD opportunities offered to them, probably the most common model of PD that U.S teachers tend to access are short-term workshops (Wei et al., 2009; Darling-Hammond et al., 2017). Research has shown that these workshops are unlikely to meaningfully improve teacher practices or student achievement. There are also difficulties that arise from the fact that formal PD tend to hold within fixed times and geographical locations (Jones & Dexter, 2014).

Opfer and Pedder's (2011) conceptualization of teacher learning from a complexity theory viewpoint assumes that the same learning effects can be achieved through multiple means

and that the factors that support teacher learning can vary across contexts and personalities. This suggests that teacher learning can stem from different sources— both formal and informal learning opportunities- and that some teachers may find certain professional learning opportunities more useful for improving their practice than others. Thus, to move the field forward and consolidate the research on teacher learning, research that explores the contributions of teacher *informal learning* to their practice and possible implications for student learning is valuable.

Slama et al. (2021) also stated that math teacher learning is in a “steady state” where support for educators in schools and districts is limited to three PD approaches: professional learning communities (PLCs), instructional coaching, and professional learning workshops; and noted that these approaches are prevalent even though there is no strong evidence for their effectiveness or strong educator support for them. They went on to challenge the field to examine the impact of teacher-led math initiatives (including those that are social media-based) that could support teacher learning.

Many researchers also agree that informal learning opportunities can be authentic sources of teacher learning (Little, 1993; Borko, 2004; Richter et al., 2011; Akiba, 2012; Akiba and Liang, 2016) and also support teacher continuous learning which has been identified as a key predictor of teacher professional development, student learning, and school improvement (Day et al, 2007; Darling-Hammond, 2008; Opfer & Pedder, 2011; Huang et al., 2020). For example, Richter et al.’s (2011) definition of professional development encompasses both the formal and informal learning opportunities that contribute to teachers’ professional competency. Furthermore, Akiba and Liang (2016) examined the effect of six types of teacher professional learning activities (professional development, teacher collaboration, university courses,

professional conference, informal communication, and individual learning activities) on student achievement growth over a 4-year period using hierarchical linear modelling and found positive associations between school average amount of participation in three types of teacher professional learning activities (teacher collaboration, professional conferences, and informal communication) among teachers and student achievement growth. Akiba and Liang's (2016) study demonstrates the promise that informal teacher learning holds for teacher professional development and student achievement. Broadly speaking, informal learning has also been shown to be useful in bringing about behavioral change (Garavan et al., 2002; Lohman, 2005; Huang et al., 2020).

So far, several reasons why the field needs to pay attention to teacher informal learning have been described. Two additional pointers to this need are the amount of time that teachers spend learning informally and the role that teacher informal learning can play in making up for possible limitations of formal PD. With respect to time, Akiba (2012) found that middle school teachers spent the majority of their PD time on collaboration, professional development programs, and individual learning activities. A similar study by McCarthy (2016) investigated the different types of learning activities that middle and high school mathematics teachers engage in for their professional development and found that teachers spent most of their time on informal learning activities. Both studies suggest that teachers spend more time engaging in informal learning activities like collaboration and individual learning (e.g., reading professional journals, searching for online resources). This evidence is consistent with Eraut (2004) who noted that informal learning occurs more often than formal learning.

Jones and Dexter's (2014) study draw attention to how some limitations of formal PD make teachers consider informal professional learning options. The researchers investigated

teachers' experiences of how the combination of different modes of learning (formal, informal, and independent learning) about technology integration in two schools helped them overcome the relative constraint of each mode; and found that teachers' effort to learn about technology integration was motivated by the limitations of the formal system for learning put in place by their respective school leaders. Some of these limitations include decisions about the scheduling and content of PD being determined by the school and not the teacher, lack of alignment between scheduling and teacher need, a "whole group" approach to PD which makes it difficult to address specific issues of content, skills, etc. Additionally, research has also shown that informal learning initiatives tend to be teacher-led, flexible, collaborative, focused on specific issues of practice, and encouraging of teacher agency and autonomy; these features are sometimes missing or less emphasized in formal PD (Jones & Dexter, 2014; Akiba & Liang, 2016; Trust, 2017). Thus, informal learning opportunities prioritize teacher voice and sometimes embody some key features of effective teacher PD.

Informal Learning: Conceptualizations, Forms, Features, and Other Issues

According to Lecat et al. (2020), researchers differ in regard to how they view informal learning. As a result, there are multiple definitions and conceptualizations of informal learning that exist in the literature. While some researchers define informal learning in terms of its features (e.g., accidental, spontaneous, implicit, self-directed), others define it in terms of learning activities (e.g., reflection, trial-and-error, feedback-seeking). More so, the approaches to informal learning also differ among scholars. Some describe informal learning in terms of its stimulus while others focus on the types of informal learning activities. Due to a lack of consensus on the definition of informal learning amidst calls for a common definition, several partially overlapping definitions are used. Lecat et al. (2020) also noted that informal learning is

already difficult to capture because it could sometimes take place unconsciously and the lack of a common definition makes measuring informal learning problematic, further compounding the irregularity and misalignment in the extant educational literature.

Eraut's (2010) discussion of some of the main problems associated with studying informal learning in the workplace further corroborate Lecat et al.'s (2020) assertion about the difficulties and complexities of informal learning research. Eraut (2010) highlighted three key problems associated with studying informal learning research:

- informal learning is largely invisible, because much of it is either taken for granted or not recognized as learning; thus, respondents lack awareness of their own learning;
- the resultant knowledge is either tacit or regarded as part of a person's general capability, rather than something that has been learned;
- discourse about learning is dominated by codified, propositional knowledge, so respondents often find it difficult to describe more complex aspects of their work and the nature of their expertise (p. 249)

Eraut (2000, 2004) viewed learning in terms of a continuum of formality such that informal learning leans toward the informal end than the formal end of the continuum. The informal end of the continuum is characterized by implicit, unintended, opportunistic and unstructured learning which take place without the need for a teacher. Mentoring belongs in the middle while a learning activity like coaching is largely formal in the majority of settings.

Eraut's (2004) description of the different informal learning types encompasses workplace learning in general, not just teacher informal learning. Eraut's description of implicit learning is based on Reber (1993) who defined implicit learning as "the acquisition of knowledge independently of conscious attempts to learn and in the absence of explicit knowledge about

what was learned” (p. 250). The researcher also makes a distinction between *reactive or opportunistic* learning which is largely spontaneous and *deliberative* learning which is much more intentional. While *reactive* learning is intentional, it occurs in the midst of a situation when there is scarcely any time to think. However, in *deliberative* learning, a specific learning objective is identified, and time is also set aside for the acquisition of new knowledge and engaging in *deliberative* learning with a definite work-related objective and learning as a potential consequence of the process. Theisinger’s (2017) explanation of Eraut’s informal learning types captured the role of the learner succinctly: informal learning is “deliberative, where the learner methodically plans learning opportunities; reactive, where the learner intentionally seeks a solution to a problem or question in the moment; and implicit, where the learner is not conscious learning has taken place” (p. 31).

In line with Billett (2004), Hoekstra et al. (2009) defined informal learning as ‘learning taking place where no PD trajectory or learning community has been explicitly organized to foster teacher learning’ (p. 76). This definition describes informal learning in terms of its features— suggests that informal learning is unstructured and possibly teacher-led. Jurasaitė-Harbison (2009) noted that informal learning is unplanned or spontaneous but added that it can stem from multiple sources and involve multiple contexts. The researcher further acknowledged the valuable role that participation and interaction in a community of practice plays in creating a working environment and motivating individuals to engage in informal learning.

Similarly, Richter et al. (2014) also highlighted additional features of informal learning while contrasting between formal and informal learning opportunities. Drawing from the works of several scholars (e.g., Putnam & Borko, 2000; Eurydice, 2008; Desimone, 2009); the authors noted that informal learning does not follow a specified curriculum, it’s not restricted to specific

contexts, it is teacher-led, and more often than not, it is embedded in the classroom or school context, and is generally non-mandated. Although their study focused primarily on two informal learning opportunities— teacher collaboration and the use of professional literature; they identified and described different example of informal learning. These include learning from classroom observations, conversations with colleagues and parents, mentoring activities, teacher networks, and study groups.

Marsick and Watkins (1990) differentiated between informal and incidental learning. They identified additional features of informal learning which align with those described in studies such as Richter et al. (2014) and Lecat et al. (2020). These include the fact that informal learning is learner-led, unstructured, and typically not classroom-based. Examples of informal learning that they identified include self-directed learning, networking, coaching, and mentoring; while examples of incidental learning include learning from mistakes or from trial and error. Furthermore, their description suggests that informal learning can be affected by different factors. Some factors that affect teacher informal learning and its antecedents are discussed in the next subsection.

For the purpose of this study, I define teacher informal learning in contrast to formal learning broadly as unstructured, unplanned, and loosely organized activities that teachers intentionally or unconsciously engage in in the course of their daily activities to acquire knowledge and skills related to their practice (Marsick & Watkins,1990; Eraut, 2004; Huang et al., 2020). This type of learning happens largely in the workplace (the school in this case); however, it transcends school walls. It can involve one person (e.g., trial and error, self-directed learning) or more than one person (e.g., mentoring, informal conversations); take place in in-

person settings (e.g., teacher lounges, classrooms) or online (e.g., teacher online communities and networks, looking for teaching resources on the internet).

Factors, Antecedents, and Motivation

Teachers' willingness to learn is a key factor and a prerequisite condition for their learning (Collinson & Cook, 2004; Rytivaara & Kershner, 2012, as cited in Kyndt et al., 2016). Teacher characteristics (age, work engagement, and stage teachers are in their career) have also been identified as factors that could influence preference for formal or informal learning opportunities. Richter et al. (2014) investigated 1939 German teachers' uptake of formal (in-service training as an indicator) and informal learning (teacher collaboration and professional literature as indicators) opportunities over a 2-year period and found that teachers tend to collaborate more at the beginning of their career than at the middle or toward the end of their careers. They suggested this could be because of early career teachers' eagerness to learn from the professional experiences and expertise of those teachers with more experience than them. The researchers also found that older teachers were more drawn to reading professional literature as a means of professional learning. They explained this in terms of older teachers being drawn more towards self-directed learning. Their study also found that teachers who had management responsibilities and those with higher work engagements paid more attention to in-service training. The context of this study is Germany, where PD participation is voluntary; as such, some of the conclusions may not hold for countries like the United States where teacher PD is mandated.

Richter et al. (2014) found that early career teachers were eager to learn from more experienced colleagues. However, Colognesi et al. (2020) contradicted this finding as their study showed that beginning or early career teachers do not necessarily rely on more experienced

colleagues; instead, they tend to turn to other novice teacher colleagues for help. The researchers noted that this action could be because novice teachers feel psychologically safe with their novice colleagues, as there is no fear of being judged or evaluated.

On their part, Jurasaitė-Harbison and Rex (2010) examined how school cultures support or hinder opportunities for teacher informal learning based on an ethnographic study of three schools: an elementary school in Midwestern United States, an elementary school in Russia, and a secondary school in a large city in Lithuania. They found that the interaction among school traditions, physical environments, leadership styles, and professional relationships appeared to influence school cultures around informal learning. These cultures in turn determined which opportunities for informal learning teachers embraced.

Studying the antecedents of informal teacher learning is useful for understanding how it can be supported, promoted, and advanced (Marsick & Volpe, 1999, as cited in Kyndt et al., 2016). In their review of the antecedents of teacher informal learning that occurs in the everyday practice of teachers in schools, Kyndt et al. (2016) organized the antecedents of employee learning based on three levels using Baert et al.'s (2006) model: the micro, meso, and macro levels. The micro level encompasses individual characteristics e.g., personality, attitude, age, educational background, and job characteristics (e.g., allocation and job design). The meso-level relates to the learning activity e.g., instructional design and anticipated benefits. Lastly, the macro-level involves organizational factors. Since the antecedents in Kyndt et al.'s (2016) study relates to schools, these factors include school culture, social support, community, and so on.

The studies discussed so far have highlighted different factors that affect teacher informal learning mostly in the school context. However, the school is not the only space where informal learning takes place as teachers also learn as they participate in online spaces (e.g., online

communities and networks). Whereas participation in an online space does not necessarily translate into learning, there is a likelihood that the factors which affect teacher participation and their level of engagement online might be relevant to the discussion about factors that affect teacher informal learning online. Macia and García's (2016) review identified different issues relevant to understanding participation in online communities and networks. Some of these include social factors influencing participation, barriers to participation, establishing dialogues for participation, and community moderation.

Varanasi et al. (2021) found that apart from sharing professional resources via WhatsApp; about 34% of posts that teachers shared were spam or malicious messages. They also noted how offensive content (e.g., messages that cast someone's religion in bad light) made some teachers leave the WhatsApp group, and the role that school management personnel (moderators) played in discouraging such anti-social behaviors (e.g., calling out individuals, reminding members of community guidelines). The researchers also described how moderators used different creative structures to encourage participation (e.g., emoji-only interactions, posting messages in English and sending follow-up audio messages in Hindi). Thus, Varanasi et al.'s (2021) study speaks to the importance of moderation in communities and networks. Macia and García (2016) noted that moderation is especially important at the inception of a community, but that advanced communities tend to share leadership role among all participants. Similarly, other studies like Patahuddin and Logan (2019) as well as Larsen and Parrish (2019) discussed teachers' engagement and the types of activities they engaged in online. Together, these studies suggest that teachers engage in different types of activities and that their level or depth of engagement or participation can vary based on different factors.

Other studies have also pointed out different factors that motivate teachers to engage in informal learning, and it seems that key motivating factors (e.g., acquiring professional knowledge and getting emotional support) are not necessarily unique to the format of the informal learning structure (whether online or in-person). Carpenter and Linton (2016) investigated teachers' motivation for attending Edcamps and coded the reasons that teachers gave for attending into four broad categories: content (what), process (how), people (who), and Logistics (where). "Content factors" pertained to things that respondents hoped they will learn about (e.g., issues related to teaching strategies, technology); "process factors" addressed issues related to the way Edcamps are organized and run (e.g., issues related to collaboration, curiosity, participant-driven nature of Edcamps); "people factors" highlighted factors related to connecting with people that attend Edcamps; while "logistics factors" captured issues related to the cost of Edcamps and where they held (location) as they influenced decisions about attendance. The researchers found that most educators were motivated by "content (who)" factors, while reasons related to logistics were the least reported.

The researchers suggested that teachers' interest and participation in informal learning activities are sometimes driven by core features of informal learning as they found that the collaborative, participant-driven and affective nature of Edcamps were part of the factors that motivated many teachers to attend. The researchers also claimed their findings suggest a significant demand for PD opportunities that are collaborative and participatory in nature. The fact that informal PD opportunities are known to embody some of these desired features could be a plausible reason for the increasing interest in informal learning opportunities. Previous research has pointed out that educators tend to prefer participant-driven, teacher-led PD, and like to feel in charge of their own learning (Bond, 2015; Carpenter & Linton, 2016).

While educators are sometimes drawn to the affordances of informal learning because of how they are organized or run, educators could sometimes have concerns about design features as well. For example, Carpenter and Linton (2016) reported that some of the participants in their study had concerns about the Edcamp model itself. One such concern is that participants define the topics for each Edcamp breakout session on the day of the event. The implication is that facilitators may not be ready with ideas and resources that teachers could take home. However, it is not clear how this design feature affects participation in Edcamps or teacher learning.

Role of Informal Learning in Teacher Professional Development

Kyndt et al.'s (2016) review of informal learning outcomes identified three broad areas within which informal teacher learning outcomes could be situated: subject knowledge, pedagogical knowledge and skills, and professional attitudes and identity. To start with, Hoekstra et al. (2009) explored relations between informal learning activities that 32 experienced teachers engaged in and teacher learning outcomes. The results of the study found correlations between observed changes in behaviour and conceptions of students' active and self-regulated learning (ASL) and specific informal learning activities.

According to Hoekstra et al. (2009), ASL rests on three key components- self-regulated learning, active construction of knowledge, and the social nature of learning. In self-regulated learning, students direct their own learning through the active regulation of cognitive learning activities in the pursuit of their study goals. Active construction of knowledge suggests that students are involved in the process of knowledge construction through active engagement in activities which help them link pre-existing knowledge to new information, while the social nature of learning speaks to the place of student collaboration in learning. Thus, ASL-oriented

pedagogy “involves teachers becoming facilitators of students' learning processes and assisting students in developing their own learning strategies” (p. 664).

Specifically, the researchers found that changes in teachers' conceptions of ASL seemed to be associated with informal learning activities such as acquiring new ideas, experimenting with new methods, and reflecting on issues of practice. Research has also shown that teacher lounges and other congregational spaces where teachers meet can be useful for professional knowledge sharing, gaining collegial support, building teaching confidence, collaborating on projects, discussing issues of practice, and developing professional skills (Paine et al., 2003; McGregor, 200, as cited in Lynnette, 2010).

Lynnette (2010) suggests that teaching is an isolated profession and that informal interactions in congregational spaces (e.g., teacher lounges) can provide the kinds of support that teachers need as they learn from each other through professional knowledge sharing. They added that such informal interactions can be a source of “spontaneous” professional development. The main limitation of Lynnette's (2010) study is that it is based on teachers' perceptions, it does not address how the professional knowledge sharing that takes place as teachers engage in informal interactions affects what takes place in the classroom. However, Akiba and Liang (2016) suggest that such informal interactions may in fact impact classroom practices as their study found positive associations between school average amount of participation in three types of teacher professional learning activities (teacher collaboration, professional conferences, and informal communication) among teachers and student achievement growth.

Meirink et al. (2009) investigated the learning activities of 34 Dutch secondary school teachers with respect to their relation to changes in beliefs about teaching and learning over a one year period. The study found that teacher informal learning activities such as collaboration with

colleagues can bring about changes in teachers' personal beliefs or views (Meirink et al., 2009). The study by Meirink et al. (2009) is important especially because research has shown that teacher beliefs tend to be deeply entrenched and difficult to change (Pajares, 1992). Additionally, modifying teacher beliefs is essential for successfully implementing educational reforms (Meirink et al., 2009).

Research has also shown that informal learning contributes to teachers' technical skills (Van Eekelen et al., 2016) and could be instrumental in bridging possible gaps in teachers' content knowledge while on the job (Fraser, 2010; Kyndt et al., 2016). Besides contributing to teachers' content knowledge, informal learning also contributes to the development of teachers' professional identity and emotional wellbeing (Burns and Schaefer, 2003; McNally et al., 2009, as cited in Kyndt et al., 2016). Different studies that report teachers' learning in the area of technology also suggest that teachers find informal learning activities useful for learning how to use technology in their classrooms (Matteson et al., 2003; Kessler, 2007; Voogt, 2010, as cited in Theisinger, 2017). Furthermore, Theisinger (2017) suggests that a large number of teachers may be learning to use technology in ways that mirror informal rather than formal learning.

While most of the studies on the role of informal learning in teacher professional development described so far largely focus on the school context, teachers' engagement in different in-person (e.g., mathematics teacher circles, Edcamps) and online informal spaces (e.g., Twitter, Facebook) outside school environments also contribute to their professional development. Several research studies have shown that teachers engage in informal online spaces to grow their practice through the sharing and receiving of professional knowledge, avoid feeling isolated, and support each other emotionally (Carpenter & Krutka, 2014; Gannon-Leary & Fontainha, 2007; Hur & Brush, 2009; Kelly & Antonio, 2016; Lin, Lin, & Huang, 2008;

Schlager et al., 2009; Seo, 2014; Seo & Han, 2013; Trust, 2013; as cited in Carpenter & Linton, 2016). For example, Varanasi et al.'s (2021) study of WhatsApp-based teacher networks in low-income Indian schools showed that teachers used different features of WhatsApp to share professional resources such as highlights and summaries of workshops that they attended with each other and celebrate each other's achievements.

Similarly, Trust (2017) investigated how Edmodo (an informal online space for educators) influenced educators' learning and practice. Their study found that 90% of teachers reported that participating in the Edmodo community changed the strategies they employed in teaching and learning. Several participants also noted that participating in the community instilled a greater sense of responsibility for their own learning in them and spurred them to adopt innovative practices related to the use of technology and student-centered pedagogy.

On their part, White et al. (2013) investigated whether participating in a four to five-day intensive mathematics teacher circle (MTC) workshop held across three sites impacted teachers' mathematical knowledge for teaching. Data for their study was obtained using the Learning Math for Teaching (LMT) instrument: an instrument designed to measure certain facets of Mathematical Knowledge for Teaching (MKT). The researchers found that LMT scores for Number Concepts and Operations improved across all three sites and concluded that MTC is effective to some extent in improving teachers' mathematical knowledge for teaching.

While there is some research that focuses on the outcomes of informal learning, they are relatively sparse, largely based on qualitative studies, the results are mixed, and they tend to be lacking in detail (Kyndt et al., 2016; Lecat et al., 2020). This study employed a mixed methods approach to investigate teachers' perceptions of the effect of informal learning on their content, pedagogical, and technological knowledge. From the preceding paragraphs in this section, it is

clear that there are different aspects of the outcomes of informal teacher learning. This study specifically focused on teachers' perceptions of the effects of informal learning as it relates to two of the three broad areas of outcome that Kyndt et al. (2016) described- subject knowledge and pedagogical knowledge and skills, and a third area, teachers' technological knowledge.

Theoretical Background

Inquiry Worldview

The theoretical perspective for this study involved a positivist and interpretivist/constructivist perspective for the quantitative and qualitative components respectively. In the quantitative phase, I employed correlation analysis, regression analysis, and analysis of variance (ANOVA) based on survey data to explore how math teachers' levels of participation in informal learning activities relate to their self-reported efficacy in select TPACK domains (CK, TK, PK, and TPACK) and differ based on teacher career stage. In the positivist quantitative phase, the researcher is said to control the research process and is external to the research site (Creswell, 2008; Taylor & Medina, 2011). In the qualitative phase, I relied on study participants' views to identify the types of informal learning that math teachers engage in in the course of their daily work and examine their perceptions of the effects of informal learning as well as factors affecting such learning. In the interpretivist/constructivist qualitative phase, I acknowledged the potential impact of my positionality on the research process and was reflexive throughout (Mackenzie & Knipe, 2006).

Theoretical Framework

In keeping with pragmatic philosophy, two key frameworks relevant to the research questions were used to frame the research study and better understand math teachers' perceptions of the effects of informal learning on their knowledge and practice. The first framework is

Marsick and Watkins's (1990) informal and incidental learning model while the second is the Technological, Pedagogical, and Content Knowledge (TPACK) framework. The first framework provides a foundation for conceptualizing informal workplace learning, different types of activities that teachers engage in as they learn informally, and a basis for making sense of instruments that measure the level of teachers' participation in different informal learning activities. In the same vein, the second framework identifies different knowledge bases and how their combination results in the kind of knowledge that teachers require to effectively integrate technology in the classroom. It also serves as a basis for making sense of instruments which assess teachers' self-reported efficacy in different knowledge domains as captured in the framework.

Informal Workplace Learning

Whereas scholars in the field have drawn upon a myriad of models and theories for their work, current understandings of informal workplace learning have been largely shaped by the works of Victoria Marsick and Karen Watkins who are leading workplace learning researchers (Cofer, 2000). This study adopts a largely workplace-based conception of informal teacher learning based on the works of these two researchers (Marsick & Watkins, 1990, 1992, 2001) and categorizes teacher informal learning activities based on the classifications presented in Huang et al. (2020) and Noe et al. (2013). The details of each are described in subsequent paragraphs.

Marsick and Watkins (1990) defined informal learning in contrast to formal learning as follows:

Formal learning is typically institutionally sponsored, classroom-based, and highly structured. Informal learning, a category that includes incidental learning, may occur in

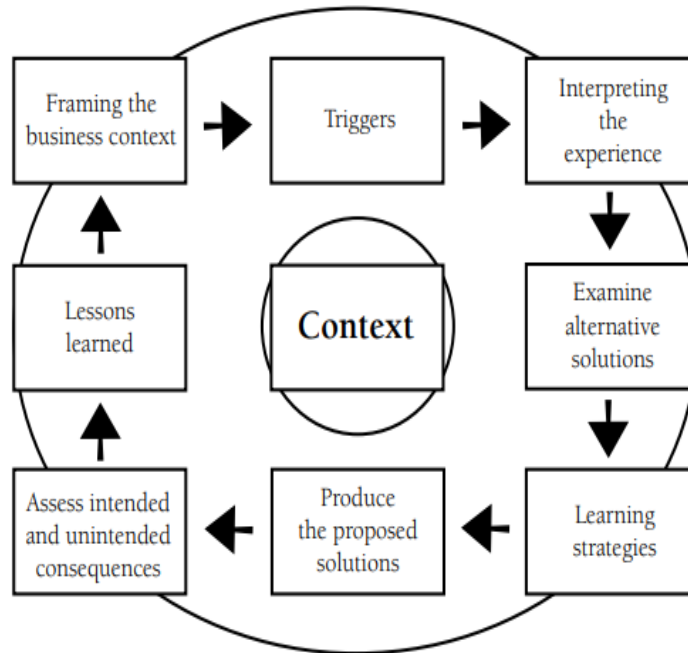
institutions, but it is not typically classroom-based or highly structured, and control of learning rests primarily in the hands of the learner. Incidental learning is defined as a byproduct of some other activity, such as task accomplishment, interpersonal interaction, sensing the organizational culture, trial-and-error experimentation, or even formal learning. Informal learning can be deliberately encouraged by an organization or it can take place despite an environment not highly conducive to learning. Incidental learning, on the other hand, almost always takes place although people are not always conscious of it (p. 12).

Marsick and Watkins (1990, 2001) noted that informal learning is more often than not incidental; however, it is not highly structured. They also noted that incidental learning may not be easily recognized because it is tacit or unconscious. Thus, their description of incidental learning resembles Theisinger' (2017) description of implicit learning as a form of learning where the learner is not conscious of the learning taking place. Marsick and Watkins (2001) describe informal learning as “self-directed learning, networking, coaching, mentoring, and performance planning that includes opportunities to review learning needs” (pp. 25–26).

Marsick and Watkins' model was initially developed in 1990 but has undergone modifications based on findings from studies which tested the model, the current revision being based on the work of Cseh (1998).

Figure 2.1

Marsick and Watkins's Informal and Incidental Learning Model as Adapted with Cseh



Note. Re-conceptualized Model for Informal and Incidental Learning From "Theory and Practice of Informal Learning in the Knowledge Era," by V.J. Marsick, M. Volpe and K. E. Watkins, 1999, *Advances in Developing Human Resources*, 29, p. 91. Copyright by SAGE Publications.

According to Marsick and Watkins (2015), the reconceptualized model (see Figure 2.1) emphasizes the significant role that context plays in informal workplace learning and is based on the belief that people (in my case teachers) learn from the everyday experiences and encounters they are exposed to in the course of living and working in a given context. This is depicted by the inner circle. The outer circle represents the context (e.g., personal, social, business, cultural) within which learning takes place. The context is believed to influence the interpretation of experiences, choices made, or actions taken as well as the learning that happens.

Whereas the model takes a circular form, the authors noted that the steps are not necessarily linear or sequential. In making sense of a situation or experience, the process of

meaning-making is more of an ebb and flow as new insight may have learners going back to question earlier understandings. The model also captures the incidental learning process which the authors assert is always happening, whether the learner is conscious of it or not. The model suggest that learning begins with a trigger, this is more often than not an abrupt internal or external stimulus which results in dissatisfaction with the learner's state of thinking or being. This new trigger or experience is then interpreted based on comparison with prior experiences. Different factors influencing interpretation in the context within which the experience is happening are also attended to. This results in choices about alternative actions or solutions that could be considered; choices could be driven by recollecting solutions that have worked in the past or searching for new ones.

After a course of action has been taken or a solution produced, the next step involves determining whether expected goals or intended outcomes have been achieved. The analysis of whether or not the intended outcomes have been achieved is used to ascertain what lessons have been learned. The lessons learned are then carried over and employed in future decisions, forming part of the new frame, worldview or understandings with which the learner approaches new situations or experiences. The cycle begins all over again.

Huang et al. (2020) drew upon Marsick and Watkins' (2001) understanding of informal learning to distinguish between learning by interaction and learning through reflection to categorize informal learning activities into five types. These are learning through: (1) media, (2) colleague interaction, (3) stakeholder (e.g., parents and friends) interaction, (4) student interaction, and (5) individual reflection (Kwakman, 2003; Henze et al., 2009). Noe et al. (2013) used a broader classification (learning from others, learning from non-interpersonal sources and learning from oneself). Learning from media as described in Huang et al. (2020) aligns with

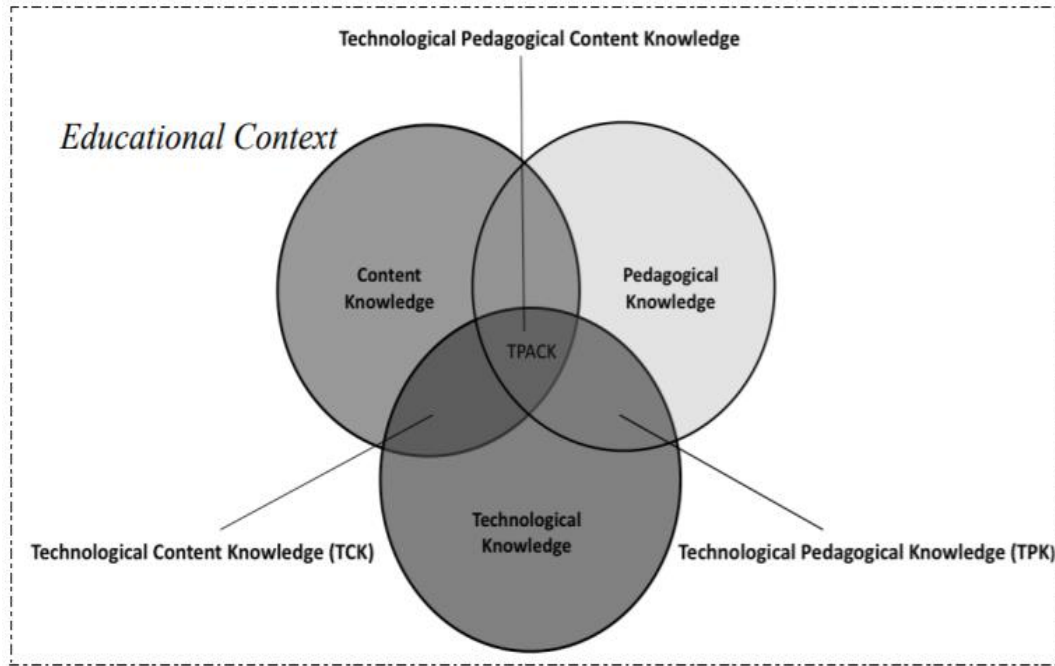
learning from non-interpersonal sources as presented in Noe et al.'s (2013) study; colleague, stakeholder, and student interaction correspond to learning from others; while individual reflection aligns with learning from oneself.

Technological Pedagogical Content Knowledge (TPACK)

The Technological Pedagogical Content Knowledge (TPACK) framework was developed by Mishra and Koehler (2006) based on Schulman's (1986) idea of pedagogical content knowledge (PCK). Cox (2008) noted that "the foundation of PCK is that general pedagogical knowledge and knowledge about content exist independently, but the overlap of these two knowledge domains creates a new type of knowledge—how to teach particular subject matter content—that is unique to teachers" (p. 1). TPACK is based on the idea that the knowledge that teachers need to effectively implement technology in their classrooms is multifaceted and is an optimal combination of the knowledge of content, pedagogy, and technology (Cox, 2008). Hervey (2015) stated that "TPACK blends the use of appropriate technology in a particular content area as part of a pedagogical strategy within a given educational context to develop students' knowledge of a particular topic or meet an educational objective or student need" (p. 18).

Figure 2.2

The Technological, Pedagogical, and Content Knowledge (TPACK) Model



Note. From “Technological pedagogical content knowledge: A framework for teacher knowledge,” by P. Mishra and M. J. Koehler, 2006, *Teachers College Record*, 108(6), p. 1017-1054. Copyright by the Teachers College, Columbia University.

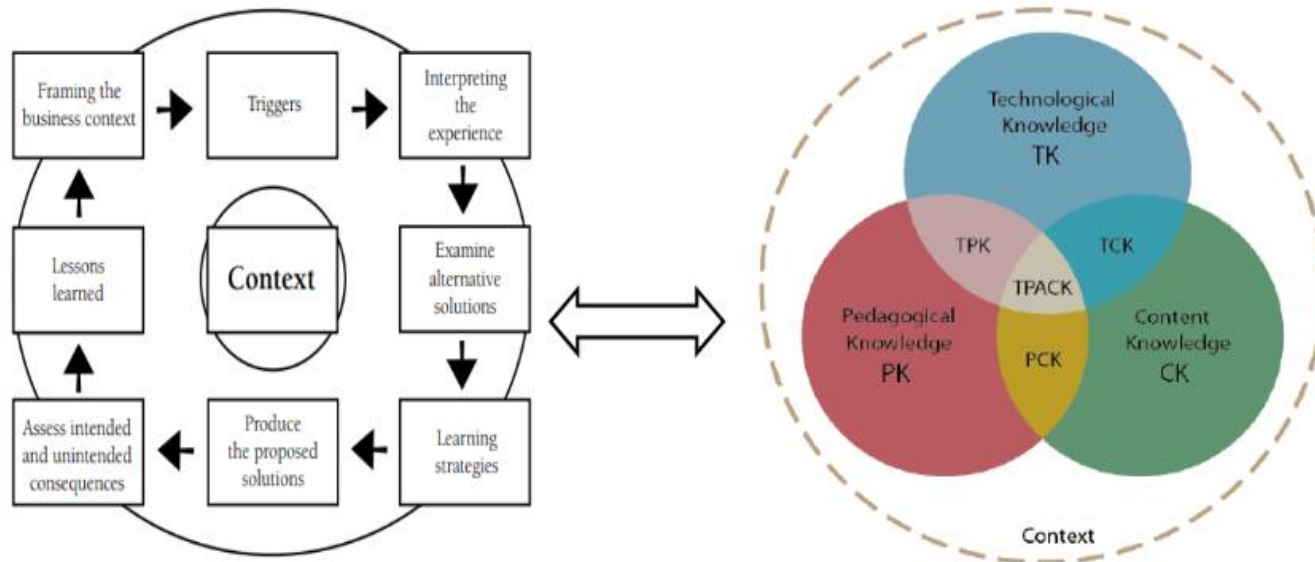
The overlap of the content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) create new knowledge domains: Technological content knowledge (TCK), Pedagogical content knowledge (PCK), Technological pedagogical knowledge (TPK), and Technological pedagogical content knowledge (TPACK). This study specifically focused on measuring teacher self-reported efficacy in four of these domains: content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK), and Technological pedagogical content knowledge (TPACK).

Schmidt et al. (2009) defined each of these seven knowledge domains captured in the TPACK framework, the four that this study focused on are worth describing briefly. Content Knowledge (CK) refers to subject matter knowledge – math content knowledge in this case. Technology Knowledge (TK) refers to the knowledge of different technological tools, e.g., interactive whiteboards, software programs, mathematical action tools. Pedagogical Knowledge (PK) refers to the knowledge of teaching strategies and teaching-related processes and activities, e.g., knowledge of classroom management, assessment, student learning. Technological pedagogical content knowledge (TPACK) refers to the type of knowledge that teachers require to incorporate technology into their teaching in a specific content area (math in this case).

Whereas Marsick and Watkin’s reconceptualized model (Marsick & Watskin, 2014) and the TPACK framework (Mishra & Koehler, 2006) are two separate models without any connection whatever at face value, I contend that there is a sense in which both frameworks are connected considering the role that teachers’ experiences (including their informal learning experiences) play in the formation of their self-efficacy beliefs (Bandura, 1997). I propose that teachers’ informal and incidental learning experiences inform their self-reported TPACK efficacy and vice-versa. By extension, I suggest that both frameworks inform each other as shown by the bidirectional arrow in Figure 2.3. Marsick and Watkin’s reconceptualized model informed the research questions and guided the analysis of data related to math teachers’ informal learning experiences. For example, the model informed the identification of factors affecting teacher informal learning. The TPACK model provided a foundation for assessing teachers’ self-reported efficacy in the four knowledge domains that this study focused on.

Figure 2.3

Conceptual Framework Combining Marsick and Watkin's Re-conceptualized Model for Informal and Incidental Learning and the TPACK Model



Note. Re-conceptualized Model for Informal and Incidental Learning (left) from "Theory and Practice of Informal Learning in the Knowledge Era," by V.J. Marsick, M. Volpe, and K. E. Watkins, 1999, *Advances in Developing Human Resources*, 29, p. 91.

Copyright by SAGE Publications. Technological pedagogical content knowledge (TPACK) framework (right) from "Technological pedagogical content knowledge: A framework for teacher knowledge," by P. Mishra and M. J. Koehler, 2006, *Teachers College Record*, 108(6), p. 1017-1054. Copyright by the Teachers College, Columbia University.

CHAPTER 3: METHODOLOGY

Introduction

The main purpose of this explanatory sequential mixed-methods study was to investigate secondary mathematics teachers' perceptions of the effects of informal learning. Specifically, this study aimed to identify the types of informal learning activities that mathematics teachers engage in as part of their continuous professional learning in the course of their daily work, examine their perceptions of the factors that support or hinder their informal learning, and explore how math teachers' frequencies of participation in different informal learning activities relate to their self-reported efficacy in select TPACK domains, as well as differ based on teacher career stage. The selected TPACK domains are content knowledge (CK), technological knowledge (TK), pedagogical knowledge (PK), and technological pedagogical content knowledge (TPACK).

This chapter discussed the study's research methodology. It also described the research design, research context, sampling, data collection, data analysis, ethical concerns and other issues as they relate to the study. A step-by-step rundown of different issues that were attended to in the quantitative, qualitative, and data integration phases of the study are also described in detail.

Research Design

This research study employed an explanatory sequential mixed methods design (quan → QUAL) (Morse, 2003). A mixed methods design allows for the collection, analysis, and combination of quantitative and qualitative data as part of a single study in order to better understand a research problem (Creswell, 2002). Thus, the justification for using a mixed methods design is to better understand math teachers' perceptions of the effects of informal

learning by combining the unique strengths of interviews and surveys. Combining quantitative and qualitative approaches allow for both approaches to complement each other and make for a more robust analysis (Green et al., 1989; Tashakkori & Teddlie, 1998; Ivankova, 2002).

There are three important issues that need to be taken into consideration while designing a mixed methods study- priority, implementation, and integration (Ivankova, 2002; Creswell et al., 2003). Priority relates to the component of a research study (quantitative or qualitative) that receives more focus; implementation speaks to the order (sequential, concurrent) in which the data collection and analysis occurs; while integration refers to the stages or points in the research process at which the mixing, merging or connecting of qualitative and quantitative takes place. In this study, the qualitative component had more emphasis in the research design (Morse, 2003; Johnson & Onwuegbuzie, 2004).

With regards to implementation, this study employed an explanatory sequential mixed methods approach with the first phase (quantitative phase) involving the collection of survey data followed by a second phase (qualitative phase) where interview data, open-ended responses from the survey, and data from survey-based journaling, all focusing on teacher informal learning experiences often occasioned and guided by their in-the-moment learning needs were collected. Specifically, the first phase (the quantitative phase) involved collecting quantitative data using a web-based survey, which was subjected to correlation analysis, path analysis (multiple regression), and analysis of variance (Kruskal-Wallis test). The open-ended survey responses were also analyzed using frequency analysis based on qualitative content analysis methods (Mayring, 2015; Schreier, 2014). The goals of the first phase were to explore possible relationships between math teachers' frequencies of participation in informal learning activities and their self-reported efficacies in select TPACK domains and determine how their participation

differ based on teacher career stage. This phase also informed a purposeful selection of participants for the second phase of the study.

The second phase involved identifying the types of informal learning activities that teachers engage in, factors that support (or hinder) such learning, as well as perceptions of its effects based on open-ended survey responses, interviews, and data from survey-based journaling completed by participants over a two-weeks period. Qualitative content analysis methods (Mayring, 2015; Schreier, 2014), including using segmentation to divide survey question responses into smaller parts, developing a coding frame and pilot testing it with a portion of the data were used to analyze open-ended survey responses.

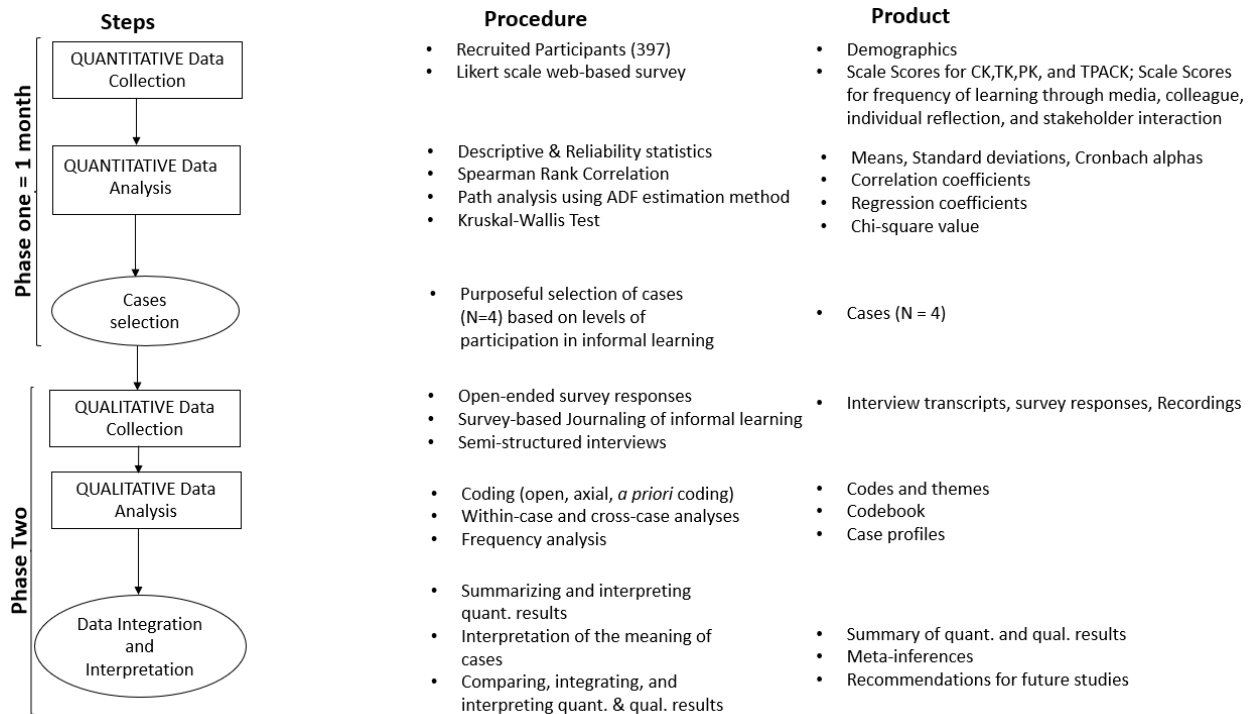
Furthermore, data from two rounds of interviews involving a small sample of four participants purposefully selected for the second phase of the study based on preliminary analysis in the first phase of the study were analyzed based on multiple coding iterations, starting with a combination of *a priori* and *open coding* to the development of emergent themes. Constructs from the theoretical framework and literature as they relate to different types of informal learning activities, factors affecting informal learning, and teachers' perceptions of informal learning formed the basis for *a priori codes*. Furthermore, codebooks with data-driven and theory driven codes were also created (DeCuir-Gunby et al., 2011). The same *a priori* codes from the literature were used in the analysis of the open-ended responses and interviews.

Besides the open-ended responses and interviews, the second phase also involved analysis of data from survey-based journaling of the four selected participants' daily informal learning experiences (for 2 weeks). The analysis of qualitative data from the four participants in the second phase was based on a multiple case study approach (Stake, 1995; 2005). Qualitative results were used to explain the statistical results obtained from the first phase and add depth to

the examination of the research questions. Specifically, the second phase involved the use of qualitative data to make sense of the relationship observed between participants' frequencies of participation in informal learning activities and their self-reported efficacy in select TPACK domains as well as the analysis of how participation levels differ based on teacher career stage. The research design diagram presented in Figure 2.4 summarizes key details of the explanatory sequential mixed methods design described so far.

Figure 2.4

Explanatory Sequential Mixed Methods Design Research Diagram



Research Questions

As earlier stated, this study was guided by the following research questions:

- 1) How do math teachers' participation in informal learning activities relate to their self-reported efficacy in select TPACK domains and differ based on teacher career stage?
 - a) Do relationships exist between math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) and their self-reported efficacy in select TPACK domains (CK, TK, PK, and TPACK)?
 - b) Do math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) differ based on teacher career stage?
- 2) What informal learning activities do math teachers engage in during their everyday practice?
- 3) What are math teachers' perceptions of the factors that affect their informal learning?
- 4) What are math teachers' perceptions of the effects of informal learning on teachers' knowledge and practice?

Research Hypotheses

Several studies have identified different sources of teacher informal learning including learning through media, colleague interaction, student interaction, stakeholder interaction, and individual reflection as contributing to teacher knowledge and practices in the areas of content, teaching, and technology (Lynnette, 2010; White et al., 2013; Richter et al., 2014; Kyndt et al., 2016; Carpenter & Linton, 2016; Huang et al., 2020; Slama et al., 2021). However, it is not clear how teachers' frequencies of participation in these informal learning activities specifically relate

to their self-reported efficacy in content knowledge, technological knowledge, pedagogical knowledge, and technological pedagogical content knowledge.

Considering suggestions from literature that informal learning contributes to teachers' knowledge and practices in the areas of content, pedagogy, and use of technology (Richter, 2014; Kyndt et al., 2016); by extension, I contend that teachers' frequencies of participation in different informal learning activities are related to their self-reported efficacy in content knowledge, technological knowledge, pedagogical knowledge, and technological pedagogical content knowledge.

Research has also shown that the amount of time teachers spend in different types of professional learning activities could vary based on different factors including career stage, education major, teaching experience, teacher certification, and district size (Scribner, 2003; Smith & Desimone, 2003; Birman, et al., 2009; Akiba, 2012; Richter et al., 2014). For the most part, this research focuses on formal learning opportunities and the result is also mixed. Some studies suggest that the amount of professional learning activities teachers engage in could vary by teaching experience and teacher qualifications, e.g., subject major or minor (Smith & Desimone, 2003; Desimone et al., 2006; Birman, et al., 2009). For example, Akiba (2012) found that middle school teachers without a major or minor in mathematics were drawn to individual learning activities as they spent more time on self-directed learning activities.

McCarthy (2016) also found statistically significant differences between teachers with permanent teaching certificates and those with temporary certificates in regard to their participation in university/college courses and coaching/mentoring activities. The study found that teachers with temporary teaching certificates participated significantly more in these professional learning activities than those with permanent certificates. Richter et al. (2014) also

suggested that teachers seem to be more drawn towards collaboration in their early years in the profession and that the emphasis shifts to veteran or more experienced teachers paying greater focus on self-directed learning in form of reading professional literature. This suggests that the types of professional learning activities that teachers engage in and how often they engage in them may have possible connections to their career stage. I contend that some of these factors may also be associated with the kinds of informal learning activities that teachers engage in. However, my hypotheses are largely exploratory.

In line with the literature on the types of informal learning activities that teachers engage in, possible factors that influence their participation in these activities and the research questions, my hypotheses are as follows:

- a) H1: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and their self-reported efficacy in content knowledge respectively.
- b) H2: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and their self-reported efficacy in technological knowledge respectively.
- c) H3: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and their self-reported efficacy in pedagogical knowledge respectively.

- d) H4: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and their self-reported efficacy in TPACK respectively.
- e) H5: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their content knowledge self-efficacy respectively
- f) H6: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their technological knowledge self-efficacy respectively.
- g) H7: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their pedagogical knowledge self-efficacy respectively.
- h) H8: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their TPACK self-efficacy respectively.
- i) H9: Math teachers' frequencies of participation in learning through media differ based on teacher career stage.
- j) H10: Math teachers' frequencies of participation in learning through colleague interaction differ based on teacher career stage.
- k) H11: Math teachers' frequencies of participation in learning through stakeholder interaction differ based on teacher career stage.
- l) H12: Math teachers' frequencies of participation in learning through individual reflection differ based on teacher career stage.

Research Context

Sampling/Participants

The target population for this study was secondary math teachers (grades 6-12) in the United States. In the quantitative phase, snowball sampling was employed to recruit teachers through social media platforms- Facebook and Twitter to be specific. A link to a web-based survey was posted on both social media platforms and participants were encouraged to share the link with other participants who may be interested in the study. Posts with a link to the web-based survey were shared on Twitter using a number of popular hashtags related to mathematics education (e.g., #iteachmath, #MTBoS, etc.). Some Facebook groups where the link was shared include:

- Desmos Educators
- Youcubed
- Middle & High School Math Teachers
- North Carolina Teachers of Tomorrow Official Community
- Math Minded Teachers
- Math Teacher Lounge
- Math Education Matters

Together, these Facebook groups bring upwards of 100,000 math teachers and other educational stakeholders together to exchange information related to the teaching and learning of mathematics. The #MTBoS and #iteachmath twitter communities have grown over the years to become valuable “go to” places for finding math teaching resources for many educators across the United States and beyond; hence, the need to target both communities. An analysis of recent activity in the aforementioned Facebook groups, Twitter feeds, and a conservative estimation of

active membership of these communities similar to Mannix (2022) suggested the likelihood of recruiting at least 100 teacher participants for this study from both platforms.

For medium effect sizes, a sample size of at least 100 cases was deemed good enough to run a multiple regression analysis for this study (Green, 1991). However, there are multiple rules of thumb as to what might be the minimum sample size required for a multiple regression analysis. For example, Benson and Nasser (1998) suggested that a minimum of 7 to 10 participants are needed per item on a survey questionnaire. Thus, the ideal estimate for the number of participants required for this study is between 259 to 370 as shown in the research design diagram (see Figure 2.4). This calculation is based on the fact that the survey that participants completed contained a total of 37 Likert scale items (excluding open-ended items and items that focus on demography) on informal teacher learning (ITL) and TPACK.

To be recruited for this study, participants had to be current secondary math teachers in the United States. This criterion was important because the United States was the context of this study. Additionally, survey items that assessed teachers' frequencies of participation in different informal learning activities also required that they indicate how often they had participated in such activities in the last 6 months. For example, one survey item measuring learning by individual reflection (one of the constructs the informal teacher learning instrument assessed) reads thus: "In the last 6 months, when my teaching has not met expectations, I have considered possible reasons why". Items such as these, to a large extent required that participants in the study be current teachers.

Data Collection

As earlier mentioned, the sequential explanatory mixed methods approach involved two phases of data collection- the quantitative and the qualitative phases. This section describes the nature of data that was collected in both phases, data collection procedures, and the instruments that were used in the process.

Instrumentation and Data Collection Procedures

In the quantitative phase, a larger web-based survey was shared on Facebook and Twitter to collect data from secondary math teachers across the country (see Appendix H for the post that was shared on Facebook and Twitter). The survey is made up of three parts. The first part focused on teacher demographic information such as their age, teaching experience, gender, school location, and so on. The second part was made up of items which captured teachers' self-reported efficacy in select TPACK domains (content knowledge, technological knowledge, pedagogical knowledge, and technological pedagogical content knowledge). The third part asked questions about teachers' frequencies of participation in five informal learning activities- learning through media, learning through colleague interaction, learning through student interaction, learning through stakeholder interaction, and learning through individual reflection.

The first page of the survey (the participant consent form) used to collect quantitative data for this study explained different issues that potential teacher participants needed to know about. These included the purpose of the study, criteria for participating in the study, risks connected to participating in the study, compensation, participants' rights, and information about who to contact in case of any concerns or questions. Participants were required to consent to the study before proceeding to complete the remaining part of the survey. Participants were also asked to indicate whether or not they would like to participate in two follow-up interviews and a

micro-survey which teachers were required to complete daily over a two-week period (10 days to be specific). Preliminary analysis of the quantitative data was also conducted before moving to the qualitative phase where qualitative data was collected via semi-structured interviews and survey-based journaling. Participants' journaling of their continual (daily) informal learning experiences was captured using a short micro-survey which was designed to be completed within 3-5 minutes. The micro-survey was sent to teachers daily for 2 weeks. The interview protocol and micro-survey items were also modified based on analysis of the larger survey data.

The next two subsections give additional information about the TPACK and informal teacher learning (ITL) instruments from which items were selected for the second and third part of the survey instrument that was used in this study.

TPACK Instrument

The TPACK instrument that was used in this study was developed and validated by Zelkowski et al. (2013) to assess preservice secondary mathematics teachers' TPACK based on the adaptation of an earlier TPACK survey developed by Schmidt et al. (2009) for elementary preservice secondary teachers. For the purpose of this study, four subscales were selected from the TPACK instrument: The Content Knowledge (CK), Technological Knowledge (TK), Pedagogical Knowledge (PK), and Technological Pedagogical Content Knowledge (TPACK) subscales. The internal validity for each of these subscales as measured by Cronbach's alpha are 0.8554 for CK, 0.8899 for TK, 0.8768 for PK, and 0.8966 for TPACK (Zelkowski et al., 2013). These Cronbach alpha values for the subscales indicate that the internal reliability of all four scales are good and meet the criteria required of reliable survey research instruments (DeVellis, 2011).

The Content Knowledge (CK) subscale has five items, the Technological Knowledge (TK) six items, the Pedagogical Knowledge (PK) five items, and the Technological Pedagogical Content Knowledge (TPACK) subscale six items. All the items used a 5-point Likert scale response (1 = “strongly disagree,” 2 = “disagree,” 3 = “neither agree nor disagree,” 4 = “agree,” 5 = “strongly agree”). Refer to chapter two for a brief description of each of these knowledge domains. Sample TPACK items from the survey instrument disaggregated based on the TPACK knowledge domains they assessed are shown in Table 3.1.

Table 3.1

TPACK Sample Items Disaggregated by Select Subscales

Content Knowledge

- I have a deep and wide understanding of algebra.
- I have sufficient knowledge about mathematics.

Technological Knowledge

- I know how to solve my own technical problems.
- I can learn technology easily.

Pedagogical Knowledge

- I can adapt my teaching style to different learners.
 - I can assess student learning in multiple ways.
-

Table 3.1 (Continued)

Technological Pedagogical Content Knowledge

- I can use strategies that combine mathematics, technologies, and teaching approaches in my classroom.
 - I can choose technologies that enhance mathematics for a lesson.
-

Note. From the *TPACK Instrument* developed and validated by Zelkowski et al. (2013)

Informal Teacher learning (ITL) Instrument

The informal teacher learning (ITL) instrument that was used to assess teachers' self-reported frequencies of participation in different informal learning activities was original developed and validated by Huang et al. (2020) to assess Chinese primary school teachers' frequencies of participating in different ITL activities. The instrument was developed based on open-ended interviews with 10 teachers in line with relevant literature and its validity and reliability was assessed based on a sample of 2880 primary teachers recruited from Chongqing in Southwestern China.

The original instrument is made up of 18 items which assess teachers' frequencies of participation in five different types of informal workplace learning activities: learning through colleague interaction, learning through media, learning through stakeholder interaction, learning through student interaction, and learning through individual reflection. This study used the revised version of the instrument which has 19 items due to the addition of an extra item to existing items which assess learning through stakeholder interaction because it recognizes university scholars as important stakeholders who contribute to teachers' informal learning.

Teacher learning through colleague interaction is assessed based on three items on the ITL instrument and the corresponding Cronbach alpha value is 0.95. The Learning through media subscale has five items and a Cronbach alpha value of 0.85. Additionally, the learning through stakeholder interaction, student interaction, and individual reflection subscales have four, four, and three items respectively. The corresponding Cronbach alpha values for the learning through stakeholder interaction, student interaction, and individual reflection subscales are 0.76, 0.93, and 0.92 respectively. These values suggest that the instrument is reliable. Samples of select items from the ITL instrument are shown in Table 3.2. In their studies, Huang et al. (2020) and Huang (2021) required teachers to indicate their frequencies of participation in the five types of informal learning activities scored on 5-point Likert scale responses: 1= Never, 2= rarely, 3= sometimes, mostly=4, and 5= Always. Both studies required teachers to indicate their frequencies of participation based on a recollection of their informal learning experiences over a 6-month period. In the same vein, this study asked teachers to indicate their frequencies of participation in these informal learning activities in the last 6 months.

Table 3.2

ITL Sample Items Disaggregated by Select Subscales

Learning through colleague interaction
<ul style="list-style-type: none"> • I have communicated with my colleagues about curricula and teaching • I have communicated with my colleagues about student learning

Table 3.2 (Continued)

Learning through media

- I have read education-related posts on social media platforms such as Facebook, Quora, etc.
- I have read hard-copy educational materials (e.g., teaching reference books, journals)

Learning through stakeholder interaction

- I have communicated with parents about educational issues.
- I have communicated with university scholars about educational issues.

Learning through student interaction

- I have discussed teaching materials or lesson content with my students outside of regular class hours
- I have discussed teaching methods with my students

Learning through individual reflection

- When my teaching has not met my expectations, I have considered possible reasons why
 - I have thought about or learned from my teaching successes
-

Note. From the *ITL scale* developed and validated by Huang et al. (2020)

In the qualitative phase, the researcher employed purposive sampling to select four participants out of the total number of participants who indicated interest to participate in two semi-structured interview sessions and completed a micro-survey (survey-based journaling)

about their continual (daily) professional learning experiences. Besides selecting participants based on their frequencies of participation in informal learning activities. Participants were also selected such that variables like their teaching experience (or career stage) and grade level are reflected. Career stage, teaching experience and related factors have been shown to affect the kinds of informal learning activities that teachers engage in (Appova, 2009; Akiba, 2012; Richter et al., 2014; McCarthy, 2016). The mean score of the ITL items (*mITL*) was used to characterize teachers' frequencies of participation in informal learning (high, average, and low users) and select participants (two high informal learning users and two average users). The mean scores (*mITL*) corresponding to high, average, and low use of informal learning are *mITL* values equal or greater than 4, greater than 2 but less than 4, and less than or equal to 2 respectively. The decision to consider reflecting different demographic characteristics and levels of participation in informal learning activities in the selection of cases for the qualitative phase was to ensure a good mix of cases for the qualitative phase. The qualitative phase involved explaining the quantitative results based on the analysis of the selected cases.

The four participants purposefully selected for the semi-structured interviews and additional survey-based journaling were reached via their email addresses to discuss their availability for interviews. The two interview sessions lasted between 40 minutes to 1 hour each and were conducted via the Zoom teleconference platform. At the beginning of each interview session, the researcher thanked participants for agreeing to participate in the study, complete micro-surveys of continual learning for two weeks and two follow-up interviews. The researcher also restated the purpose of the study and defined key terms, e.g., what informal learning meant in the context of the study.

Each interview session was recorded but participants were notified before the recording started. The interview questions focused on three broad issues: 1) Teachers' views about the kinds of informal learning activities they engage in to develop their content, pedagogical, and technological knowledge in the course of their daily activities; 2) Teachers' perceptions of how these activities impact their math content knowledge, teaching practices, and use of technology in the classroom; 3) Teachers' views of the factors (e.g., personal, organizational) that support or hinder their informal learning opportunities in the workplace; 4) follow-up questions based on participants survey responses; and 5) observed trends in their continual professional learning experiences as captured by the micro-survey they completed. The researcher ended each interview session by asking participants if there is anything else, they would like to say, then thanked them for their time.

The purpose of the micro survey (survey-based journaling) was to capture teachers' continual professional learning experiences in "real time" and make better sense of their informal learning opportunities. Teacher participants were required to complete the micro survey daily over a two-week period. The frequency of the micro-survey is important for capturing teacher everyday learning outside of school-sponsored PD which could easily go unnoticed. The micro-survey was also modified based on the larger survey results and the first interview conducted with teachers and sent out to teachers daily over a 2-week period, beginning after the first interview. A follow-up interview (the second interview) was then conducted to further discuss the observed trends in teachers' professional learning experiences with a focus on their informal learning.

Data Analysis

The data analysis and results were carried out and discussed respectively in two main phases: the quantitative (first phase) and qualitative (second phase). A summary of key findings and a discussion section which integrated data across phases to answer the research questions were later presented. Quantitative analysis from the first phase was used to select participants for the qualitative phase. For the second phase, four participants were purposefully selected based on demographic information and their mean score for the informal learning scale following a preliminary analysis of the survey data. These participants took part in semi-structured interviews and completed micro-surveys about their continual learning experiences over a two-week period in the second phase of data analysis. The interview protocol in the second phase was modified based on results from the quantitative phase. In the same vein, the micro-survey was modified based on the results of the larger survey and first interview conducted with teachers. The second interview session followed after teachers had completed the micro-survey. Furthermore, the second phase also involved the analysis of open-ended responses from a sample of 173 respondents who completed two open-ended items on the larger survey.

Qualitative content analysis methods (Mayring, 2015; Schreier, 2014), including using segmentation to divide survey question responses into smaller parts, developing a coding frame and pilot testing it with a portion of the data were used to analyze open-ended survey responses. Interviews were analyzed based on multiple coding iterations, starting with a combination of *a priori* and *open coding* to the development of emergent themes. Constructs from the theoretical framework and literature as they relate to different types of informal learning activities, factors affecting informal learning, and teachers' perceptions of informal learning formed the basis for *a*

priori codes and the same *a priori* codes from the literature were used in the analysis of the open-ended responses and interviews.

Data integration was done mainly at the methods level. Creswell et al. (2011) conceptualized integration in terms of linking data collection and analysis methods and identified four approaches to linking: (1) connecting; (2) building; (3) merging; and (4) embedding. This study employed two of these data integration approaches- connecting and merging. Connecting happened through sampling as participants in the second phase of the study were sampled or selected based on preliminary analysis of survey data in the first phase. Merging occurred through the bringing together and comparison of quantitative and qualitative data to answer the research questions, especially in chapter 5.

The overall goal of integration was to make for a deeper understanding of math teachers' informal learning activities; their perceptions of the effect of these activities on their knowledge (content and technological) and teaching practices; and factors that affect opportunities for such activities. Each research question was answered based on meta-inferences obtained from both the quantitative and qualitative phases as described shortly.

The STATA software was used to analyze survey data in the quantitative phase while Atlas.ti was used to analyze the interviews, open-ended survey responses, and data from the survey-based journaling in the qualitative phase. The survey data collected using Qualtrics was first downloaded as an SPSS file, then exported into the STATA software for analysis. The data was cleaned and summary scores from the survey obtained for further analysis.

Reliability and Validity

To ensure the validity and reliability of the results of this mixed methods study, several steps were taken. To start with, the researcher ensured that only validated instruments are used in the study. The TPACK and ITL instruments used in this study were both developed based on extant literature (and/or existing instruments), they are both validated and reliable judging from the Cronbach alpha values of their subscales as described in the previous section (Zelkowski et al., 2013; Huang, 2021). The instruments are of good quality and they align with the purpose of this study (Creswell & Clark, 2017). They have also been used in different studies (Lehtinen et al., 2016; Huang et al., 2020; Hill et al., 2020; Huang and Wang, 2021).

Furthermore, Creswell and Miller (2000) suggest multiple techniques for addressing validity and reliability issues that were attended to in the qualitative phase. They include conducting member checks with participants (this was implemented by having participants double-check interview transcripts), use of multiple data sources to ensure triangulation (semi-structured interviews, micro-survey data, interview transcripts), review of relevant literature on the phenomenon under consideration (literature related to teacher informal learning were reviewed), reflexivity (the researcher reflected on his positionality throughout the research process), subjecting interview questions to expert review (researcher's dissertation committee), and peer coding.

Some of the steps for ensuring reliability and validity described so far and additional steps are captured in Papadimitriou et al.'s (2013) seven recommendations for ensuring the quality of meta-inferences in mixed methods sequential quan → QUAL designs. They include:

- Apply validation strategies recommended for quantitative and qualitative research approaches in quantitative and qualitative study phases

- Select participants for qualitative follow-up phase consistent with the overall purpose of the study
- Use systematic statistically grounded process for selecting participants for qualitative follow-up phase
- Qualitatively follow up on important results from initial quantitative phase
- Elaborate on unexpected quantitative results in the qualitative follow-up phase
- Allow for interaction between qualitative and quantitative study phases
- Create meta-inferences grounded in both quantitative and qualitative results

Each of these recommendations were taken into consideration to ensure the reliability and validity of this study.

Ethical Issues

Different ethical issues were addressed in the course of this study. Firstly, permission to conduct this study was first sought from the North Carolina State University Institutional Review Board (IRB) before the study commenced. An informed consent form was also developed and included on the first page of the survey. This page described the purpose of the study, criteria for participation, risk involved in participating (the study is categorized as having minimal risk), compensation, as well as participants' rights. Participants were also required to indicate their consent to complete the study.

Anonymity of participants and confidentiality was maintained throughout the research study. No identifiable information about the participants was included on the survey. Even though participants who showed interest in voluntary follow-up interviews were required to provide their email addresses, this was strictly for private communication regarding the study. Pseudonyms were also used to conceal participants' identity while describing participants and

reporting research findings. All data collected was securely stored on the researcher's computer and will be destroyed sometime in the future. Participants were also assured that even though study results will be disseminated through subsequent research and presentations, e.g., conference presentations, there is no chance of being identified through their responses or information they have shared. Other ethical issues as they appear in the North Carolina Institutional Review Board (IRB) guidelines were also attended to in the course of the study.

CHAPTER 4: FINDINGS

The purpose of this explanatory sequential mixed-methods study was to investigate secondary mathematics teachers' perceptions of informal learning, especially in regard to perceived effect on content, pedagogical, and technological knowledge. Specifically, this study aimed at identifying the types of informal learning activities that mathematics teachers engage in as part of their continuous professional learning in the course of their daily work, examining their perceptions of the factors that support or hinder informal learning, and exploring how math teachers' frequencies of participation in different informal learning activities relate to their self-reported efficacy in select TPACK domains, and differ based on teacher career stage.

This chapter presents findings from the first and second (quantitative and qualitative) phases of the study more broadly, and a more concise summary and integration of quantitative and qualitative findings based on the research questions at the end. In the first section (first phase), I presented quantitative findings related to the first research question which examined relationships between math teachers' frequencies of participation in informal learning activities and their self-reported TPACK efficacies as well as how these frequencies of participation in learning through informal activities differ based on career stage. The analysis presented is based on quantitative survey data obtained from a sample of 258 respondents.

In the second section, I presented qualitative findings relevant to the second, third, and fourth research questions based on the analysis of open-ended survey responses from the subset of respondents who completed one or two of the open-ended questions on the survey. To recap, the second research question focuses on the types of informal learning activities math teachers engage in in the course of their everyday practice. The third examines math teachers' perceptions

of factors that affect their informal learning while the fourth research question focuses on math teachers' perceptions of the effects of informal learning.

Additionally, within and cross case analysis based on a sample of four purposefully selected cases from the pool of survey respondents are then presented to support findings from the analysis of open-ended survey responses. The third and last section presented a summary and integration of key findings across sections based on the four research questions. Specifically, qualitative findings were used to inform quantitative findings from the first research question while qualitative findings from the analysis of the open-ended survey responses and case analysis were combined to address the second, third, and fourth research questions.

Findings from Phase One (Quantitative Phase)

This subsection described the demographic variables and presented descriptive and reliability statistics on the relevant TPACK domains (CK, PK, TK, TPACK) and informal learning variables (frequencies of participation in learning through colleague interaction, media, individual reflection, and stakeholder interaction). Next, inferential statistics (correlation and regression analysis as well as analysis of variance) results showing relationships between the relevant TPACK and informal learning variables and how the informal learning variables differ based on teacher career stage are presented. Lastly, the study hypotheses are addressed in the light of the nature of relationships between the relevant TPACK and informal learning variables.

Demographic Variables

A total of 397 responses were obtained from the survey which was open for about 3 weeks. 139 survey responses incomplete responses were eliminated leaving a total of 258 complete responses which were used in this study. Participants' demographic variables that were considered include sex, school level (middle/high school), career stage (beginning, mid-career,

or experienced teacher), educational qualification, degree major, certificate type (permanent/temporary), and US region (Northeast, West, Midwest, Southeast, and Southwest). A detailed breakdown of participant demographic variables is presented in Table 4.1. Note that some percentages may not add up to 100% due to approximations.

Majority of the respondents (approximately 89%) identified as females while the remaining approximately 11% identified as males. The number of respondents who taught middle and high school were roughly equal. Most of the respondents (appro. 90%) also had either a bachelor's or master's degree; very few teacher participants reported having a specialist or doctoral degree. Over 50% of participants had either a major in mathematics or mathematics education. Other majors that respondents reported besides these were mostly in education-related fields (e.g., elementary education).

Approximately 47% of the respondents were experienced teachers (16 years or more teaching experience), the remaining 53% were either beginning (0-5 years teaching experience) or mid-career teachers (6-15 years teaching experience). About 94% of the respondents held permanent teaching certificates. Lastly, most respondents (77%) came from the North-eastern, Mid-western, or South-eastern regions of the United States.

Table 4.1*Frequency table showing Participants' Demographic Variables*

Variables	Frequency	Percent
<i>School level</i>		
Middle School	126	49
High School	132	51
<i>Level of education</i>		
Bachelor's Degree	67	26
Master's Degree	165	64
Specialist/Doctoral Degree	20	8
Others	6	2
<i>Career Stage</i>		
Beginning teachers	43	17
Mid-career teachers	94	36
Experienced teachers	121	47
<i>Degree Major</i>		
Mathematics	61	23.64
Mathematics Education	105	40.7
Others (mostly education-related)	92	35.66

Table 4.1 (Continued).

<i>Certificate Type</i>		
Permanent Teaching Cert.	242	94
Temporary Teaching Cert.	16	6
<i>Sex</i>		
Male	29	11.24
Female	229	88.76
<i>U.S Region</i>		
West	35	14
Northeast	65	25
Midwest	64	25
Southwest	23	9
Southeast	71	28

Note. N = 258

Descriptive and Reliability Statistics for TPACK Variables

Mean scores representing teachers' self-reported efficacy in four knowledge domains—content knowledge (CK), pedagogical knowledge (PK), technological knowledge (TK); and Technological, pedagogical, and content knowledge (TPACK) – were obtained based on subscales from a 22-item TPACK self-report questionnaire developed by Zelkowski et al. (2013) as described in the methods section. Specifically, the average scores of all the items in the same subscales (measuring the same construct) were obtained for each respondent and the relevant TPACK domains (CK, TK, PK, TPACK). These scores range from 2.16 to 5 with respondents

having the lowest and highest self-reported efficacy on the technological and pedagogical knowledge domains on average (see Table 4.2).

Table 4.2

Descriptive Statistics on CK, TK, PK, and TPACK

Variable	Obs	Mean	Std. dev.	Min	Max
CK	258	4.30	0.50	3	5
TK	258	3.99	0.64	2	5
PK	258	4.35	0.49	2.8	5
TPACK	258	4.15	0.61	2.17	5

Cronbach alpha values for each of the TPACK subscales were computed using STATA software program to examine the reliability of the survey instrument. The Cronbach alpha values for the CK, TK, PK, and TPACK subscales were 0.77, 0.87, 0.82, and 0.91 respectively. These values suggest internal consistency among survey items and reliability of the survey instrument. Each of the subscales had 5, 6, 5, and 6 items respectively.

Descriptive and Reliability Statistics for Frequencies of Participation in Informal Learning Activities Variables

Mean scores representing teachers' frequencies of participation in four informal learning activities (learning through media, colleague interaction, stakeholder interaction, and individual reflection) were obtained based on subscales from the informal teacher learning instrument developed by Huang et al. (2020) as described in the methods section. The scores ranged from 1

to 5, with respondents reporting the highest frequencies of participation scores of 3.08 and 4.52 for stakeholder interaction and individual reflection respectively on average.

Cronbach alpha values for each of the four informal teacher learning subscales as computed using STATA software program suggest internal consistency of survey items and reliability of the survey instrument. The Cronbach alpha values for the learning through media, colleagues, stakeholder reflection, and individual reflection subscales were 0.77, 0.89, 0.70, and 0.81 respectively. Each of these subscales had 5, 3, 4, and 3 items measuring the same construct respectively.

Table 4.3

Descriptive Statistics on Frequencies of Participation in Informal Learning Activities Variables

Variable	Obs	Mean	Std. dev.	Min	Max
Media	258	3.60	0.70	1.4	5
Colleagues	258	4.28	0.69	1	5
Individual reflection	258	4.52	0.48	3.33	5
Stakeholder interaction	258	3.08	0.74	1.25	5

Correlation, Regression, and Analysis of Variance with TPACK and/or Informal Learning Variables

Spearman Rank Correlation Analysis

The correlation analysis was guided by the following research question and hypotheses:

Research Question 1a. Do relationships exist between math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) and their self-reported efficacy in select TPACK domains (CK, TK, PK, and TPACK)?

Research hypotheses. There were four specific hypotheses relevant to this research question, specifically as it relates to correlational relationships; they are as follows:

- a) H1: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and self-reported efficacy in content knowledge respectively.
- b) H2: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and self-reported efficacy in technological knowledge respectively.
- c) H3: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and self-reported efficacy in pedagogical knowledge respectively.

- d) H4: There is a statistically significant positive relationship between math teachers' frequencies of participation in learning through media, colleague, stakeholder interaction and individual reflection; and self-reported efficacy in TPACK respectively.

To proceed with the analysis, each of the dependent (CK, TK, PK, TPACK) and independent (frequencies of participation in learning through media, colleague interaction, stakeholder interaction, and individual reflection) variables were assessed for normality using both graphical (boxplot and histogram) and numerical techniques (Kolmogorov–Smirnov test and Shapiro–Wilk test) in STATA. This step was necessary to determine the appropriate measure for determining possible correlation between variables. Except for two variables (frequencies of participation in learning through media and stakeholder interaction), all the remaining variables were not normally distributed. This means the data is largely not normally distributed and a correlation measure (Pearson correlation coefficient) which assumes normality will not be appropriate (Akoglu, 2018).

As a result, Spearman's rank order correlation was computed to assess relationships between TPACK and informal learning variables. Spearman rank correlation requires ordinal data or continuous data that follows a monotonic relationship (Frost, 2022). The pairs of study variables compared show a monotonic relationship; hence, using Spearman rank correlation is appropriate. In any case, Likert scale data is ordinal data strictly speaking, even though it tends to be used as interval scale (Wu & Leung, 2017). Spearman calculates correlations from the ranks of data not from their actual values (Akoglu, 2018). Table 4.4 displays pairwise correlations for the study variables.

Table 4.4

Correlation coefficients among self-efficacy in CK, PK, TK, TPACK, and Frequencies of Participation in Learning through Colleague Interaction, Media, Individual Reflection, and Stakeholder Interaction

	Colleagues	Media	IR	SI	TK	CK	PK	TPACK
Colleagues	1.00							
Media	.29*	1.00						
Individual Reflection (IR)	.54*	.39*	1.00					
Stakeholder Interaction (SI)	.44*	.49*	.39*	1.00				
TK	.20*	.23*	.17*	.16*	1.00			
CK	.28*	.21*	.20*	.18*	.27*	1.00		
PK	.32*	.18*	.36*	.28*	.24*	.36*	1.00	
TPACK	.30*	.22*	.31*	.24*	.53*	.47*	.57*	1.00

*Statistically significant ($p < 0.05$)

There was a significant weak positive correlation between teachers' frequency of participation in interaction with *colleagues* and their technological knowledge self-efficacy ($r_s(256) = .20, p < .05$). This suggests that as teachers' frequency of participation in interaction with *colleagues* increased, their technological knowledge self-efficacy also tends to increase.

There was also a significant weak positive correlation between teachers' frequency of participation in interaction with *colleagues* and their content knowledge self-efficacy ($r_s(256) = .28, p < .05$); suggesting a tendency for increase in teachers' content knowledge self-efficacy as their reported frequency of participation in learning through interaction with *colleagues* increased.

In the same vein, the correlation analysis revealed a weak, positive, statistically significant correlation between teachers' frequency of participation in interaction with *colleagues* and their pedagogical knowledge ($r_s(256) = .32, p < .05$); and technological, pedagogical, and content knowledge ($r_s(256) = .30, p < .05$) self-efficacies respectively. These results suggest that teachers who reported higher frequencies of participation in informal learning through interaction with *colleagues* tended to also report higher self-efficacy ratings in the pedagogical and technological pedagogical content knowledge domain respectively.

The correlation analysis also showed a weak, positive, statistically significant correlation between teachers' reported frequency of participation in learning through *media* and teachers' technological knowledge ($r_s(256) = .23, p < .05$), content knowledge ($r_s(256) = .21, p < .05$), and their technological pedagogical and content knowledge ($r_s(256) = .22, p < .05$) self-efficacies respectively. In addition, there was a very weak, positive, statistically significant correlation between teachers' reported frequency of participation in learning through media and their pedagogical knowledge self-efficacy ($r_s(256) = .18, p < .05$). These results indicate a tendency

for increase in teachers' self-reported efficacy in the respective TPACK domains (technological knowledge, content knowledge, pedagogical knowledge, and technological pedagogical content knowledge) as their participation in learning through media increases.

There was a statistically significant weak positive correlation between teachers' frequency of participation in learning through *individual reflection* and their reported pedagogical knowledge ($r_s(256) = .36, p < .05$), content knowledge ($r_s(256) = .20, p < .05$), and technological pedagogical and content knowledge ($r_s(256) = .31, p < .05$) self-efficacies respectively. There was also a statistically significant very weak positive correlation between teachers' frequency of participation in learning through individual reflection and their reported technological knowledge self-efficacy ($r_s(256) = .17, p < .05$). These results suggest that teachers who reported higher levels of participation in informal learning through *individual reflection* tended to also report higher self-efficacy ratings in the pedagogical, technological, content, and technological pedagogical and content knowledge domains respectively.

Similarly, there was a statistically significant weak positive correlation between teachers' frequency of participation in learning through *stakeholder interaction* and their reported pedagogical knowledge ($r_s(256) = .28, p < .05$); and technological pedagogical content knowledge ($r = .24, p < 0.05$) self-efficacies respectively. Additionally, there was a statistically significant very weak positive correlation between teachers' frequency of participation in learning through *stakeholder interaction* and their reported content knowledge ($r_s(256) = .18, p < .05$), and technological knowledge ($r_s(256) = .16, p < .05$) self-efficacies respectively. Together, these results suggest that teachers reported self-efficacies in the TPACK domains in question tend to increase as their frequency of participation in *stakeholder interaction* increased.

Since the correlation analysis results in Table 4.4 showed statistically significant positive relationships between self-reported efficacy in the relevant TPACK domains and frequencies of participation in informal learning variables, we fail to reject hypotheses (a) through (d).

Regression Analysis

Like the correlation analysis, the regression analysis was also guided by the following research question and hypotheses:

Research Question 1a. Do relationships exist between math teachers' frequencies of participation in informal learning (learning through media, colleague interaction, individual reflection, and stakeholder interaction) and their self-reported efficacy in select TPACK domains (CK, TK, PK, and TPACK)?

Research hypotheses. There were also four hypotheses relevant to this research question, specifically as it relates to predictive relationships; they are as follows:

- e) H5: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their content knowledge self-efficacy respectively.
- f) H6: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their technological knowledge self-efficacy respectively.
- g) H7: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their pedagogical knowledge self-efficacy respectively.

h) H8: Math teachers' frequencies of participation in learning through colleague interaction, media, stakeholder interaction, and individual reflection *predict* their TPACK self-efficacy respectively.

In order to lend support to the results from the correlation analysis and establish possible cause and effect relationship between the study variables, a path analysis model with Asymptotically distribution free (ADF) estimation method was fit using teachers' self-efficacy in CK, TK, PK, and TPACK as endogenous variables; and teachers' frequencies of participation in informal learning activities (learning through colleague interaction, stakeholder interaction, media, and individual reflection), career stage, gender, certificate type, and school level (middle/high school) as exogenous variables.

Whereas path analysis is a form of multiple regression, the asymptotically distribution free (ADF) method estimates parameters and tests models without requiring that variables meet the normal distribution assumption (Huang & Bentler, 2015). This property informed the choice of path analysis with ADF estimation method for the regression described in this study. Recall that only two out of the eight variables (dependent and independent) in this study are normally distributed.

The path analysis model explained 13.4%, 7.3%, 17.9%, and 13.4% of the variance in CK, TK, PK, and TPACK respectively. Overall, the model explained 30% of the variance in the dependent variables. The analysis also revealed that CK was significantly predicted by colleague interaction ($b = .12, s.e = .05, p < .05$) and media ($b = .10, s.e = .04, p < .05$). This means that controlling for gender, career stage, school level, certificate type; a 1 unit increase in the frequency of participation in learning through colleague interaction and media leads to .12 and .10 units increase respectively, in teachers' self-reported efficacy in content knowledge (CK).

TK was significantly predicted by media ($b = .18, s.e = .06, p < .05$), suggesting that controlling for gender, career stage, school level, and certificate type; a 1 unit increase in the frequency of participation in learning through media leads to .18 units increase in teachers' self-reported efficacy in technological knowledge (TK). Similarly, PK was significantly predicted by colleague interaction ($b = .12, s.e = .04, p < .05$) and individual reflection ($b = .20, s.e = .06, p < .05$). This means that controlling for gender, career stage, school level, certificate type; a 1 unit increase in the frequency of participation in learning through colleague interaction and individual reflection leads to .12 and .20 units increase respectively, in teachers' self-reported efficacy in pedagogical knowledge (PK).

TPACK was significantly predicted by colleague interaction ($b = .14, s.e = .06, p < .05$) and individual reflection ($b = .18, s.e = .08, p < .05$). This means that controlling for gender, career stage, school level, and certificate type; a 1 unit increase in the frequency of participation in learning through colleague interaction and individual reflection leads to .14 and .18 units increase respectively, in teachers' self-reported efficacy in Technological pedagogical and content knowledge (TPACK). These results show that, except for learning through stakeholder interaction; controlling for gender, career stage, school level, and certificate type; all other independent variables (learning through colleague interaction, media and individual reflection) were significant predictors of one or two dependent variables (CK, PK, TK, TPACK).

In line with the results from the regression analysis presented so far, we fail to reject the following hypotheses:

- Math teachers' frequency of participation in learning through media *predict* their content knowledge self-efficacy.

- Math teachers' frequency of participation in learning through colleague interaction *predict* their content knowledge self-efficacy.
- Math teachers' frequency of participation in learning through media *predict* their technological knowledge self-efficacy.
- Math teachers' frequency of participation in learning through colleague interaction *predict* their pedagogical knowledge self-efficacy.
- Math teachers' frequency of participation in learning through individual reflection *predict* their pedagogical knowledge self-efficacy.
- Math teachers' frequency of participation in learning through colleague interaction *predict* their TPACK self-efficacy.
- Math teachers' frequency of participation in learning through individual reflection *predict* their TPACK self-efficacy.

Relatedly, we reject the following hypotheses:

- Math teachers' frequency of participation in learning through individual reflection *predict* their content knowledge self-efficacy.
- Math teachers' frequency of participation in learning through stakeholder interaction *predict* their content knowledge self-efficacy.
- Math teachers' frequency of participation in learning through colleague interaction *predict* their technological knowledge self-efficacy.
- Math teachers' frequency of participation in learning through individual reflection *predict* their technological knowledge self-efficacy.
- Math teachers' frequency of participation in learning through stakeholder interaction *predict* their technological knowledge self-efficacy.

- Math teachers' frequency of participation in learning through media *predict* their pedagogical knowledge self-efficacy.
- Math teachers' frequency of participation in learning through stakeholder *predict* their pedagogical knowledge self-efficacy.
- Math teachers' frequency of participation in learning through media *predict* their TPACK self-efficacy.
- Math teachers' frequency of participation in learning through stakeholder interaction *predict* their TPACK self-efficacy.

Overall, math teachers' frequency of participation in learning through different informal activities (except stakeholder reflection) predicted math teachers' self-reported efficacy in at least one TPACK domain.

Analysis of Variance with Informal Learning Variables as Dependent Variables and Teacher career stage as Independent

The analysis of variance was guided by the following research question and hypotheses:

Research Question 1b. Do math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) differ based on teacher career stage?

Research hypotheses. There were four hypotheses relevant to this research question, they are as follows:

- i) H9: Math teachers' frequency of participation in learning through media differ based on teacher career stage.
- j) H10: Math teachers' frequency of participation in learning through colleague interaction differ based on teacher career stage.

- k) H11: Math teachers' frequency of participation in learning through stakeholder interaction differ based on teacher career stage.
- l) H12: Math teachers' frequency of participation in learning through individual reflection differ based on teacher career stage.

To determine if teacher participants' frequencies of participation in learning through informal activities (learning through media, colleague interaction, stakeholder interaction, and individual reflection) differed based on teacher career stage; both the Kruskal-Wallis H test and one-way ANOVA were considered. One-way ANOVA and the Kruskal-Wallis H test are used to determine whether or not statistically significant differences exist between two or more groups of an independent variable on a continuous or ordinal dependent variable where the independent variable is normally distributed and non-normally distributed respectively. Both tests were considered because two of the independent variables were normally distributed (frequency of participation in learning through media and stakeholder interaction) and two were not (frequency of participation in learning through colleague interaction and individual reflection). Eventually, one-way ANOVA could not be employed for a test of significance for the frequency of participation in learning through media because of the presence of outliers. Instead, the Kruskal-Wallis H test which is a non-parametric equivalent was used. Thus, the Kruskal-Wallis H test was employed to test for statistical significance in three of the informal learning variables, and one-way ANOVA for the fourth variable.

Specifically, one-way ANOVA was used to assess whether statistically significant differences existed in the frequency of participation in learning through stakeholder interaction between the three categories of teachers in terms of career stage – beginning ($n=43$), mid-career ($n=94$), and experienced ($n=121$) teachers, after checking that appropriate assumptions were not

violated. The result of the analysis showed that there were no statistically significant differences between groups ($F(2,255) = 2.41, p=0.09$).

The Kruskal-Wallis H test which is a non-parametric equivalent was used to assess whether statistically significant differences existed in the frequency of participation in learning through stakeholder interaction between three teacher categories (beginning, mid-career, and experienced). The analysis showed that there was no statistically significant difference in the frequency of participation in learning through media between the three groups ($\chi^2(2) = 3.86, p = 0.15$).

The Kruskal-Wallis H test was also used to determine whether significant differences existed in the frequencies of participation in learning through colleague interaction and individual reflection respectively, between the three teacher categories (beginning, mid-career, and experienced). There were no significant differences in the frequencies of participation in learning through colleague interaction ($\chi^2(2) = 2.90, p = 0.23$) and individual reflection ($\chi^2(2) = 2.19, p = 0.34$) respectively, between the three teacher groups.

Overall, the analysis showed that there were no statistically significant differences between participants' frequencies of participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) and teacher career stage respectively. Thus, we reject hypotheses (i) through (l).

Findings from Phase Two (Qualitative Phase)

This section presented the analysis of the open-ended responses and data obtained from participants' survey-based journaling of their informal learning experiences and interviews. Each of these data sources were analyzed to answer research questions two, three, and four specifically; and to also inform the quantitative results obtained from the first phase. The open-

ended responses are based on a sample of 173 survey respondents while the survey-based journaling and interviews were based on a sample of four purposefully selected participants from the first phase.

Analysis of Open-ended Survey Responses

To examine the types of informal learning activities math teachers engage in, their perceptions of the effects of informal learning, and factors that affect such learning; open-ended survey responses were analyzed using qualitative content analysis methods (Mayring, 2015; Schreier, 2014) with a priori codes taken from Kyndt et al. (2016) and Jeong et al. (2018). Frequency analysis was employed to examine the number of occurrences and percentages of informal learning activities and perceived factors affecting informal learning. In the same vein, survey responses related to teachers' perceptions of the contributions or effects of informal learning were also categorized and described based on frequency analysis. In all cases involving open-ended responses, sentences were used as the unit of analysis.

Informal Learning Activities that Math Teachers Engage in

Analysis of the survey responses revealed four distinct categories of informal learning activities that math teachers engage in; the coding was based on a systematic literature review by Kyndt et al. (2016) and de Jong et al. (2019). In their review, Kyndt et al. (2016) grouped the informal learning activities reported in the 74 articles they analyzed based on seven distinct categories: interaction and discussion with others, consulting information sources, learning from others without interaction, practicing and testing, reflecting in and on action, engaging in extracurricular activities, and encountering difficulties. This study used five of these categories as shown in Table 4.5 and described in Appendix G. However, the subcategories used in this study do not necessarily reflect those in Kyndt et al. (2016) every time.

Table 4.5*Frequency Analysis of Informal Learning Activities Math Teachers Engage in (N=173)*

Categories of Informal Learning Activities	Sub-categories	# quotations	% quotations (Within categories)	% quotations (overall)
Interaction and Discussion with others	Collaboration with			
	colleagues	77	93.9%	29%
	Non-colleague interaction	5	6.1%	1.9%
	Total	82	100%	30.9%
Consulting information sources	Reading professional			
	literature	39	22.9%	14.7%
	Social media	91	53.5%	34.3%
	Online courses and web-			
	based resources	40	23.5%	15.1%
	Total	170	100%	64.1%

Table 4.5 (Continued)

Learning from others without	Feedback (written)	1	25%	.4%
Interaction	Observation	3	75%	1.1%
	Total	4	100%	1.5%
Practicing and Testing	Experimenting	6	100%	2.3%
Reflection	Reflection	3	100%	1.1%
in and on Action				
Grand Total		265		100%

Interaction and Discussion with others. As can be seen from Table 4.5, the first category of informal learning activities that math teachers engage in is interaction and discussion with others. It had two subcategories—collaboration with teacher colleagues and non-colleague interaction (e.g., interaction with family, friends, students). The most frequent informal learning activity in this category is collaboration with colleagues which constituted 29% of all survey quotes and 93.9% of quotes within the first informal learning activities category. Collaboration with colleagues took the form of discussion, joint work, sharing, and/or meetings.

Several teachers reported engaging in one or more of these activities. For example, a teacher wrote “conversations with colleagues are my primary activities” (T-13). Another teacher suggested that such conversation or discussions between teachers can be frequent and beneficial: “I only have one math colleague of my small private school, but we are in constant communication. Our conversations have inspired me to stick with new ideas even when they are challenging” (T-37). Collaboration also took the form of joint work such as shared-planning as this teacher pointed out—“I meet informally with a teaching partner multiple times a week to debrief lessons, discuss student progress, and plan future lessons including unit project” (T-7). Sometimes it took the form of meetups as this teacher pointed out— “Met with colleagues for happy hour and discussed issues” (T-5). At other times, it was more structured as another teacher suggested— “...In fact, in 2012, the MTBoS (Math Twitter Blog-o-Sphere) actually got together for our own ‘for math teachers by math teachers’ conference in St Louis called Twitter Math Camp” (T-25). It always involved some form of information exchange (e.g., tips, insights, ideas), materials, and practices between teachers.

Non-colleague interaction is the second subcategory of *interaction and Discussion with others*; it involves teachers’ interactions with family, friends, students, and parents around

educational issues. Non-colleague interactions accounted for 1.9% of all informal learning activities that teachers report engaging in. For example, one teacher wrote “I have many conversations with friends and family”. Another said, “I have been involved with our local university mathematics project for many years”.

Consulting information sources. Consulting information sources is the second category of informal learning activities; overall, it accounted for 64.1% of all learning activities that teachers reported. This category of informal learning had three subcategories — reading professional literature, social media, and online courses and web-based resources. Each of these subcategories accounted for 68.3%, 25.6%, and 6.1% of all survey quotes in the *consulting information sources* category respectively. Overall, reading professional literature, social media, and online courses and web-based resources accounted for 14.7%, 34.3%, and 15.1% of all informal learning activities reported, respectively. The most cited activity was learning through social media (34.3%), followed by collaboration with others (29%) in the second place. Learning through online courses and web-based resources (15.1%) and reading professional literature (14.7%) followed in the third and fourth places respectively.

Many teachers reported learning from different social media platforms; for example, one teacher wrote “I am in many Facebook groups for math educators and I follow a plethora of educators of all types on TikTok. I have learned so much from these outlets” (T-1). Similarly, several teachers reported reading professional literature (e.g., articles, books). An example of this is a teacher who mentioned that they read books to improve their practice and went on to list some titles- “I read books like ‘building thinking classrooms’ or ‘limitless mind’ or ‘creating cultures of thinking’” (T-38). A subset of teachers also reported learning by attending online courses and/or consulting web-based sources. For example, one teacher wrote “I take online

classes from Udemy, I watch videos to refresh my memory, I have taken and watched webinars for using Desmos in the classroom. I'm looking at ways to enhance statistics instruction using Python” (T-112).

Learning from others without Interaction. The third category of informal learning activities, learning from others without interaction, accounted for 1.5% of all learning activities that teachers reported and had two subcategories- feedback from others and observation. Although it involves learning from others, no direct interaction is involved. There was only one reported case of feedback without interaction from a teacher who reported “*students’ reflection on quizzes/exams*” (T-4) as an informal learning opportunity. Otherwise, the remaining three survey quotes in this category focused on observation; specifically, observing others teach as this teacher wrote:

I’ve been able to visit other math classrooms grades 6-12 in person and through technology- talking and listening to students and teachers during class time and planning. Visiting has given me an opportunity to understand more about how and what my students are taught at levels below and above my classroom (T-16).

Practicing and Testing. Practicing and testing was the fourth category of informal learning activities that teachers reported engaging in. Overall, this category accounted for 2.3% of informal learning activities. Although it has two sub-categories, experimenting and experiencing, only experimenting was reported in this study. Experimenting involves implementing and trying out new ideas while experiencing involves learning from curricular activities that are part of a teachers’ daily practice. There were a couple of survey quotes that bordered on experimenting. For example, a teacher wrote “I always try out a new technology from the student viewpoint before assigning it to my classes” (T-46).

Reflection in and on Action. Reflection in and on action was the fifth category of informal learning activities that teachers reported engaging in. Reflection refers to the mental activities associated with analyzing or thinking about issues of practice (Kyndt et al., 2016). There were very few survey quotes (1.1% of all quotes) that identified reflection as an informal learning activity that teachers engage in. For example, a teacher noted “In person, I often reflect on my own teaching to myself, with my professional colleagues and with family or friends” (T-99).

Factors Affecting Math Teachers’ Informal Learning

Analysis of the survey responses revealed three distinct groups of factors that affect (support or hinder) math teachers’ informal learning as captured in Table 4.6. The complete coding scheme describing each of these factors in detail can be found in Appendix E.

Table 4.6*Frequency Analysis of Factors Affecting Math Teachers' Informal Learning (N=173)*

Factors		# quotations	% quotation (within categories)	% quotations (overall)
Personal factors	Teacher Characteristics	2	4.3%	.8%
	Teacher Attitude	28	59.6%	11%
	Perception	2	4.3%	.8%
	Knowledge	2	4.3%	.8%
	Time (personal)	9	19.1%	3.5%
	Teacher Burnout	4	8.5%	1.6%
	Personal	47	100.1%	18.5%
Interpersonal/group level factors	Networking	6	21.4%	2.4%
	Teacher Collaboration & Support	22	78.6%	8.6%
	Interpersonal Total	28	100	11%

Table 4.6 (Continued)

School-level factors	Admin Attitude	23	12.8%	9%
	School characteristics	9	5.0%	3.5%
	School policy/culture	18	10.1%	7.1%
	Teacher workload	16	8.9%	6.3%
	Time and scheduling	94	52.5%	36.9%
	Work tools and resources	19	10.6%	7.5%
	School level Total	179	99.9	70.3%
Grand Total		255		99.8%

School Level Factors. School level factors refer to the broader organizational level (cultural, institutionalized, and systemic) issues that affect informal learning (Jeong et al., 2018). As Table 4.6 shows, the overwhelming majority of quotes (70.3%) from the survey described school-level factors that either supported or hindered math teachers' informal learning. More specifically, 36.9% of the quotes bordered on issues of time and scheduling. In most responses bordering on time, many teachers noted how job-related responsibilities during school hours and personal commitments outside school left little to no time for informal learning. For example, one teacher noted:

There is no time for informal learning during my school day. Classes are 3/4 of the day; planning periods, when we get an uninterrupted one, must be for grading, completing my sped reports, used for drop ins to evaluate children, or for lesson plans/modifications.

After school (45 min of my contracted hours) is usually tied up with meetings. Usually planning periods a week are taken for curriculum/team meetings. There are not enough contractual hours, so I do my informal learning on my own time (Survey response from T-24).

Several teachers also reported that issues such as not having a common planning time with other math teacher colleagues or subbing during planning time limited their informal interactions. One teacher wrote "Insufficient time to interact with other teachers -- lunch duties, meetings held online instead of in person, subbing during planning time". Besides time constraint, the other school level factors that affected teacher informal learning include work tools and resources (7.5% of quotes), school policies and practices (7.1% of quotes), teacher workload (6.7% of quotes), and school characteristics (3.5% of quotes).

One teacher noted “We have a good professional library to access professional books” while another wrote “Rural communities in my area may not have access to internet or wifi to participate in online settings due to geographical pitfalls. For example my personal wifi is very limited because I live in a rocky and heavy tree populated area with a small number of data towers so data signal of any kind is weak”. Both quotes border on work tools and resources that supported or hindered math teachers’ informal learning experiences respectively. Teachers’ responses also suggested that school policies and practices (or culture) as well as teacher workload affect their informal learning experiences. For example, where teachers do not have opportunities to observe other teachers as one teacher wrote- “We don’t have opportunities to observe other teachers” (T-50), or where they are made to strictly follow a “mandated scripted curriculum” (T-117); their informal learning experience could be impacted.

Closely linked to time constraint is teacher workload. Several teachers noted that their job commitments stand in the way of their informal learning. For example, a teacher noted “There are just so many things that we have to attend to that a teacher’s own learning takes a back seat” (T-65). Others noted that school characteristics such as school size, location (e.g., rural school), and the absence of physical facilities, e.g., a teacher lounge are important factors that could impact teachers’ informal learning. For example, one teacher wrote “No group eating space for teachers. A lot of informal collaboration used to start over lunch but that space had to be used for classrooms so we no longer have those interactions” (T-45); while another teacher suggested that teaching in a small school increases opportunities for informal engagements with colleagues- “our school is tiny so we all know each other and know all the students. We interact casually all the time” (T-71). However, a different teacher opined that being in a small school limited her informal learning opportunities—“ I teach at a small private school, and so have fewer

opportunities to learn and share with my colleagues. I rely on learning networks outside of my school for more varied input” (T-52).

Interpersonal Factors. Interpersonal or group level factors refer to issues related to teacher interaction, rapport, or collegiality within a school either at the individual (teacher to teacher) or group level (group to group) as they affect teachers’ informal learning experiences (Jeong et al., 2018). Admin attitude, teacher collaboration and support, and networking were categorized as interpersonal or group level factor. Overall, interpersonal factors accounted for 20% of all quotes about factors affecting informal learning. Also, admin attitude and teacher collaboration and support were the third and fourth most reported factors that affected teachers’ informal learning.

Several teachers mentioned teacher collaboration and support as a factor that affected their informal learning experiences. For example, one teacher wrote “we have a strong union which advocates for teacher planning time and manageable course load” (T-51). In the same vein, a different teacher noted that teacher unionism was a factor that supported their informal learning- “my union fighting for us to have academic freedoms” (T-84). The responses from these teachers point to teacher unionism as a factor that could possibly affect teachers’ informal learning experiences, especially where the actions of such unions free-up teachers’ by reducing their workload, give them access to funds and opportunities for personal development etc. Besides pointing to the support system that unions provide, several teachers also hinted on additional issues that border on collaboration and support.

For example, one teacher hinted on the importance of teacher collaboration and support when they noted “If teachers do not work well with their grade level teachers that can prohibit informal learning. Also if teachers are not feeling supported within a building they, tend to

withdraw and not learn” (T-30). Another teacher also wrote “Some teachers need more hand holding than others, and this is a factor too if that isn't available” (T-144). Thus, the willingness and commitment of teachers to collaborate and support each other is a factor that supports informal workplace learning as another teacher hinted when giving an example of factors that affect teacher informal learning —“Willingness of colleagues to share experiences, knowledge, resources...” (T-138).

Several teachers also highlighted both the positive and negative impact that a supportive and unsupportive administrators or school leadership respectively, can have on teachers’ experience of informal learning. For example, one teacher wrote “If superiors don’t acknowledge and value informal learning and harness the energy it takes to engage in informal learning, then the desire to share and contribute is highly impacted” while another said “We are hindered by our admin when they take our plan time, don’t provide time to visit other classes, pit teachers against other teachers, or don’t provide resources (financial) to obtain access to best practice”. Another teacher wrote that they have a very supportive admin and went on to hint on how admin attitude could impact teachers’ informal learning:

I have very supportive admin, so the factor that does support teacher informal learning is a community mindset in the school building. Teachers need to feel like they can share their ideas and weaknesses with each other. They need to feel like when they share their lessons, it won't be “stolen” but reciprocated. Instead of admin saying this teacher's pass rate was such and such and that teacher's pass rate was such and such, it needs to feel like all teachers combined had a certain pass rate. Individual teacher pass rates should never be calculated. If the school community is truly a community, teachers will go beyond their duties and try to improve themselves (Survey response from T-99).

Personal Factors. Personal factors refer to issues that affect informal learning at the individual level. These are specific to the teacher as a person or individual (Jeong et al., 2018). The personal factors identified from the analysis of the open-ended survey responses are teacher characteristics, knowledge, teacher attitude, perception, and teacher burnout. Overall, the second most cited factor affecting math teachers' informal learning after time was teachers' attitude.

Teacher attitude refers to ways of thinking or feeling about informal learning activities or opportunities (e.g., interest or willingness to learn, resistance to change). Specifically, 11% of the quotes from teachers' survey responses bordered on issues related to teacher attitude as can be seen from Table 4.6. Positive teacher attitudes led to greater commitment to informal learning, for example, one teacher wrote:

Most of the teachers in my school are constantly looking for new ways to improve their teaching and student learning. We have had to do a lot of informal learning on our own time these past two years due to COVID and needing to transition back and forth from online to in person learning (Survey response from T-36).

In the same vein, negative teacher attitudes close them up to informal learning opportunities as another teacher noted:

My last colleague was more unwilling to work together. She was not interested in ensuring that our curricula were standards based and taught mostly from the book. So we did not collaborate much. Some teachers are less interested in new technology (Survey response from T-37).

Additionally, teachers' personal commitment outside school hours also affected informal learning. For example, a teacher wrote "*Time. I do a lot of this in the summer. It's so busy in the*

school year, not much time for “extra” school stuff when you are off work” (Survey response from T-13).

Perceived Effects of Informal Learning Activities on Teachers’ Learning and Professional Practice

Although one of the open-ended questions in the survey asked teachers to mention the different informal learning activities they engage in and the contributions or effects of such activities on their professional learning and/or practice; there were a lot more teachers that listed the informal learning activities they engage in compared to those who went further to describe the effects of such activities on their professional learning or practice. Analysis of the survey responses showed four categories under which the contributions or effects of informal learning that teachers described may be captured- content knowledge, pedagogical knowledge, technological knowledge, and support for practice.

Table 4.7*Frequency Analysis of Math Teachers' Perceptions of the Contributions of Informal Learning (N=173)*

Contributions		# quotations	% quotations (within categories)	% quotations (overall)
Content knowledge	Math content Knowledge	4	57.1%	4.0%
	Curriculum and standards	3	42.9%	3.0%
	Total	7	100%	7.0%
Pedagogical knowledge	Teaching ideas and strategies	37	72.5%	37.4%
	Grading practices	2	3.9%	2.0%
	Lesson planning	6	11.8%	6.1%
	Classroom management	6	11.8%	6.1%
	Total	51	100%	51.6%

Table 4.7 (Continued).

Technological knowledge	Tech tools and ideas	6	66.7%	6.1%
	Technology implementation	3	33.3%	3.0%
	Total	9	100%	9.1%
Support for practice	Motivation and emotional wellbeing	14	43.7%	14.1%
	Resources and unspecified learning	18	56.3%	18.1%
	Total	32	100%	32.2%
Grand Total		99		100%

Content Knowledge. Several teachers noted that engaging in informal learning contributed to their content knowledge. This category had two subcategories—knowledge of math content and knowledge of math curriculum and standards. Overall, content knowledge, that is teachers’ knowledge of subject matter or a content area (mathematics in this case), accounted for 7% of all areas of contribution of informal learning that teachers identified. For example, a teacher wrote:

Speaking with colleagues, online groups. Interacting with colleagues and these groups has grown my math content knowledge, increased my teaching practices knowledge, and increased my knowledge around technologies in the classroom (T-45).

Another teacher also mentioned how engaging in informal learning contributed to their knowledge of math content when they wrote “I am part of Facebook groups for calculus and that helps me hone calculus skills specifically in preparing students for the AP test” (T-61). In regards to the contribution of informal learning to teachers’ knowledge of math curriculum and standards, one teacher wrote:

I’ve been able to visit other math classrooms grades 6-12 in person and through technology- talking and listening to students and teachers during class time and planning. Visiting has given me an opportunity to understand more about how and what my students are taught at levels below and above my classroom (T-16).

This quote suggests informal learning could contribute to teachers’ understanding of vertical alignment. In the same vein, another teacher’s comment captured how informal learning contributes to teachers' knowledge and skills related to curricula:

I'm an obsessive audiobook listener, and the books I've listened to recently have addressed the knowledge gap between students of different socioeconomic statuses, and for students with learning differences. This inspired me to seek a knowledge-building curriculum to use with my students for both math and language arts (I teach both subjects at a special education school for students with dyslexia). As a result of this search, I piloted the Core Knowledge curriculum this summer, and it has been so successful that I, and several colleagues, will be using it in the fall (T-59).

Pedagogical knowledge. The majority of survey quotes (51.6%) on the contributions of informal teacher learning bordered on pedagogical knowledge. The pedagogical knowledge category had four subcategories- teaching ideas and strategies, grading practices, lesson planning, and classroom management. Overall, teacher ideas and strategies accounted for 37.4% of all survey quotes; lesson planning and classroom management accounted for 6.1% of all survey quotes respectively, while grading practices accounted for 2%. Many teachers mentioned that they learned about different teaching ideas and strategies through their informal learning engagements. For example, one teacher wrote:

I spent this year having lunch daily with one colleague. The majority of that time was spent informally discussing our teaching and thinking about how to improve. I learn a lot from those discussions that I can take into the classroom (T-53).

In regard to the contribution of informal learning to lesson planning, one teacher wrote "I recently bought a book about planning effective and engaging math lessons. It takes you through the process of creating a lesson. I found that I do a lot of the stuff already. It helped me tweak my lesson planning"(T-65). On the contribution of informal learning to classroom management, one teacher wrote:

I participate in a number of teacher groups on Facebook. Some are specific to math, others are more general. *Through these groups I have learned about various methods of classroom management, ways to assess students, as well as ways to teach math concepts* (T-72).

Lastly, in regard to the contribution of informal learning to grading practices, a teacher wrote:

My closest friends are also my closest colleagues, pedagogical discussion is a given and the sharing of resources is second nature...Through informal learning I have adopted complex instruction, desmos integration, Geogebra integration, and more equitable grading practices. Almost all of my more equitable practices have been a result of informal learning that I have then advocated to become formal learning for my colleagues across multiple disciplines (T-59).

Technological knowledge. A couple of survey quotes about the contributions of informal learning bordered on ideas around options for technology as well as implementing technology. Overall, this category accounted for 9.2% of all survey quotes and has two subcategories- Tech tools and ideas and Technology implementation. These two subcategories accounted for 6.1% and 3% of all survey quotes respectively. In regard to the contribution of informal learning to the first subcategory, tech tools and ideas, a teacher wrote “I’ve really gotten a lot of ideas from the Desmos group on Facebook. I also search online for project ideas and various grading options” (T-57). On the contribution of informal learning to technology implementation, one teacher wrote “...Through informal learning I have adopted complex instruction, desmos integration, Geogebra integration, and more equitable grading practices...” (T-59).

Support for practice. Several teachers noted that informal learning was a source of motivation and support for their overall practice as teachers, as well as a means for learning about different resources relevant to their professional learning, e.g., articles, books, videos, websites, etc. Besides issues of motivation, emotional wellbeing, and resources (unspecified); the *support for practice* category also captured any learning that teachers reported that could not fit into earlier categories (unspecified learning). Survey responses in this category were analyzed based on two sub-categories: *motivation and emotional wellbeing* and *unspecified resources and learning*. The Unspecified resources and learning sub-category refers to resources or learning which teachers reported that could not be specifically identified as related or contributing to content, pedagogical or technological knowledge.

Support for practice accounted for 32.2% of all survey quotes about the contributions of informal learning: 18.1% of this number bordered on resources while the remaining 14.1% was about motivation and emotional wellbeing (see Table 4.7). In regard to the contribution of informal learning to teachers' motivation, a teacher wrote "I only have one math colleague of my small private school, but we are in constant communication. Our conversations have inspired me to stick with new ideas even when they are challenging" (T-37). An example quote under resources and unspecified learning (specific to unspecified learning) was from a teacher who wrote the following:

Many of my informal activities are self-sought out and on my own time. They have helped immensely, especially as a new teacher and then a Covid teacher. I follow teachers on twitter and instagram, and learn via their posts and TPT. There are also facebook groups (T-98).

Whereas this teacher noted that they benefit immensely from informal learning, the aspect of their professional practice (e.g., pedagogy, use of technology) that they may be referring to is not exactly clear. An example quote specific to resources is from a teacher who wrote “I’m a member of several math emails that provide articles on new things, best practices, etc” (T-14). Another teacher noted “Collaboration with colleagues across the world through various Facebook groups has given me resources I may never have discovered on my own” (T-28).

Within Case Analysis

This subsection presents a description of each case or teacher participant (in the case analysis), the unit of analysis, purposefully selected based on preliminary results in the quantitative phase, to illustrate teachers’ perceptions of informal learning. This includes perceptions of factors that affect their informal learning, the types of informal learning they engage in, and their perceptions of the effects of engaging in informal learning. Specifically, four participants were selected based on their average frequencies of participation in the four different informal learning activities that this study focused on (learning through colleague interaction, media interaction, stakeholder interaction, and individual reflection).

Table 4.8 captures the demographic make-up of each of the cases while Table 4.9 shows the TPACK scores and scores for frequencies of participation in different informal learning activities for the cases. Note that pseudonyms were used to protect the identity of participants. Furthermore, Table 4.10 presents scores for the average frequencies of participation in different informal learning activities for each case. As can be seen from Table 4.10, the first case (Carlos) and second case (Natasha) are average users of informal learning, while the third (Jane) and fourth cases (Debbie) are high users of informal learning. Survey respondents with average

scores equal or greater than 4 were categorized as high users of informal learning, those whose scores are greater than 2 but less than 4 as average users, while those with scores less than or equal to 2 as low users of informal learning.

Table 4.8*Demographic Make-up of Cases*

Case (pseudonym)	Sex	Race	Teaching Experience	School level	Career stage	Educ. Qual.	Degree Major
Carlos	Male	Hispanic	2 years	High school	Beginning teacher	Doctorate degree	Mathematics Education
Natasha	Female	Non- Hispanic Black	12 years	Middle school	Mid-career teacher	Master's degree	Elementary Education
Jane	Female	Non- Hispanic White	30 years	Middle school	Experienced teacher	Bachelor's degree	Music/spec. Education
Debbie	Female	Non- Hispanic White	28 years	Middle school	Experienced teacher	Master's degree	Mathematics Education

Table 4.9

Brief Overview of TPACK and Scores for Frequencies of Participation in Informal Learning Activities for Cases

Case	CK	PK	TK	TPACK	Media	Colleague	Stakeholder	Ind. Refl
Carlos	4.40	4.60	4.16	4.83	3.40	3.33	2.75	5.00
Natasha	3.40	4.60	2.83	4.66	2.40	5.00	3.00	4.67
Jane	3.60	4.40	4.50	3.66	4.00	4.00	4.25	5.00
Debbie	4.80	5.00	4.33	5.00	5.00	5.00	4.25	5.00

Table 4.10

Mean Frequencies of Participation in Informal Learning Activities (mITL) Scores for Cases

Case	mITL Scores	Type of Informal Learning Users
Carlos	3.62	Average User
Natasha	3.77	Average User
Jane	4.31	High User
Debbie	4.81	High User

The case analysis presented in the remaining part of this subsection is based on open-ended responses, interview data, and data from survey-based journaling obtained from each of the four cases. As Table 4.8 shows, three of the cases are female middle school math teachers while the only male is a high school math teacher. Cases were selected across three teacher career stages- beginning, mid-career, and experienced teachers.

The qualitative results presented in this section helped to make better sense of the TPACK scores and scores related to the frequencies of participation in informal learning activities for each case (quantitative measures). For example, Natasha's score for Technological knowledge self-efficacy and frequency of participation in media were 2.83 and 2.40 respectively. These scores are low compared to related TPACK and informal learning constructs on which Natasha rated herself in the survey. Because of this, during the interviews, I asked questions about why she rated herself low on these constructs and her answers helped explain the thinking behind these quantitative data. In a nutshell, she rated her technological knowledge self-efficacy low mainly because she sometimes struggles with technology, especially coding in Desmos. Also, the interviews suggested that she prefers asking colleagues for help rather than taking the pain to look for resources on her own online (social media inclusive) because it saves more time. The rest of this section gives a detailed description of the informal learning experiences of each of the cases and their perceptions of informal learning opportunities.

Carlos

Perceptions of factors affecting informal learning. The findings on factors affecting informal learning presented are based on the analysis of open-ended survey responses and two rounds of interview data specific to the first case, Carlos. To start with, I present a brief overview of the school context where Carlos teaches. This is important because the workplace (or school) context is central to teachers' perceptions of informal learning.

Brief Overview of Workplace (School) Context and School Level Factors. Carlos teaches tenth, eleventh, and twelfth grade math in a new school located in Northeastern United States. The school is a virtual school with a learning system run by Pearson. Pearson provides online education services including state-aligned curriculum, educational management system,

professional development to schools. Students watch recorded lessons and take quizzes on days set aside for independent work and meet with teachers (virtually) twice a week. On days when teachers meet with the students, they plan instruction to support student learning based on data from quizzes, review topics with students, and work on more challenging problems with students as appropriate to deepen their understanding.

Students are not required to come to school except for standardized testing from the State or optional monthly special activities organized to help students interact face to face with peers, while teachers alternate between coming to school and working from home. Because this school is an online school, there is a huge focus on technology; specifically, using technology to engage students. Teachers also have professional development which focuses mostly on technology and related issues every couple weeks. Although all the teachers in this school have only spent two years working in the school at best, they are generally supportive of each other. There is also a strong teacher union which advocates for the rights of teachers.

Carlos' description of school level factors that affect informal learning bordered mainly on issues around school characteristics (e.g, an online school where only about half of the staff have to come to school sometimes) and school policy (e.g, bureaucracy around accessing resources that support teachers' informal learning). While commenting on factors that support informal learning, Carlos made reference to the school theme for the year, suggesting that this school is a space where teacher collaboration and professionalism is valued:

So I think the theme of our school this year is "Together, we are all experts". So the idea is that we are going to be learning from each other and if we are experts in one area maybe we can share with others, so that we can then learn together and grow.

Meanwhile, there were also unique school level factors that limited informal learning. For example, Carlos noted that being the only teacher in the entire school that teaches the courses he teaches meant he had no one to specifically compare experiences with:

...you know something that may hinder the informal learning is that I am the only teacher teaching my courses right? If there were other teachers teaching my courses, I think we would be able to compare how they teach versus how I teach and all those things.

While commenting on factors that affect teacher informal learning in the open-ended section of the survey, Carlos hinted on how issues related to work tools and resources could affect informal learning:

Funding for and facilitation of informal resources may hinder teachers informal learning in schools. I just bought a whole year of resources for precalculus and algebra II for like \$60. Some of the resources are great and I will be using many of them. However, teachers should not pay for these things themselves.

I followed up on this response during the first round of interviews and found out that even though the school makes funds available for teachers to get certain resources that they need, the policy in place is that all such resources must be purchased through state/county approved qualified vendors. Carlos noted that these vendors take a long time to deliver requested items. Sometimes, they may not even have the items in stock. This frustrates teachers, forcing them to resort to paying for resources (for which they are not reimbursed) out of pocket like Carlos did with the \$60 Algebra II resources he mentioned.

Interpersonal Factors. When asked about what teacher relationship looks like in his school, Carlos mentioned that about half of the teachers in the school this year are new, and last year the school had a policy in place that had only about half of the teachers showing up in

school. The remaining half worked from home. As a result, Carlos almost never got to see the other half of the teachers last year. He also noted that him and the older teachers are still getting to know the new teachers and haven't had many opportunities to get to know them closely yet. That notwithstanding, teachers are pretty open and supportive of each other.

Due to the focus on technology in Carlos' school, teachers tend to support each other in their quest to master the use of online tools and technologies. The school principal is supportive of teachers' efforts to improve their practice. There is also a strong teacher union in place which advocates for teachers' rights and welfare. Carlos mentioned that the union successfully reached an agreement that will make up to 200 dollars directly available for teachers to purchase resources that they need starting from next year:

Fortunately, we have a union, and the Union, in the latest agreement was able to get like one hundred or two hundred dollars for teachers for whatever they wanted like If they wanted to decorate or buy some more resources, we would get that one for that. But I think that starts next year.

Personal Factors. Most of the personal factors affecting informal learning that the interviews with Carlos brought to the fore bordered on teacher attitude, previous experiences with technology, perception of informal learning, and self-efficacy. Carlos noted that he learns from both formal and informal learning opportunities. As such, he believed that informal learning is important, except that the perception of its benefit may depend on individual teachers. He mentioned that the things he learns informally are sometimes more interesting and surprising because such moments are unplanned. Carlos believes that he benefits more from learning opportunities (formal or informal) which pique his interest and are not required:

I think that with informal learning, I think I get to those because I am interested in those things. I am engaging in a conversation because I am interested in that conversation. And then I learn something from that conversation. On the other hand, when I select my own professional development, I select the ones that I am interested on. The problem is when I am required to take some specific PD in a specific topic. I think that's when it becomes a little bit less useful.

For Carlos, besides interest, the autonomy associated with informal learning seemed to be another support factor. Although he believes that informal learning can be beneficial, Carlos also thinks it can be difficult figuring out exactly where to find the resources one is looking for. An endless search for resources can be overwhelming for some teachers and not every teacher is cut out for that:

There are just so many resources out there, and we can learn from them in an informal way, but sometimes it's so hard to get through those resources, to access them or like to discriminate between them, like which ones are the good resources, right? So it can be a little bit overwhelming. So I think that's why it can be... for some teachers it can be good and bad.

He went on to add that the burden of having to spend a lot of time searching for resources is the reason why some teachers settle for formal PD because that way “they don’t have to decide what’s good and what’s not”. Also, formal learning is more structured and “when you go for formal professional development, you know what you're getting into most times. You know the topic, you have a description, maybe you even know the presenter”.

Although Carlos holds a doctorate degree in mathematics education and has considerable experience teaching at the college level, he is very receptive to learning from other teachers at

his school. He noted that his teaching experience at the college level makes him feel very confident as though he is not a new teacher and makes other teachers in his school treat him as such; however, his openness to learning from other teachers is partly attributable to his belief that his experiences teaching at the college level doesn't necessarily translate to teaching at the high school level. Carlos' experience here point to teacher perceptions of informal learning and attitude as factors that affect informal learning.

Additionally, Carlos strongly believes that his experiences with learning management systems such as Canvas during his graduate studies and his flair for exploring or experimenting with new technology (a form of informal learning activity) made it easier to learn and master the Pearson online platform in his school to the point that he became a resource for other teachers in the school. I had asked him if as a new teacher to the Pearson system he has had cause to reach out to other teachers for help in using the Pearson system and he said:

I think that working with Pearson... with this system could be like working in Canvas or something like that, right? And we are used to working on those things, especially like people who went to graduate school recently...all that knowledge is transferable among systems, and I was able to catch all the information very quickly, and how to manage the system very quickly. And yeah, so sometimes teachers do get to me specifically. And very often I am able to help them.

The aforementioned excerpt and the corresponding description before it identified teacher self-efficacy beliefs and prior experiences with technology as factors that affect teacher informal learning.

Informal Learning Activities Math Teachers Engage in: The Case of Carlos. The open-ended survey responses, interview data, and two-weeks survey-based journaling completed by the case revealed different types of informal learning activities he engaged in. This includes referencing web-based resources, collaboration with colleagues, using social media, and observing other teachers. In responding to the open-ended survey question asking participants to describe the types of informal learning activities they engage in and the effect on their professional learning, Carlos wrote:

I often look for pictures that can succinctly describe and summarize important mathematical concepts. I also look for and adapt lesson plans, especially when they are created to be shared and used in digital platforms like Nearpod. I am very engaged when I do things like these because I go deep into what I can implement and how I can make it even better for my students.

Upon following up on this response during the interviews, Carlos added that he specifically looks out for pictures that succinctly describe and summarize mathematical concepts on Facebook. He also visits websites like teachers-pay-teachers as well as the Desmos and Nearpod websites for ideas on lesson planning and student engagement. In addition, Carlos also references books and relevant curricula through the Pearson website.

Moreover, Carlos also engaged in informal conversations about teaching with his teacher colleagues and persons outside his school setting as well as reflected on issues of practice. When asked about those he discusses issues related to teaching math with outside the school setting, Carlos mentioned that he talks mostly to family members:

Um yeah, with my wife. I sometimes speak to her. With my parents-in-law. Sometimes I do speak to them, they're staying with us right now, so they're visiting so I speak with them sometimes. My mother-in-law was a teacher and also a principal for a time she's now retired. So that's why I kind of talk to them both my wife and her, and also when I, when I speak with my mom on the phone. Sometimes I do talk to her about school things, too.

To make sense of the extent to which some of these informal learning activities form part of Carlos' continuous or everyday learning, results from his survey-based journaling of informal learning experiences for 10 days and perceptions of the usefulness of such informal learning activities are summarized in Table 4.11. Overall, referencing web-based resources for lesson planning was the most frequent informal learning activity that Carlos engaged in within the period, this is followed by discussing with colleagues in second place. In the next subsection, I describe Carlos' perceptions of the effects of informal learning and offer additional detail about his continuous learning profile.

Table 4.11*Carlos' Everyday/Continuous Learning Profile*

Days	Learning activities reported	Description	Topic/focus of activity	Perceptions of usefulness
Day 1	Referenced websites	<u>Desmos</u> : I used Desmos to show students how to solve systems of linear equations using graphs.	--	
		<u>Pearson curriculum</u> : Accessed curriculum through the Pearson system which my school uses for classes.		Extremely useful
Day 2	Discussed with a colleague	I shared ideas for engaging students online with a lateral entry teacher colleague.	Group work strategies	Moderately useful.
	Referenced books & used social media	I referenced books, teacher resources from our platform (Pearson) and I saw a Calculus video on Facebook	--	Extremely useful
Day 3	I did not engage in any informal learning activity today	--	--	--

Table 4.11 (Continued).

Day 4	Discussed with colleagues	I taught my colleagues how to add assessments in Pearson and correctly use weighted grades. The interaction also touched on how best to contact parents-using the school phone and school messenger app rather than one's phone.	Strategies for interacting with stakeholders (parents, community, administration, etc.); Technology ideas; Grading practices.	Moderately useful
	Referenced a book/website	I used a book to help me plan and create a lesson. Accessed a resource that I had bought from teachers-pay-teachers for an interactive student activity.		Extremely useful
Day 5	PLC meeting	Today we had a meeting about the new way to adapt due dates in the Pearson platform. Also, I got a formal observation today. I had asked to find ways to have my students talk more in the classroom, but they said that I was doing a great job at engaging the students. They suggested that I start with a warm-up (today I did not) and have the students read the objectives for the day rather than me doing it.	Facilitating classroom discussions	Extremely useful
	Formal observation			
Day 6	Referenced a website	<u>Pearson website</u> : The curriculum and the content of my courses are provided by Pearson. I use it all the time for planning.	--	Extremely useful

Table 4.11 (Continued).

Day 7	Referenced websites	<u>Pearson platform, teachers-pay-teachers website:</u> I used documents from these websites to plan and create lessons.	--	Extremely useful
Day 8	Referenced websites	<u>Desmos and Nearpod:</u> I used Desmos and Nearpod for my lessons today	--	Extremely useful
Day 9	Spoke to persons outside school	There was a problem related to grading in the Pearson system that we use in my school and I was venting and talking about it with my wife	Grading practices	Neither useful nor useless
Day 10	Mini survey was not filled out	--	--	--

Perceptions of the Effects of Informal Learning. To examine participant's perceptions of the effects of informal learning, I examined their open-ended responses, interview data, and data from their survey-based journaling for possible references to how informal learning activities have contributed to their professional learning and practice. An analysis of these three data sources for Carlos revealed that Carlos perceived informal learning as useful for his professional learning and practice. Although Carlos primarily learns from formal PD opportunities, there were several instances where he reported benefiting from informal learning. Overall, the analysis showed that he found informal learning activities useful for mostly learning about useful resources as well as ideas or strategies for engaging students online.

Carlos mentioned how he struggled with student engagement in his first year as a teacher. Because instruction was entirely online, Carlos noted that it was difficult to engage students. They would turn off their cameras and refuse to talk or participate. He went on to describe how observing other teachers and talking to them helped to improve student engagement in his classes. On observing other teachers, Carlos stated:

Sometimes just watching other teachers interact with other students, you realize that you can do things differently. So as a new teacher, you know, it was good to see other teachers interacting with students and reflect on how students can see my interactions with them, or how they can perceive my interactions with them.

He also made references to several strategies that he and teacher colleagues started adopting as a result of the informal conversations they had had about student engagement: "...We started doing breakout rooms...we would have students work in groups. And you know, I think many, many other strategies came from just talking with teachers in the hallway". Carlos also reported instances of learning about new resources that he used in his class from discussing with

colleagues and using social media. For instance, he described how he had learned how to create escape rooms using google forms from a teacher colleague, an activity which he found very useful for engaging students:

...The other math teachers, we learn a lot from each other. I would say that, for example, my next door math teacher has used Google forms to create escape rooms...activities like that for students, and I didn't know about that until very recently. And so it is an engaging activity in which they have to work in groups, they have to communicate with other students, and this is especially hard in an online environment... this is one great activity that I learned from her, and that I will be using on Thursday for the first time, and I plan to continue using them. So that's one way which I have learned from other teachers in a very informal way, because it wasn't in professional development. It wasn't in a planning time or anything.

He also mentioned how he finds Facebook useful (from time to time) for accessing pictures, emojis, cartoons and other representations that are useful for summarizing key mathematical concepts:

I am a member of some Facebook groups that share very nice representations of mathematical concepts like very good pictures summarizing the laws of exponents, conic sections, or things like that, and it is already prepared. They use emojis or things like cartoons that might be entertaining or fun for students...I take those pictures, and I share it with them, and I think it's a good way of learning from social media and using those things. But other than that, I don't use it very often for my classes, but every time I see something I save the photos, and then try to integrate them into my presentation.

Carlos also described how he learnt about a compilation of resources accessible on teachers-pay-teachers website through a math teachers group on Facebook and bought them for use in his class. Furthermore, he references books from time to time for lesson planning and adapts lesson plans freely available online.

Carlos' continuous learning profile shows that informal learning activities are a part of his everyday learning. Specifically, Table 4.11 shows that besides formal learning opportunities such as PLC meetings and formal observation (see day 5) which Carlos leverages on for his practice, informal learning activities, mostly referencing websites, are a major part of his everyday learning opportunities. Out of the 13 instances of learning opportunities he reported, 11 of them were informal experiences: five of these informal learning experiences involved referencing websites, two involved referencing/reading books, two involved discussions with colleagues, and one involved using social media and discussing with persons outside school respectively.

Carlos found all five instances of referencing websites, two instances of referencing/reading books, and one instance of using social media extremely useful. Lastly, the two instances of discussing with colleagues were moderately useful. The follow-up interviews showed that this was because Carlos was the one sharing, he did not benefit much from the conversations. The only instance of discussing with persons outside school that Carlos reported was neither useful nor useless. Carlos had explained during the follow-up interview that there was a problem related to grading in the Pearson system his school uses, and he was just explaining the situation to his wife.

In conclusion, Carlos' informal learning experiences as described so far are useful for making sense of the scores reflecting his TPACK self-efficacies and his frequencies of

participation in informal learning activities (see Tables 4.9 and 4.10). Although Carlos is a beginning teacher, having a Ph.D. in mathematics education and his previous experiences teaching at the college level and using technology (e.g., learning management systems such as Canvas) made him very confident about his content, pedagogical, and technological knowledge. This is evident in the score of 4.16 that he had for technological knowledge self-efficacy; 4.4 for content knowledge self-efficacy; 4.6 for pedagogical knowledge self-efficacy; and 4.8 for technological, pedagogical, and content knowledge self-efficacy. His self-efficacy seem to have influenced his informal learning experiences.

Carlos did point out that he does not feel like a new teacher and nobody treats him as such either. The lowest self-efficacy score of 4.16 that he had was in technological knowledge. This may have a connection to his initial struggles with engaging students virtually using technology and his deliberately seeking to observe and talk to colleagues to learn how to better engage students online. The scores representing his frequencies of participation in media, colleague, and stakeholder interaction were 3.4, 3.3, and 2.75 respectively. For individual reflection, his score was a 5. Although Carlos noted that he learns a lot from reflecting on practice, justifying the score of 5 for individual reflection in a way; his scores for media, colleague, and stakeholder interaction may well explain why he is an average user of informal learning. It is also noteworthy in many of the interactions with colleagues that Carlos reported, he was more on the giving or sharing rather than receiving side.

Natasha

Perceptions of factors affecting informal learning. Similar to the first case, Carlos, the results presented here are based on data from the open-ended survey responses and interview data of the second case, Natasha. To start with, I provide additional information on the case and their workplace (school) context.

Brief Overview of Workplace (School) Context and School Level Factors. Natasha teaches sixth grade math in a middle school in Northeastern United States. She has taught in the same school for the last ten years although she taught seventh grade math for four years out of this time. The school Natasha teaches is an inclusion school with kindergarten through twelfth grade. Students with significant disabilities who would normally be in a small class somewhere else in the school are put in the same class with everyone else. Natasha is the general education teacher; she co-teaches with the special education teacher and is also friends with her as well as the math coach.

Natasha's description of school level factors that affect informal learning bordered mainly on issues around time, teacher workload, and school policy (the practice of co-teaching and a school mission that espouses the use of technology to reach all students). She pointed out that "there's a system technology that some of our (the) students use to help them get through their day because of the nature of their disabilities. So it's (referring to technology) really actually very important in our (their) school". When asked about their perceptions of factors that hinder informal learning, she stated "I think time would be the number one barrier". Natasha went on to explain that teachers have a lot to attend to, and this affects the time available for informal learning:

...you know as a teacher, your time is overloaded with teaching. You know you need to lesson plan. You need to call parents. You need to grade so many things you have to do so a lot of times you don't have the time to really spend learning the way you need to.

She also noted that the school tends to steer teachers in specific directions with regards to how to spend available time during school hours—"when there is time we are usually told what to focus on or steered in a particular direction". The school's commitment to reaching all students through the use of technology appears to be a factor that drives Natasha's informal learning in the area of technology:

...we need technology in order to meet the needs of all of our students. And so technology is a must. It's actually in the mission of our school that we use technology to teach all of our students, to reach everybody. So it's something we're committed to.

Interpersonal Factors. When asked about the nature of teacher interpersonal relationships in their school, Natasha mentioned that there is a strong sense of community among teachers in the school and that they are very supportive of each other:

...So our school is just like that we're pretty close to everybody. So outside of school hours we can just call and email if we have any question... we do a lot of collaboration. It really is just a normal part of our teaching like a lot of times when people come to the school from other places that's one of the things they comment on. So I'm always talking to teachers about teaching really. Even other people on the team who don't teach math just talking about different strategies for students.

This commitment among the teachers in the school to support each other goes beyond school hours as Natasha pointed out. Besides current colleagues, she mentioned that she sometimes reaches out to former colleagues for help with problems of practice as necessary:

So if i'm planning alone and I just see something that is confusing, or I need help with. I just call them up, and you know, ask or get their thoughts and opinions. Um, you know, or even past people I've worked with. If there's a challenging problem and a lot of my students didn't get it. I might call and ask for help...

Personal Factors. Most of the personal factors affecting informal learning that the interviews with Natasha brought up focused mainly on self-efficacy beliefs, lack of time due to personal commitments, perceptions of formal and informal learning opportunities, and teacher attitude. Overall, Natasha is very confident about her content and pedagogical knowledge. However, she is relatively less confident about her technological knowledge, especially as it relates to programming or coding in Desmos and creating engaging videos- two specific things she mentioned she does not know how to do. Natasha had rated her confidence in her technological knowledge lower compared to their content and pedagogical knowledge and my follow-up on this during the interviews revealed that the reason was that she struggled with the programming aspect of Desmos.

Time and perceptions of usefulness of informal learning opportunities were two reoccurring issues in the course of the interviews with them. Even when Natasha identified useful resources that could help with honing one's technological skills, these two factors seemed to be the major considerations for not exploring such opportunities further:

So I remember a PD that we had specifically where the majority of it was about technology. People were going over pear deck, there's another one that a lot of people use. So they basically had different teachers do like a little video or a paragraph about the specific technology. And then we had a Google sheet where they linked everything, and we were supposed to go in and learn about it. And it was really a great idea, and I have

gone back, maybe once or twice, to look at it. I think the issue with it was in the moment of planning a lesson, do I have time to go back and learn this new piece of technology that someone had...or do I even feel like It's going to be meaningful in my classroom or in my teaching.

Natasha had earlier suggested (in their open-ended survey response) that besides issues of time, teachers' workload or commitments in the course of the school day could lead to fatigue, making it difficult to create time for additional informal learning outside school hours:

The stressors of the day do not leave a lot of energy for participating in additional informal learning activities...you know I have a child, I'm teaching. I don't even know if I would have the time really to do it. So that's another barrier, frustrating part I think.

With regards to perceptions and attitude, Natasha perceives formal learning as more useful and prefers spending time outside school hours on personal concerns rather than job-related matters. However, she believed attention could be paid to informal learning outside school hours when it is useful for planning. While she believed that informal learning can be helpful, she also expressed concerns about possible difficulties in knowing where exactly to find what one is looking for. Moreover, Natasha views social media learning opportunities as lacking in depth and prefers informal learning engagements that address issues deeply and can be sustained over time:

I think social media is so quick, and I feel like what I need is more in-depth than what it can give me like you know, a response on social media would be really fast.

I feel like I need like real teaching, like sitting down and showing me over time how to do something so that I can do it well. So I guess I view social media more as something

like an instant answer to a question or a really quick answer to a question, not something that's like sustained over time.

As a result, even though she belongs to different Facebook groups and watches how other teachers ask for support for issues of practice, Natasha noted that it has never occurred to her to ask for help with coding or programming in Desmos—an aspect of Desmos that she struggles with. She would rather reach out to colleagues on such issues and does that from time to time as the next subsection will show.

Informal Learning Activities Math Teachers Engage in: The Case of Natasha. The open-ended survey responses, interview data, and two-weeks survey-based journaling completed by Natasha showed the different types of informal learning activities she engages in. These include experiencing, co-teaching, collaboration with colleagues, conversations with persons outside school, referencing web-based resources, and using social media. In responding to the open-ended survey question asking participants to describe the types of informal learning activities they engage in and the effect on their professional learning, Natasha wrote:

I discuss with colleagues on a regular basis outside of formal meetings. We often brainstorm ways to improve instruction and student learning.

For Natasha, collaboration with colleagues is a given, especially considering that she co-teaches with a colleague who is also a friend. She is also a member of several Facebook groups, including a Desmos group for teachers. Natasha also pointed out that she visits different websites (e.g., Khan Academy, Math Antics) for useful resources such as videos and programs that help students practice math skills. Outside school hours, Natasha also talks to her mom about school related issues from time to time.

In order to make sense of the extent to which some of the informal learning activities mentioned form part of Natasha's continuous or everyday learning, results from their survey-based journaling of informal learning experiences over a two-week period and perceptions of the usefulness of such informal learning activities are summarized in Table 4.12. Overall, collaboration with their co-teacher was the most frequent informal learning activity that Natasha engaged in within the period, this is followed by referencing web-based resources in second place.

In the next subsection, I describe Natasha's perceptions of the effects of informal learning and offer additional detail about their continuous learning profile.

Table 4.12*Natasha's Everyday/Continuous Learning Profile*

Days	Learning activities reported	Description	Topic/focus of activity	Perceptions of usefulness
Day 1	Referenced a website	<u>Desmos:</u> Desmos has pages that explain what prerequisites a student may need to access content. I was reading this information, so I know how to better prepare my students.	--	Slightly useful
Day 2	Discussed with a colleague (Co-teacher)	We do not typically have students take notes because we have a large population of students with executive functioning challenges as well as difficulty with writing. However, we feel that the skill is necessary for math success. We discussed strategies to help students who struggle. We decided to provide notes and/or tools to students with special needs. While other students are writing notes these students would be discussing how to use the notes and/or tool that was provided to them.	Supporting students with special needs	Extremely useful

Table 4.12 (Continued)

Day 3	Discussed with a colleague (Co-teacher)	--	Grading practices	Extremely useful
	Referenced a website	Desmos	--	Extremely useful
Day 4	PLC meeting	Meeting with math team	Group work strategies, Technology ideas, Grading practices, Supporting students with special needs, Classroom routines	Extremely useful
Day 5	Discussed with a colleague (Co-teacher)	--	Assessment practices, Unit/lesson design (plans, tasks, activities, etc.), Supporting students with special needs	Extremely useful

Table 4.12 (Continued)

Day 6	Discussed with a colleague (Co-teacher)	We tried a group activity where students had to build a figure using connecting cubes. In order to do this each group member was given 1 or 2 clues. That had to make sure their group members understood their clue because no one else could read their clue. It was very challenging because some students did not know how to participate or help their group members. Some also did not know how to interpret their clue. My colleague and I spoke about how to help students since we did the activity in 2 additional classes.	Facilitating classroom discussions, classroom routines	Moderately useful
Day 7	Discussed with colleague (co-teacher) Referenced websites	-- <u>Desmos</u> <u>Common core standards:</u> I needed to know what students learned in the previous year so I could accurately plan for this year	Mathematical content knowledge, Unit/lesson design (plans, tasks, activities, etc.), Strategies for interacting with stakeholders (parents, community, administration, etc.), Supporting students with special needs, Classroom routines	Extremely useful Moderately useful

Table 4.12 (Continued)

Day 8	Discussed with colleague (co-teacher)	Open response questions are difficult for students to master so we discussed ways to help students answer open response questions accurately	Assessment practices	Extremely useful
Day 9	Discussed with colleague (co-teacher)	--	Assessment practices, Strategies for interacting with stakeholders (parents, community, administration, etc.), Supporting second language learners, Supporting students with special needs	Extremely useful
Day 10	Referenced websites	Desmos	Supporting students with special needs	Extremely useful

Perceptions of the Effects of Informal Learning. An analysis of the three data sources for Natasha indicate that informal learning activities have contributed to her teaching, technology integration, and to some extent content knowledge. Although Natasha finds formal PD to be more useful, she mentioned several ways she has benefited from informal learning activities.

Natasha mentioned that she sometimes struggles with implementing technology in her classroom as effectively as she would have wanted and has found informal learning opportunities such as collaborating with colleagues useful for helping her implement technology:

So when it comes to Desmos, I'll go back to that, because that's the most recent thing. I did have a colleague that understood some of the coding behind it, so she would show me how to do small things, so I can make slides. There's some things I can do, but not nearly as much as is possible with the platform. So yeah, we definitely help each other out in using technology more. And you know there are different programs out there. If I don't know how to use it. I do have colleagues that will help even like Google suite, Google classroom, Google slides like all those different things that we have access to ... parts of which we don't fully understand...I have had people assist me with those.

Natasha also mentioned that she finds discussion with colleagues useful for brainstorming and getting feedback on lesson planning and teaching:

I teach with a colleague and I'm friends with her. So we talk all the time with her and my math coach, i'm also friends with her. So if i'm planning alone and I just see something that is confusing, or I need help with. I just call them up, and you know, ask or get their thoughts and opinions. Um, you know, or even past people I've worked with. If there's a challenging problem and a lot of my students didn't get it. I might call and ask for help.

Natasha also corroborated the role that informal learning plays in her teaching through her open-ended survey response: “I discuss with colleagues on a regular basis outside of formal meetings. We often brainstorm ways to improve instruction and student learning”. She also visits websites like teachers-pay-teachers to find resources that could help her better teach specific contents and carry out class projects:

I go to teachers pay teachers a lot. I try to find content there to see if anybody has a way of doing something that I haven't thought of, and you know, sometimes doing that shows me where I've gone wrong like, for example, last year I did it, it was for scale factor. I wanted to do a scale factor project at the end of the year, and I realized what I had been asking my students to do for the last four years was actually seventh grade, not sixth grade.

Besides getting feedback from colleagues and finding resources to improve her teaching, Natasha also suggested that she sometimes takes advantage of informal learning opportunities to improve her content knowledge. For example, she recalled reaching out to a colleague to ask for help on a scale factor problem she was struggled with:

I text my former co-teacher from seventh grade. I was doing just what I was telling you the scale factor and I text him. And I said, I don't understand this problem, and he came up like five minutes later to look at it...

All except one of the learning activities Natasha reported were informal learning opportunities. The most common informal activity she engages in is discussing with her co-teacher colleague. This is evident from Natasha’s 2-week learning profile captured in Table 4.12. This is followed by referencing websites, the Desmos website to be specific. Seven out of the eleven instances of informal learning opportunities Natasha reported involved discussion with

her co-teacher; she found six of these instances extremely useful and one moderately useful. Four out of the eleven instances of informal learning opportunities involved referencing the Desmos website; two of the instances were extremely useful, one was moderately useful while the last was slightly useful.

In conclusion, similar to Carlos, the informal learning experiences that Natasha described are helpful for making sense of the scores reflecting her TPACK self-efficacies and frequencies of participation in informal learning activities (see Tables 4.9 and 4.10). Natasha had a score of 2.83 for technological knowledge self-efficacy; 3.4 for content knowledge self-efficacy; 4.6 for pedagogical knowledge self-efficacy; and 4.67 for technological, pedagogical, and content knowledge self-efficacy. Similarly, the scores representing her frequencies of participation in media, colleague, and stakeholder interaction were 2.4, 5, and 3, respectively. For individual reflection, her score was a 4.67. The interviews showed that Natasha felt less confident about her technological knowledge compared to her technological and content knowledge. She also preferred interacting with colleagues compared to searching for resources online (social media, internet) because it's saves her time and addresses her specific needs more, especially needs related to using technology. This may have explained the score of 5 for colleague interaction. Natasha co-teaches and because of that, talks to her co-teacher and plans with them frequently, meaning she may likely have belonged to the category of high users of informal learning except that her media interaction was quite low.

Jane

Perceptions of factors affecting informal learning. Similar to the first two cases, Carlos and Natasha, the results presented here are based on data from the open-ended survey responses and interview data of the third case, Jane. I begin by providing additional information on the case and their workplace (school) context.

Brief Overview of Workplace (School) Context and School Level Factors. Jane is the most experienced of the four cases this study focused on, having taught for thirty years, mostly at the middle school level. She has mostly taught math (as an language arts in grades six through eight in a very small school in southeastern United States and but have also taught science and social studies in the past. She currently serves as the special Ed teacher for an inclusion class but at the same time are teaching a math class by themselves for the first time. Because of the size of the school and the fact that it is situated in a small community, teachers know one another and most of their students closely. This makes them a very tight-knit community, making it possible to teach the “whole student” (to say it in Jane’s words).

The major school level factors affecting informal learning in Jane’s opinion is time and scheduling:

Time and scheduling are probably the two biggest obstacles -- there is a lot to do, and only so many hours to do it in.

Whereas sixth and seventh grade teachers have their planning at the same time, EC teachers are bounded between grades. Jane suggests that this could limit teachers’ informal learning opportunities.

Interpersonal Factors. On the interpersonal level, Jane points to leadership support and the co-operative attitude of teacher colleagues as factors that affect informal workplace learning. Although Jane thinks that teachers in their school are not rewarded enough, the administrators, all of whom were former teachers support informal learning indirectly. The following quote captures the supportive and co-operative attitude of the administrators and teachers respectively:

I feel like it's a very cooperative attitude. They encourage us to work together.

You know...one of the administrators may see an issue and she'll say, Hey, you know I saw you had this issue. Why don't you talk to such and such, and see how they stopped it? Or I see you're having this situation with this kid, talk to this teacher they had last year. So the administration encourages it, and most of the teachers are very willing to help, so it's a very positive environment for informal learning among us.

Jane went on suggest she has been in a situation where some teachers were not willing to share:

...I have taught in situations where people are like... this is my idea. You can't use it. I'm not going to share it with you.

Besides teachers, she also hinted on the role knowledgeable and helpful support staff. For example, Jane describes the media specialist as an incredible resource for ideas and feedback on technology.

Personal Factors. The personal factors affecting informal learning that came up during the interview with Jane focused mainly on self-efficacy beliefs and perceptions of formal and informal learning opportunities. To start with, Jane is teaching language arts (as a special Ed teacher) and math by herself for the first time. Whereas she is confident about teaching language arts having taught it for several years, she is less confident about teaching math even though she believes she knows how to do middle school math. Jane had reported a lower self-efficacy score

for her content knowledge compared to her technological and pedagogical and I had followed up on that. When asked about her mathematical content knowledge and how confident she is about it, Jane responded:

A lot of time that changes. Last year I was teaching science and social studies for the very first time, so my content knowledge was much lower. This year I'm doing language arts and maths, and my language arts is higher but my math is lower just because I've never taught it before, so I'm kind of having to learn it as I go if that makes sense. I know how to do middle school math but I'm having to learn how to teach middle school math for the first time.

Jane went on to add that one way she goes about building her confidence and learning to teach middle school math is by leveraging informal learning opportunities around her, including observing a more experienced teacher colleague and searching for resources on social media:

Yeah, this year I'm fortunate because while I'm teaching one class resource math by myself. I'm also doing an inclusion math at the same grade level with a national board-certified teacher who is a great teacher. I'm able to see how he does it, and then I can model from him. Also, I found a Facebook page that is just for math teachers, middle school math teachers. So I've been able to read about a lot of their resources and things they're doing and some of the same issues my kids have with topics their kids have. So I'm able to see how they're able to do that. So that was kind of a neat little find.

The last two quotes from the interview with Jane both touch on her self-efficacy beliefs. Besides self-efficacy, another major personal level factor that came up in the interviews relates to her perceptions of formal and informal learning. Jane believes that although informal learning may not be as structured as formal learning or have defined goals and objectives; nonetheless, it is as

relevant and valuable as formal learning, especially for getting quick answers to questions. In fact, it's self-directed nature makes it more relevant at times:

It probably (referring to informal learning) may not be as structured as formal learning, and it may not have the defined goals and objectives, but it's still as relevant and valuable as formal learning is, and in some ways, because it's more self-directed it's got the same or more relevance and more important

Here, Jane seems to also be drawn to the autonomy associated with informal learning opportunities owing to their self-directed nature. She mentioned that she has attended a lot of formal PDs that were not useful, and from experience, formal PD has been more useful when it is something she sought for:

Every now and then I've been to some (referring to formal PD) or had some that were very useful, and were engaging, and were helpful. Frankly, a lot of them not so much. You feel like you're sitting there, and you're like, Okay, I've already done that it didn't work. Or yeah, that's not going to work in my situation. But sometimes I've had some that were professionally given that encouraged me to try new things. It seems to be that a lot of those were ones that I sought out... maybe I had an issue where I felt like I needed some more formal training and something, and I sought those. Some of the more not as useful ones, are the ones where maybe the administrators or the county says, Hey, you're going to do this, or they set it up for everybody. And it's just kind of vague in general, and not as useful if that makes sense.

Informal Learning Activities Math Teachers Engage in: The Case of Jane. The open-ended survey responses, interview data, and two-weeks survey-based journaling completed by Jane showed different types of informal learning activities she engages in. These include discussing with colleagues and persons outside school, co-teaching, observing teaching, referencing web-based resources, trial and error (experimenting), and using social media. In the previous subsection where I had described Jane's perceptions of personal factors affecting informal learning, she had mentioned how she observes and tries to model the teaching of a national board-certified co-teacher colleague whom she described as a great teacher.

Furthermore, while responding to an open-ended question (in the survey) about the informal learning activities she engages in and her perception of the effects on her practice, Jane wrote:

My co-teachers and I have frequent and regular discussions about students that are struggling. By comparing strategies, I am frequently able to adjust my teaching methods to better serve that student.

When asked how she goes about learning about new technologies and implementing technology in her class, she said:

We have a media specialist that's really good about keeping up with the newest and what works and what doesn't. And she'll introduce them to us. Our system has also tried to give us resources, but sometimes it's just trial and error. I'll see something mentioned on social media or I'll google something, and it comes up and I'll try it.

Jane also engages in conversations about teaching with persons outside school, mostly teacher colleagues. When I asked Jane about who she talks to about teaching mathematics outside school

and her perception of how such conversations contribute to her professional learning, she had this to say:

Probably the only conversations that I have in that regard are my daughter's double tennis partner. Her mom is one of our superintendents at school, so sometimes we'll talk about school stuff, but not anything terribly specific. Maybe just general trends that are happening in the county at the time, or something like that. Most of my conversations outside of school about school were with just other teachers that maybe their kids and my kids know each other or are friends.

Whereas Jane engages in a variety of informal learning activities, it seems the most common informal activity she engages in is discussing with colleagues. This is clearly evident from Jane's everyday learning profile captured in Table 4.13. Her continuous learning profile also suggests that the second most frequent informal learning activity she engages in is referencing websites e.g., deltamath.com. In the next subsection, I describe Jane's perceptions of the effects of informal learning and offer additional detail about her continuous learning profile.

Table 4.13*Jane's Everyday/Continuous Learning Profile*

Days	Learning activities reported	Description	Topic/focus of activity	Perceptions of usefulness
Day 1	Discussed with a colleague	As I have never taught this math class before, I was asking my colleague the best way to present new information to ensure my students with disabilities could access it	Supporting students with special needs	Extremely useful
	Referenced a website	Delta math	--	Slightly useful
Day 2	Discussed with a colleague	--	Supporting students with special needs	Slightly useful
Day 3	Discussed with a colleague	Received guidance on using an online platform our school uses for math practice (deltamath.com)	Technology ideas	Extremely useful
	Referenced a website	<u>Deltamath.com</u> : Delta math is a web platform that allows the students to practice specific math skills	Technology ideas	Extremely useful

Table 4.13 (Continued)

Day 4	Discussed with colleagues	With one colleague, I discussed the sharing of materials in order to best serve our EC population. With another colleague, I discussed potential methods of approaching new concepts and the best ways to present them	Mathematical content knowledge, Supporting students with special needs	Extremely useful
	Referenced a website	https://valeriefaulknermathclub.com/		Extremely useful
Day 5	Discussed with a colleague	We are using pre-assessments and benchmarks to identify students who may potentially have problems with the 7th grade curriculum and the best ways to meet those needs and support the students towards growth	Assessment practices, interpreting student work, Math games, Supporting students with special needs	Extremely useful

Table 4.13 (Continued)

	Referenced a website	EasyCBM	Our school is using easyCBM as a way of monitoring periodic progress for our students that are underperforming.	Extremely useful
Day 6	Discussed with a colleague	I spoke with another EC teacher to brainstorm ideas and strategies for helping EC students access grade level content	Unit/lesson design (plans, tasks, activities, etc.), Math games, Supporting students with special needs.	Moderately useful
	Referenced a website	https://valeriefaulknermathclub.com/ : Seeing how the subitizing works and reading resources to help my students better understand and develop stronger number sense.	--	Extremely useful
Day 7	Discussed with a colleague/Referenced a website	We discussed how the state assesses the standards and exactly what we need to cover in order for the students to be prepared and to have a complete understanding of the grade level curriculum.	Assessment practices, Interpreting student work, Technology ideas	Moderately useful

Table 4.13 (Continued)

Day 8	Formal observation (Feedback from Assistant principal)	Provided a rationale during a formal observation about why I reviewed what I did, used the strategies and techniques I did and covered the information in the order that I did.	Scope & sequence of your subject Classroom management, Supporting students with special needs	Slightly useful
Day 9	Discussed with a colleague	Discussed key concepts on upcoming benchmark testing. Also discussed strategies for helping to develop number sense with students with learning differences.	Assessment practices, Supporting students with special needs	Moderately useful
	Referenced a website	marcycookmath.com	--	Slightly useful
Day 10	Coaching (discussion with coach)	Strategies for teaching fractions conceptually	Supporting students with special needs	Moderately useful

Perceptions of the Effects of Informal Learning. An analysis of the three data sources for Jane indicate that informal learning activities have contributed to her teaching practices, understanding of curriculum, self-efficacy, and students' learning. To start with, one of her open-ended responses read:

My co-teachers and I have frequent and regular discussions about students that are struggling. By comparing strategies, I am frequently able to adjust my teaching methods to better serve that student.

This suggests that Jane finds the interactions she has with her co-teachers useful for adopting better teaching approaches. While part of the discussions referred to in this quote could have been in the context of formal learning opportunities (PLC meeting, coaching); Jane's school context, her continuous learning profile and follow-up interviews suggest some of it was informal. For example, her continuous learning profile as captured in Table 4.13 showed discussion with colleagues as the most frequent informal learning activity Jane engaged in.

Furthermore, most of the conversations center around pedagogical issues (e.g., assessment practices, accessing grade level content, etc.) as they pertain to serving the EC population that Jane teaches. Jane is teaching a math class by herself for the first time; before now, she was a special Ed teacher. She mentioned that most of the discussions she has about her new role happens with the lead teacher (some type of a coach) and other teachers who teach the same grade level as her and are more experienced general education teachers:

This is my first time teaching math by myself. I've done an inclusion class before. So a lot of my discussions are with other teachers that have taught math and my lead teacher about ...okay..this is what i'm doing. Am I on the right track? Am I doing the right thing? Should I be doing something different?

Jane also noted that such conversations are useful for double-checking some of her thoughts or ideas about teaching and for serving the students she teaches better:

They (discussions with colleagues) help me to further clarify some of the thoughts I was having, and are helping me better serve that population of students. I feel like we're making some progress in developing, filling some gaps that they have from their elementary years.

Specifically, Jane noted that she discusses with and observes a national board-certified co-teacher colleague who is a great teacher and tries to model his teaching. She also finds the feedback and suggestions from him very useful:

Yes, many of the suggestions he's given me are very useful just because he has taught seventh grade math for so many years, and knows the curriculum so well. He has some good insights as to how to approach it, and what seems to work best for our students.

Jane suggested that her informal interactions with colleagues have been useful for helping her understand the curriculum better, including vertical alignment. To be precise, on day seven of journaling her informal learning experiences, Jane had mentioned that she discussed how the state assesses standards and exactly what teachers needed to cover in order for the students to be prepared and have a complete understanding of the grade level curriculum. I had asked Jane who she had this conversation with, and she replied:

Again, probably one of the other math teachers that has taught the curriculum has seen the EOGs that integrate assessment, and just helping me understand how the curriculum works here. This is my first year in seventh grade. Just helping me understand what they covered in sixth grade, what they should have covered in the sixth grade versus what they're going to need in the eighth grade, and then where that puts me in the middle.

Jane's example also demonstrates how formal interventions or training could foster informal learning. To be precise, Jane's continuous learning profile suggests that the second most frequent informal learning activity she engages in is referencing websites, and one of these websites, Valerie Faulkner's math club website, was first introduced to her by her lead teacher who had learnt about the website from a professional development workshop she attended. Jane reported visiting this website on day 4 and day 6 (see Jane's continuous learning profile- Table 4.13) and found it extremely and moderately useful on both days respectively.

Jane stated that she first came across the word subitizing from this website and described how useful the website has been for teaching her EC class:

So...I didn't know that word (*referring to subitizing*), either, until I had been there (*referring to the website*). It's called subitizing, and it helps kids. Many students naturally, when they see a group they naturally group it in like five or ten, so they can count it quickly. Students that have learning differences in math don't always do that, and they try to count like, even if you hold up fingers. If you hold up five fingers instead of just knowing that's five, they'll try to count the fingers. So the Subitizing are drills and exercises that help them learn how to group numbers and add quickly, without actually consciously going five plus four is five, six, seven, eight, nine. They just see the five and the four, and they know that's nine.

In the same vein, Jane mentioned that it was a teacher colleague that first introduced her to the delta math website and showed her how to use it, and that she found it useful for helping students practice specific skills. She also made reference to two other websites (easyCBM and marcycookmath.com) which she references for her teaching during the interviews and survey-based journaling. As she pointed out on day 5 of the survey-based journaling, the easyCBM is a

diagnostic tool that her school uses for benchmark and progress monitoring for underperforming students who are not identified as EC.

Jane also suggested that her informal learning experiences have contributed to her self-efficacy; specifically, her confidence in her ability to teach the math class that she was teaching for the first time. Recall that Jane had said even though she can do middle math, she is learning to teach it as she goes. When I asked if she believes her informal learning experiences have contributed to her confidence to teach the content in question, she replied:

Yeah, this year I'm fortunate because while I'm teaching one class resource math by myself. I'm also doing an inclusion math at the same grade level with a national board-certified teacher who is a great teacher. I'm able to see how he does it, and then I can model from him. Also, I found a Facebook page that is just for math teachers, middle school math teachers. So I've been able to read about a lot of their resources and things they're doing and some of the same issues my kids have with topics their kids have. So I'm able to see how they're able to do that. So that was kind of a neat little find.

In conclusion, Jane's continuous learning profile shows that informal learning activities are most likely an integral part of her everyday learning. Specifically, Table 4.13 shows that besides formal learning opportunities such as coaching and formal observation (see days 8 and 10) which Jane leverages on for her practice, informal learning activities are a major part of her everyday learning experiences. Out of the 17 instances of learning activities she reported, 15 of them were informal experiences: eight of these informal learning experiences involved discussion with colleagues or some form of collaboration while the remaining seven involved referencing websites.

Jane found four of these instances of discussions with colleagues extremely useful, three moderately useful, and one slightly useful. Four instances of referencing websites were extremely useful, two were slightly useful, while one was moderately useful. Whereas these interactions touched on different topics including assessment practices, technology ideas, mathematical content knowledge, lesson planning, and supporting students with special needs; they frequently focused on supporting students with special needs.

To conclude, Jane's informal learning experiences described so far are helpful for explaining one or two scores reflecting her TPACK self-efficacies and levels of participation in informal learning activities (see Tables 4.9 and 4.10). Jane had a score of 4.5 for technological knowledge self-efficacy; 3.6 for content knowledge self-efficacy; 4.4 for pedagogical knowledge self-efficacy; and 3.66 for technological, pedagogical, and content knowledge self-efficacy. For her frequencies of participation in informal learning; Jane had a score of 4, 4, and 4.25 for media, colleague, and stakeholder interaction respectively. She had a score of 5 for individual reflection.

Jane co-teaches and works at a very small school (in a small town) where teachers know each other and their students closely. Her teaching math by herself for the first time may have contributed to the high scores she reported for media and colleague interaction, as she may be using these sources a bit more to learn about teaching middle school math. It may also be the case that the high score for pedagogical knowledge despite being less experienced in teaching middle school math by herself may be connected to her confidence about teaching math in general. Although she said she can do middle school math, a content knowledge score of 3.6 compared to the other TPACK self-efficacy scores may suggest less confidence in this area.

Debbie

Perceptions of factors affecting informal learning. Similar to the first three cases (Carlos, Natasha, and Jane); the results presented here are based on data from the open-ended survey responses and interview data of the fourth case, Debbie. I begin by providing additional information on the case and her workplace (school) context.

Brief Overview of Workplace (School) Context and School Level Factors. Debbie teaches seventh grade math in a public school in Northeastern United States. Although she is a new staff at this school, she has about 28 years of experience teaching math across multiple grades, mostly the middle grades. She was the middle school math coordinator at her previous school- a private school. Whereas most of the experiences of informal learning she shared focused on her new school, she sometimes makes reference to her former school.

The current school holds faculty meetings on Tuesday every week and PD is sometimes fit into this time. Meanwhile in the former school, teachers were not required to keep up with professional development because they did not have to worry about certification. That notwithstanding, the school paid for teachers to attend professional conferences, several of which Debbie attended. However, she suggested that her former school was not as supportive of her ideas and projects (her informal learning by extension considering the amount of personal research that goes into them) as the current school:

I still feel like with these notebooks and with that “get more math program”, if we can get this stuff up and running, I feel that I'm going to be able to effect change much quicker at my new school because I'm going to see the results and I'm being supported. I didn't feel supported at my other school with some of these. It took a very long time for them to try anything different and be like, Hey, she actually has a good idea. It's like I was doing

executive function things talking about that 16 years ago and people just were like, whatever. Now that's a buzzword.

Debbie mentioned that the “get more math program” is an online program she was trying to get into her school. The program is similar to IXL and helps deliver spiral review sessions personalized for each student. She described it as follows:

It's strictly review. There's no instruction. It's probably similar to ixl, but a little bit more engaging. It's not timed. And what's nice with it is that you pick the problems, like the types of problems you want, and as soon as the kids are done with those, you know, six to eight problems, it automatically brings you back into content area that supports what they've already learned. So if we were doing proportions, it would then bring you back to equivalent fractions or adding, subtracting fractions, multiplying, dividing fractions basic math facts. So it just spirals on itself automatically. The whole point is you don't forget.

Overall, the school level factors that Debbie hinted on are time, access to formal PD, and a strong support for her projects at the administrative level. Debbie mentioned how her former school paid for her to attend three different conferences where she presented her project on interactive notebooks and how the current school is supportive of her ideas. As mentioned earlier, receiving support or funding for her interactive notebook project supports informal learning indirectly because the interviews showed that Debbie spends a lot of time personally researching and learning about interactive notebooks and has consistently done so for the last 9 years. In the same vein, research has shown that participation in formal PD supports informal learning by equipping teachers to share knowledge and skills (Schürmann & Beusaert, 2016).

Interpersonal Factors. Most of the issues that came up in the interview with Debbie focused on personal or individual level factors. Besides suggesting that teachers in the math department are supportive of each other, there was no mention of additional factors at the interpersonal level. Although there is a teacher union in the school that takes up teachers' concerns with school administration, it is not clear how their operation affects teachers' informal learning as we saw in the case of Carlos.

Personal Level Factors. There were several personal level factors affecting informal learning that came up both in Debbie's open-ended survey response and her interviews. This includes teacher attitude (e.g., interest or willingness to learn), personal commitments, and perceptions of formal and informal learning opportunities. While answering the open-ended survey question about factors affecting teachers' informal learning, Debbie wrote "lack of interest, lack of time, lack of initiation, lack of a willingness to try something new, laziness". Apart from time, the rest of the issues in the aforementioned quote border on teacher attitude. I followed-up on this quote during the interviews and Debbie further explained that one factor affecting teachers' informal learning is resistance to change even though both kids and society have changed:

I don't know why teachers are resistant to change. I think it's just this has worked in the past. I mean, the kids have changed. Society has changed. I don't think we should be teaching the same novels that we taught ten, twelve years ago. There are better ones out there. The classics are not just because it was a classic. I mean, James Joyce is great, but honestly, like, you know..look at Kwame Alexander. Look at Jason Reynolds... Those are up and coming African-american writers who are amazing. And African-american students or black students need to be able to see. Hey, there's someone who understands

what i'm going through. And so I think ...people need to be open to change. In my old school, nobody made them, so they didn't do it because nobody made them. I think it's a stickler of just laziness. People don't want to. I'll say people not everybody. I had quite a few colleagues who were willing to do different things, but at my old school I think it was people just weren't...

In general, Debbie loves learning, and she is highly committed to her professional growth as well as helping other teachers improve their practice. This reflects in her yearly goals and the way she views professional learning:

I look at professional development. Not only what can I get? What is the school giving to me, but what can I do to grow outside? And so I try to learn something new every summer...every year I try to learn something new and try something new. Last year was my big push with equity, and so I spent a lot of time reading books like Joe Feldman's grading for equity, and just trying to make sure that I was treating everybody the same. Taking into consideration what the students needed, trying to learn more about their home life and their backgrounds...This year I'm, focusing more on Peter Liljedahl's building thinking classrooms.

She is constantly looking for ways to improve instruction for her students and work with teachers who have similar passion to effect change. This motivates her to read books and explore different formal and informal learning opportunities. Her status as a new teacher in the current school appears to be a factor limiting how quickly she is able to get them to key into some of her ideas and practices. However, she seems to be gradually getting the attention of some of them already:

...And because i'm at a new school and it's hard, I don't want to go in there and be like, Hey, You need to do this because I see the benefits. But I have teachers coming in my classrooms, and I think the word will get out that the kids need to be up and moving and talking and debating in math and not sitting in straight rows. I think i'm going to be optimistic and and confident, and say, I think within a couple of years i'll be able to get the other math teachers to follow along with some of what i'm doing, because I think it's beneficial.

Although Debbie is a new teacher, it appears her experience with leadership as the middle school math coordinator in her former school reflects in how she thinks about her role as a teacher in relation to other teachers and may be a factor in her commitment to professional growth through informal learning. Debbie also listens to podcasts from different educators such as Pam Harris, Kyle Pearce, and Jon Orr and follows them on Facebook. She opines that learning from these informal sources has been better PD than what she got at her old school:

I am on on Facebook and I am part of the building thinking classrooms group. I do follow Pam Harris. She does Math is Figureoutable. I do follow John Orr and Kyle Pearce. It's like making math moments matter or something and I find that that has actually been better PD than I was getting at my old school because you would fire (sic) out a question or say, Hey, I want to try this, and you would get so many responses, and they're always really good. I would just be like Oh, my gosh, this has been amazing!

Whereas Debbie learns a lot from Facebook, she doesn't think twitter is equally as useful:

I'm not a huge twitter, fan. I don't find the the Twitter MTBoS community helpful. But that's just me. Maybe i'm not out there enough in tagging things, but I would rather just go to those couple of groups on Facebook.

She also believes that teachers in public schools that don't have the funding for formal PD can take advantage of informal learning opportunities as a way of supplementing their PD needs.

Also, that it is incumbent on teachers to make their craft stronger:

My colleague in Public School doesn't have the funding, So it's like... If you don't have the funding, there are things that... you can just read a book. You can watch a Youtube video, you can, you know, get on on social media. And just... I like learning. I don't know. I just think learning's fun, you know. I think it's incumbent on us to try and make our craft stronger.

Informal Learning Activities Math Teachers Engage in: The Case of Debbie. The open-ended survey responses, interview data, and two-weeks survey-based journaling completed by Debbie showed different types of informal learning activities she engages in. These include discussing with colleagues and persons outside school, sharing resources, referencing web-based resources, reading professional literature, and using social media. In responding to the open-ended survey question which required teachers to mention the informal learning activities they engage in, Debbie wrote “sharing examples of what I do in the classroom in the hopes other teachers will try them (WODB, Open Middle problems, etc.); sharing Desmos activities to enhance student learning and understanding”.

Debbie also has two other seventh grade math teachers that she collaborates with. Furthermore, she watches YouTube videos and listens to podcasts from math educators such as Pam Harris, Kyle Pearce, and Jon Orr as well as follows them on Facebook and/or belongs to Facebook groups associated with them. She also brainstorms ideas related to teaching mathematics with her dad who used to be a teacher, as well as use her husband, a former cub scout leader, as a sounding board. While following on a discussion Debbie had with her husband

about an online math program she piloted, I had asked if her husband is a teacher and she replied:

No, he's just a sounding board. We walk every morning with the dog. When we get up, we have our coffee, we go for a walk, and we just, that's when we do the same thing after dinners. We walk and we kind of debrief from the day or we, we talk about things. You know, he's he was a coach. He was a, a cub scout leader, so he's involved with our boys and he's around kids, so he kind of gets how they are, and I would just throw things out. And because he is a parent, and so sometimes it's nice to hear a, even though it's my husband, a parent perspective on what I want to do.

Debbie also referenced websites such as the Get more math and SERP institute websites and reads books and professional literature e.g., dissertations for her professional learning. Judging from Debbie's continuous learning profile as captured in Table 4.14, the most frequent informal learning activity she engages in is referencing websites; this is closely followed by reading professional literature and discussion with colleagues in second place. In the next subsection, I describe Debbie's perceptions of the effects of informal learning and offer additional detail about her continuous learning profile.

Table 4.14*Debbie's Everyday/Continuous Learning Profile*

Days	Learning activities reported	Description	Topic/focus of activity	Perceptions of usefulness
Day 1	Discussed with a colleague (math resource teacher)	We talked about whether students should be allowed to retake a test and if the higher grade (or the second grade) prevails. We also discussed whether students should be required to complete corrective action and conference with the teacher before they can retake an assessment. I also spoke with a teacher about how to best help a student with an IEP who will not request notes, etc. when that is clearly stated in the paperwork. The math resource teacher and I also talked about connecting me with another teacher at another school who sets her room up like I do and follows the Building Thinking Classrooms model.	Grading practices, Supporting students with special needs, Classroom routines	Extremely useful
Day 2	Persons outside school (husband)	There is an online math program I piloted at my former school that I would like to try at my new school. I shared a short video about it with a colleague and she loves it. I also tossed some ideas around with my husband on how to suggest help for a student who is struggling but it very social in class.	Strategies for interacting with stakeholders (parents, community, administration, etc.), Supporting students with special needs, review material	Extremely useful

Table 4.14 (Continued)

	Referencing a website	<u>Get More Math:</u> Get More Math is the online review tool that spirals through previously learned concepts.	--	Extremely useful
Day 3	Discussed with a colleague (math resource teacher)	Starting unit on proportions and our math resource teacher and I reviewed different proportions activities to kick off lesson.	Unit/lesson design (plans, tasks, activities, etc.), Group work strategies	Extremely useful
	Referenced a website	Dan Meyer 3-act tasks and SERP institute. SERP has great activities.	--	Extremely useful
Day 4	Reading professional literature	Ways to work with perfect squares and cubes (we had no school today).		Extremely useful
	Referenced websites		--	
	Social media (YouTube)			

Table 4.14 (Continued)

Day 5	Discussed with a colleague	We are asked to give a performance task at the end of each unit and count it as a grade. The tasks are supposed to be done in groups. This one was extremely hard for the level of the class and we had to guide the students through it. Everyone "earned" an A. But they cannot do the work independently; the work was hard even in groups. We also talked about ways to help students read questions so they know what they are answering. I also had a parent insist that I tell her the class average so she can compare how her child did to others. I am chatting with colleagues on how to best answer her without going into detail about the other students.	Assessment practices, Group work strategies, Strategies for interacting with stakeholders (parents, community, administration, etc.), Supporting students with special needs	Moderately useful
Day 6	Discussed with a colleague	Talked about how to incorporate number sense strategies into the lessons.	Classroom routines	Slightly useful
	Referenced a website	Pam Harris' Math is Figure-out-able	Questioning strategies, examples like As Close As It Gets	Extremely useful

Table 4.14 (Continued)

Day 7	PLC meeting/Discussion with colleague	Talked with math team about grading practices and extra time for non-special Ed students, especially those in advanced classes who cannot finish work (and may be improperly placed). Talked with resource teacher about Building Thinking Classroom model and teaching others how to implement some of the steps.	Assessment practices, Grading practices, Classroom routines, Questioning	Moderately useful
	Reading professional literature	Used Peter Liljedahl’s book	--	Extremely useful
Day 8	Discussed with an administrator	<u>Interactive notebooks</u> : I brainstormed with our principal a grant I want to write so I can have funds to purchase spiral notebooks for all my students. I want to use interactive notebooks in our math classes to build up their executive function skills and help students with organization.		Extremely useful
	Reading professional literature	Research from various dissertations about the benefits of interactive notebooks. I also had presented at NCTM regional conferences in 2017 but wanted to update my research.		Extremely useful

Table 4.14 (Continued)

Day 9	Persons outside school (Dad)	Talked to my dad, a former, about how to get parents more involved	Strategies for interacting with stakeholders (parents, community, administration, etc.)	Extremely useful
Day 10	Social media	Looking for support for struggling readers who are in my math class. Posed question on Facebook in the Jo Boaler group but only have one response to use a strategy I have done before.	Grading practices, supporting students with special needs	Slightly useful

Perceptions of the Effects of Informal Learning. An analysis of the three data sources for Debbie indicated informal learning activities have contributed mostly to her teaching practices and use of technology. As earlier mentioned, Debbie sets yearly goals that help her improve her teaching. Last year, her goal centered around paying attention to equitable teaching practices. As part of efforts to achieve her goal, Debbie spent a lot of time reading books on equity and met with colleagues who were interested in equity to learn from their experiences. One of such books was Joe Feldman's *grading for equity*. Debbie stated a couple of changes she made in her practice as a result of what she learned from these informal learning opportunities.

For example, she started paying greater attention to learning about students' home life, culture, and backgrounds. She also stopped giving homework during weekends as well as grading homework in general. She realized that homework interferes with family time based on what she was hearing from her students. Also, grading homework may not be fair to some students because while their colleagues get assistance on homework, they may not get similar assistance because their parents work night shift. The following excerpt captures some of the statements Debbie made about equity:

Every year I try to learn something new and try something new. Last year was my big push with equity, and so I spent a lot of time reading books about um like Joe Feldman's um grading for equity, and just trying to make sure that I was treating everybody the same. Um, taking into consideration what the students needed, trying to learn more about their home life and their backgrounds. And there were a couple of teachers at the school, who also were interested in equity. So we would meet every once in a while on our own time, and just talk about what we, what we had learned how we were implementing it, and the results we were seeing.

The following excerpt also captured specific changes pertaining to homework that she made based on her informal learning experiences around equity:

I stopped giving homework on the weekends, because I realized that family time is really important, and the more that I read these books and learn about the different cultures and and talk to my kids and see who they're hanging out with, I realized that the family is really really important, because it is to me, and I don't want my kids spending hours doing homework. I don't grade homework as a result of I don't know who's doing the homework, and it's not fair If someone has a parent who's working nights and can't give the same assistance.

This year, Debbie is reading Peter Liljedahl's *Building Thinking Classrooms* (Liljedahl, 2020) and the ideas she has implemented from the book so far seem to be yielding some results although she is struggling to share same with teachers because she is new:

...And because i'm at a new school and it's hard, I don't want to go in there and be like, Hey, You need to do this because I see the benefits. But I have teachers coming in my classrooms, and I think the word will get out that the kids need to be up and moving and talking and debating in math and not sitting in straight rows.

Debbie also noted that she learns about new technologies as well as how to better use technology (e.g., Desmos) through colleagues, watching YouTube videos, and googling. For example, she mentioned that she first heard about Flipgrid and got a brief introduction to it through a colleague. Afterwards, she spent some time learning more about Flipgrid by watching YouTube videos:

...one of my class my colleagues said have you looked at Flipgrid? So she gave me a brief introduction, and then I just went on Youtube and just learned how to use it. So

that's how a lot of times if there's something on Desmo that I don't know. I just go to Youtube and I Google, How do I do this? And i'll watch either a Desmos-created video or there are other teachers out there who have done things and I will follow they do...How to use technology is mostly by a colleague or just going on to Google and just searching.

Debbie's continuous learning profile shows that informal learning activities are most likely an integral part of her everyday learning. Specifically, Table 4.14 shows that besides the PLC meeting on day 7 which is considered formal, the remaining 16 out of 17 instances of learning opportunities reported are informal. Six of these instances involved discussion with colleagues; Debbie found three of these extremely useful, two moderately useful, and one slightly useful. She found all four instances of referencing websites and three instances of reading professional literature extremely useful. The two instances of discussion with persons outside school that Debbie reported were extremely useful. One out of the two instances of using social media was extremely useful while the second was slightly useful.

In conclusion, similar to the other cases, the informal learning experiences that Debbie described are helpful for making sense of the scores reflecting her TPACK self-efficacies and frequencies of participation in informal learning (see Tables 4.9 and 4.10). Debbie had a score of 4.33 for technological knowledge self-efficacy; 4.8 for content knowledge self-efficacy; 5 for pedagogical knowledge self-efficacy; and 5 for technological, pedagogical, and content knowledge self-efficacy. Similarly, the scores representing her frequencies of participation in media, colleague, and stakeholder interaction were 5, 5, and 4.25, respectively. For individual reflection, her score was a 5. Overall, Debbie had the highest TPACK self-efficacy and participation in informal learning of all four cases. Whereas these scores are pretty high, they are not surprising given Debbie's commitment to professional growth and the professional

development of other teachers around her. While the other teachers' engagement in informal learning was mostly driven by the need to solve problems of practice, Debbie goes "above and beyond" as hers was driven by sheer love for learning and a passion to effect change.

Cross Case Analysis

The previous section focused on a case-by-case description of each of the four participants, including their school context, perceptions of factors that affect informal learning, types of informal learning activities engaged in as well as perceptions of effects of informal learning. In this section, I present and discuss themes that emerged from the cross-case synthesis of the data on each participant obtained based on interviews, open-ended survey responses, and survey-based journaling of their informal learning experiences. Specifically, the cross-case analysis explored common themes that emerged across cases in response to research questions two, three, and four. There were three themes in general: teacher learning across multiple pathways, factors affecting informal learning, and Teachers' perceptions of the effects of informal learning.

Theme 1: Teacher Learning Along Multiple Pathways

A major theme that came up repeatedly in the course of analyzing the data related to the four participants is the idea of learning through multiple means or pathways. All four participants relied on both formal, informal (sometimes incidental) for their professional growth and practice. The type of learning that participants leveraged depended on factors such as preference, specific teacher needs, school context, and teacher beliefs. Some of these will be discussed later on in this section, although mostly in the context of informal learning as that is the focus of this study.

For the purpose of this study, recall that formal learning involves any type of learning that is school-led while informal learning activities are unstructured, unplanned activities that are teacher-led.

Formal learning opportunities. Some formal learning pathways that teachers utilized in a bid to improve their pedagogical, content, technological knowledge include attending professional conferences and PD workshops, PLC meetings, and coaching. The interviews and survey-based journaling showed that besides the informal learning activities participants reported engaging in, all the participants reported participating in PLC meetings and interacting with math coaches on a regular basis and attending PD workshops from time to time.

Formal learning opportunities were the primary sources of participants' learning; however, they relied on informal learning opportunities such as discussions with colleagues for meeting "in-the-moment" needs and addressing issues of everyday practice. Furthermore, participants also described significant changes in their practice that have resulted from their informal learning engagements (more on that shortly). All participants believed that both formal and informal learning opportunities are important even though both learning formats are different and there can be pros and cons associated with both. For example, Carlos believes the structure and focus that is often associated with professional development makes it useful:

...But having a structure and a focus that are often provided with formal professional development can also be useful. Like, for example, for us, we are very focused on technology, and when I went to...it was like a weekend-long professional development about Nearpod, and I learned so much about Nearpod, and I loved it, and I am using it. So that PD which was formal, I think it was very very helpful in that way. But I've been to other formal PDs that were not useful.

For a formal PD workshop, one will most likely know the topic, the names of the facilitator(s), and probably what to expect. Also, because it tends to be focused, one can leverage it to learn specific skills as Carlos suggested. Both Carlos and Natasha expressed concerns about the unstructured nature of informal learning. Natasha opines that searching for resources online (a form of informal learning) can be frustrating and time consuming when one does not know where exactly to look, while Carlos believes that although informal learning is important, it may not be suitable for every teacher. Whereas participants noted that formal PD workshops can be useful, they also pointed out that there are several times when formal PD was not that helpful. Furthermore, they found formal PD opportunities more helpful when it was something they were interested in; formal PD was more often than not less useful when it was required.

Informal learning opportunities. The open-ended survey responses, interview data, and two-weeks survey-based journaling completed by all four participants showed different types of informal learning activities they engage in. Overall, there were 10 informal learning activities identified across participants: collaboration with colleagues (including discussion, shared-planning, etc.), sharing, non-colleague interaction, using social media, referencing web-based resources, reading professional literature, observing practice, individual reflection, experimenting, and experiencing.

These activities can be categorized into four groups- consulting information sources (e.g., reading professional literature, social media, referencing web-based resources), interaction and discussion with others (e.g., collaboration with colleagues, sharing, non-colleague interaction), learning from others without interaction (e.g., observation), experiencing and experimenting, and reflection in and on action (individual reflection). Whereas participants reported engaging in these informal learning activities; their continuous learning profile showed that participants were

more likely to engage in some informal learning activities than others. While they engaged in some informal activities as part of their daily practice; they seemed to engage in others occasionally.

Overall, the analysis of participants' two-weeks continuous or everyday learning profile as captured in Table 4.15 identified five informal learning activities that most likely contribute to teachers' continuous learning. The top two on this list are referencing web-based resources and collaborating with colleagues (mostly discussion with colleagues). All participants reported engaging in both informal learning activities. Besides these two informal learning activities, two participants also reported reading professional literature, using social media, and talking to persons outside school. Furthermore, participants also found these informal activities useful. To be specific, out of a total of 54 informal learning instances reported; participants reported that 37 instances were extremely useful, 10 were moderately useful, six were slightly useful, while one was neither useful nor useless. The kinds of activities that individual teachers reported participating in largely depended on personal preference, personal and school context. Participants' informal engagement also focused on different topics including assessment practices, technology ideas, lesson planning, and supporting students with special needs.

Table 4.15*Summary of Two-week Continuous Learning Profile for Cases*

Informal learning activity	Carlos	Natasha	Jane	Debbie	Total	Perception of usefulness			
						E	M	N	S
Referencing Web-based resources	5	4	7	4	20	15	2	-	3
Collaboration with colleagues (mostly discussions)	2	7	8	6	23	13	8	-	2
Reading professional literature	2	-	-	3	5	5	-	-	-
Social media	1	-	-	2	3	2		-	1
Persons outside school	1	-	-	2	3	2	-	1	-
Total	11	11	15	17	54	37	10	1	6

Key: E= Extremely useful; M= Moderately useful; N=Neither useful nor useless;

S= Slightly useful

Theme 2: Teachers' Perceptions of Factors Affecting Informal Learning

The analysis of data from all four participants revealed three levels or categories of factors that affect informal learning- personal factors, school level factors, and interpersonal factors.

School Level Factors. School context was central to participants' experience of informal learning. Among other things, school context determined the kinds of opportunities participants had for informal learning, access to resources that support informal learning, and sometimes the focus of such learning. School level factors affecting informal learning that participants

identified included school size, time and scheduling issues, access to formal PD, school culture/vision, staff strength, and admin attitude.

In Carlos' case, a school theme that read "Together, we are all experts" seemed to foster a culture of collaboration among teachers. Furthermore, a huge emphasis on the use of technology and classes being delivered entirely online naturally made Carlos gravitate mostly towards issues related to technology in his informal learning engagements. For example, his informal interactions such as discussion with colleagues, searching the web, and observing other teachers tend to largely focus on issues around teaching with technology and supporting student engagement in online settings. Being the only math teacher for three courses also limited his informal learning opportunity because there was no colleague to compare notes on content or teaching related to these courses with.

Similarly, Jane believed not having a common planning time limited her opportunities for interaction with teacher colleagues. However, for Jane, teaching in a small school meant that all teachers knew each other and their students closely. This made the school a tight-knit community and fostered teacher collaboration. Both Jane and Natasha teach in inclusion schools; as such, opportunities to collaborate and observe colleagues teach was commonplace.

Also, Debbie and Carlos viewed issues related to access to funds as factors that affect informal learning. While Debbie was excited that her current school is more supportive of her class projects which involve a great deal of personal research than her former school, Carlos noted that the bureaucracy around accessing resources that are not available in his school frustrates teachers. School policy stipulates that resources such as books that teachers request can only be purchased through qualified vendors. However, from his experience these vendors often take a long time to supply requested resources. Even when they do not have requested materials

in stock, it could take some time to notify the school. The result of such delays is that teachers are forced to purchase resources with their own money to avoid being disappointed or waiting for too long. Sadly, they are not reimbursed for such purchases.

Besides issues of access to funding, another school level factor that came up in the interviews was admin attitude. For example, Jane noted how one of the school administrators sometimes came around to discuss challenges and offer advice that pointed her in the direction of informal learning opportunities as the following excerpt shows:

...one of the administrators may see an issue and she'll say, Hey, you know I saw you had this issue. Why don't you talk to such and such, and see how they stopped it? Or I see you're having this situation with this kid, talk to this teacher they had last year. So the administration encourages it (referring to informal learning), and most of the teachers are very willing to help, so it's a very positive environment for informal learning among us.

Formal PD opportunities and having access to knowledgeable support staff also contributed to teachers' informal learning, albeit indirectly. For example, some participants noted how they took time on their own to explore specific web-resources after being introduced to such resources by their math coach or support staff. Lastly, all participants mentioned teacher workload and time as key factors affecting teachers' informal learning. Teachers have to grade, call parents, plan and teach lessons; these commitments leave little time to attend to informal learning. For example, Natasha expressed concerns about how work commitments impact the time available for informal learning as follows:

... you know as a teacher, your time is overloaded with teaching. You know you need to lesson plan. You need to call parents. You need to grade so many things you have to do so a lot of times you don't have the time to really spend learning the way you need to...

Interpersonal Factors. Besides school level factors, analysis of the data obtained from participants showed that issues related to teacher collegiality, rapport or interpersonal relationships were key to their experience of informal learning. All participants noted that working in school settings where teachers were co-operative and very supportive of each other contributed to their informal learning experiences.

The supportive environment they had in their schools gave participants opportunities to brainstorm ideas with colleagues and get feedback, learn about new resources, and benefit from the stories of successes and challenges that colleagues shared. As a result, they could open up about issues of practice that they struggled with and ask for help from colleagues, sometimes outside school hours. For example, Natasha described how she texted back and forth multiple times with a colleague while seeking help with coding in Desmos:

...I told you about the lady that helped me code some Desmos. That was not during formal hours. I just text her, you know. While I was sitting looking at Desmos, I sent her a text message like, you know. Do you know anything about this? And then we sent text back and forth with her, explaining some things to me. So our school is just like that we're pretty close to everybody. So outside of school hours we can just call and email if we have any question.

This and several other instances that participants made reference to are pointers to how interpersonal factors could affect teacher informal learning. Another way that teacher collaboration and support for each other found expression was through teacher unionism. Both Debbie and Carlos mentioned that their schools have strong teacher unions which advocate for teacher welfare. It was not clear how teacher unionism affected teachers' experience of informal learning in Debbie's case. However, Carlos made it clear that the teacher union in his school has

been able to reach an agreement that will ensure that teachers can access funds up to 200 dollars to purchase whatever resources they need for their classes:

...Fortunately, we have a union, and the union, in the latest agreement was able to get like one hundred or two hundred dollars for teachers for whatever they wanted like If they wanted to decorate or buy some more resources, we would get that one for that. But I think that starts next year.

While such an agreement does not necessarily affect teachers' informal learning directly, chances are that it may indirectly affect informal learning because teachers like Carlos and others like him can take advantage of such funds to purchase resources such as textbooks or pay to access materials on teachers-pay-teachers as he had done in the past.

Personal Factors. Personal factors refer to individual factors affecting teachers' experience of informal learning. Examples of personal factors that came up in the course of analyzing data related to the four participants include teacher attitude, self-efficacy beliefs, lack of time due to personal commitments, experience, and perceptions or beliefs about formal and informal learning opportunities.

Participants' self-efficacy beliefs seemed to determine the aspects of practice their informal engagements focused on, and the extent to which they paid attention to these aspects. Overall, all four participants were pretty confident about their content knowledge. Except for Natasha who reported an occasion where she had to reach out to a teacher colleague to help her understand a particular scale factor problem, there was hardly any clear instance where participants relied on informal learning, particularly collaboration with colleagues as a way of improving their content knowledge. Whereas Jane was very confident of her knowledge of middle school math, she was less confident about her ability to teach it because she was teaching

a math class by herself for the first time. As such, she closely and regularly observed her colleague, an experienced national board-certified teacher with whom she co-taught another math class and tried to model her teaching after his. Similarly, Natasha was not as confident of her technological knowledge as she was, her content and pedagogical knowledge. Consequently, she seemed to seek help more in this area.

For Carlos, prior experience working with Canvas (a learning management system similar to the Pearson system his school uses) during his graduate studies made it easier to explore and master the school's learning management system. This placed him in a position where he did not need to depend on colleagues for issues related to the school's Pearson system but instead focused on discovering things for himself. In fact, he mastered the system so much so that he became a resource for other teachers.

Teacher attitude was another personal factor that participants cited. Where there was interest and a willingness to learn, participants were more open to engaging in informal learning and vice versa. Carlos is naturally drawn to new technology and that interest informed his commitment to exploring the learning management system his school uses. Both Natasha and Debbie gave instances of when they had opportunities to improve their technological knowledge but chose not to follow-up on such opportunities for lack of interest. Debbie also believes that it is the responsibility of a school's technology director to look for resources and let teachers know and that teachers only take up that responsibility because they are curious. Overall, she didn't seem to have any concerns about implementing technology or care much about it.

In general, participants' informal learning was mostly triggered by problems of practice. This was true for all the participants except that beyond engaging in informal learning to address problems of practice, Debbie as a person loves learning and is deeply committed to her

professional growth. Beyond solving everyday problems of practice, her commitment to informal learning was partly motivated by the desire to effect change, including influencing other teachers positively. This is expressed in the following excerpt which captures Debbie's attitude towards professional learning:

...I look at professional development not only in terms of what I can get or what is the school giving me, but what can I do to grow outside? And so I try to learn something new every every summer.

Time constraints due to personal commitments was one of the major factors that participants noted affects their informal learning. All four participants mentioned time as a major barrier. For example, Natasha is a nursing mother and her personal commitments at home leave little to no room for additional learning. As such, she makes a practice of giving her best to her job while at school and rarely engages in any form of informal learning or school related work while at home, except it becomes very necessary to do so.

Lastly, there were several personal factors bordering on teachers' beliefs or perceptions of formal and informal learning that participants mentioned. Both Natasha and Carlos believed that informal learning can be challenging at times because it may involve taking considerable amount of time to search for resources, especially where teachers do not exactly know where to look. As such, Natasha prefers asking her colleagues questions to engaging in such web-searches.

Similarly, for the same reason, Carlos thinks searching for resources on the web may not be for every teacher even though informal learning is equally as important as formal PD. While it may benefit some, it may not be beneficial to others. While acknowledging that informal learning activities can be a useful source of teacher learning, Carlos and Jane believe that the

structured and organized fashion that formal PD tend to take can be an advantage, especially where it is optional and meets teachers' specific needs. However, both of them still showed appreciation for the autonomy that often comes with informal learning as it allows teachers to focus on what they are really interested in.

Theme 3: Teachers' perceptions of the effects of informal learning

As the findings summarized under theme one suggested, informal learning activities form a major part of teachers' daily practice and continuous learning. While they found these informal learning engagements useful for their practice for the most part, they did not necessarily gain new knowledge by engaging in such activities every time. Also, although participants reported engaging in a variety of informal learning, there were five common informal learning activities that participants seemed to engage in regularly: collaborating with colleagues (mostly discussions), referencing web-based resources, using social media, and talking to persons outside school. In this subsection, I described participants' perceptions of the contributions of informal learning to their knowledge and professional practice with an emphasis on these five common informal learning activities that they seemed to frequently engage in. The findings are presented under four sub-themes: content knowledge, pedagogical knowledge, technological knowledge, and support for practice.

Content Knowledge. The analysis revealed that informal learning contributed way more to participants' pedagogical knowledge than their content or technological knowledge. However, there were about two instances (from the interviews and survey-based journaling) that suggest participants may find the use of social media and interaction with colleagues useful for improving their content knowledge- knowledge of math content as well as math curriculum and standards. Carlos, Natasha, and Jane mentioned specific instances when they found social media

and interaction with colleagues useful for improving or at least refreshing their knowledge of specific math content and standards.

Jane mentioned that she was teaching seventh grade math for the first time and described how a conversation she had had with a more experienced colleague contributed to her knowledge of vertical alignment. The colleague in question has seen the EOGs that integrate assessment and has a deeper knowledge of sixth, seventh, and eighth grade curriculum. On his part, Carlos reported stumbling on a calculus video in Spanish on Facebook and thought it was a good refresher:

...I was just scrolling through the newsfeed and one of my friends who graduated from the same university as me in Puerto Rico just posted one calculus video of a retired lady that was teaching one concept about calculus. I don't quite remember which one it was, but I think maybe just going through like the concept behind calculating the area under a curve but in a very conceptual way, and that was to me very interesting to see her doing that, and it was in Spanish. So it was fun to me to get to see that. I am not teaching calculus but still, it was a good refresher.

Natasha also mentioned how she reached out to a colleague for help with a scale factor problem she struggled with:

...I text my former co-teacher from seventh grade. I was doing just what I was telling you the scale factor and I text him. And I said, I don't understand this problem, and he came up like five minutes later to look at it...

Overall, participants seemed to find informal learning activities useful for learning about content. They did random online searches, read books, curriculum materials, and sometimes visited specific websites to learn about math content and standards. However, except for a few

instances like the ones described above, most of the reference to learning about content through informal sources was either general or described in the context of lesson planning or finding.

Technological Knowledge. Similar to content knowledge, there were a couple of specific instances when participants found their informal learning engagements useful for learning about new technologies and implementing technology in the classroom; however, much of the contributions participants talked about focused on pedagogical knowledge. For example, both Natasha and Carlos described instances when discussion with colleagues and persons outside their schools contributed to their use of technology. Specifically, Carlos mentioned how he struggled with getting students to be engaged during his classes when he first started teaching. He had a conversation about this challenge with his mom and she advised him to bring in elements of competition into his class. Carlos heeded her advice and for the first time started using Kahoot in his class. He noted that the conversation with his mom helped to improve student engagement in his class. Carlos captured that experience in the following excerpt:

I remember just talking to her during my first year as a teacher, saying that some students were kind of disengaged, or simply not very engaged. And then I remember her saying like, Hey, you know, when I try to study with granddaughters they don't get very motivated. But when I get them to compete with each other, then they get more motivated, and I remember about that and I started to implement games like Kahoot to have students more engaged in the classroom.

In the same vein, Natasha mentioned a particular colleague she goes to from time to time for help with coding in Desmos. Debbie also mentioned how she was first introduced to Flipgrid by a colleague. She later watched YouTube videos and read more about how Flipgrid works and began using it in her classes.

Pedagogical Knowledge. As earlier mentioned, most contributions of informal learning that participants mentioned pertained to their pedagogical knowledge- teaching practices, classroom management, lesson planning, etc. All participants mentioned specific instances when they found informal learning useful for improving their pedagogical practices. While some of the informal learning experiences that participants described helped address immediate or momentary needs (e.g., feedback on lesson planning), others point to enduring changes born out of informal learning experiences (e.g., adopting new practices to promote equity).

Carlos noted how informal conversations with colleagues serves as a source of feedback and helped him and his colleagues identify different teaching practices for promoting student engagement in his class:

...We would have students work in groups. And you know, I think many, many other strategies came from just talking with teachers in the hallway. Yeah, like not necessarily sitting in a classroom and talking about PD. Not necessarily having a presentation or anything, just talking. Hey, how are you doing with your students? What is working for you? How do you get students to do this? And what do you do when this happens? So, I think all those things were learned to experience and shared from teacher to teacher.

On their part, Jane and Debbie described how observing teaching and reading professional literature proved useful for teaching seventh grade math for the first time and learning strategies for promoting equity in the classroom respectively. Natasha co-teaches with a colleague; as such, regular discussions around teaching and co-planning is a given. She also noted how discussion with colleagues has contributed to helping her promote student discourse in the classroom.

Support for Practice. Besides its contributions to teachers' content, technological, and pedagogical knowledge; participants also reported "unspecified learning" from informal sources. This sub-theme captured contributions in terms of unspecified learning (not specific to content, pedagogy, or technology) and emotional wellbeing from participants' informal engagements. There were several instances where participants noted learning from informal learning without specifically mentioning how. For example, both Jane and Carlos noted learning a lot from individual reflection. However, while Jane pointed out how reflecting contributes to her practice, Carlos did not specifically address that.

The interviews with Carlos and Debbie also suggested that they may have found talking with persons outside school as a source of emotional support. Both of them, especially Debbie makes a practice of talking to family about issues of practice regularly. Debbie for example, discussed issues of teaching with her Dad every morning while driving to school, primarily because he is a good listener:

...he was a teacher for 40 years, and I call him every morning on my way in. So he taught a different generation where parents weren't involved, but I always talked to him about what I'm doing. He's interested in how things have changed and he suggested maybe you could reach out to parents and tell them what you're telling the students...And so he just kind of reinforced what I wanted to do, he would play devil's advocate sometimes, but a lot of it, I think is, he's a very good listener, and so reinforcing what I thought I wanted to do, and, and he was like, Yes, I think that's gonna be a good idea, and maybe you could add this to it...

Similarly, Carlos mentioned how he and other teachers in his school had encountered a problem related to grading on the Pearson system his school uses one time. He recalled going home that day and expressing his frustration.

Summary of Findings from Phases One and Two

Survey data (from closed-ended items) found significant positive relationships between math teachers' participation in informal learning and their self-reported efficacy in specific TPACK domains. Specifically, correlation analysis showed statistically significant positive relationships between each of the TPACK variables (self-reported efficacy in CK, TK, PK, TPACK) and the informal learning variables (learning through colleague interaction, media interaction, stakeholder interaction, and individual reflection).

Regression analysis was further used to lend support to the results from the correlation analysis. Except for math teachers' participation in stakeholder interaction, their participation in the remaining three informal activities (learning through colleague interaction, media, and individual reflection) were predictors of one or two of the self-efficacies in TPACK domains that this study focused on. To be specific, controlling for gender, career stage, school level, and certificate type; the results showed that math teachers' participation in learning through colleague interaction and media are significant predictors of their content knowledge self-efficacy. Math teachers' media interaction was also a significant predictor of their technological knowledge self-efficacy. Similarly, math participation in colleague interaction and individual reflection were significant predictors of their pedagogical knowledge self-efficacy. Lastly, math teachers' participation in colleague interaction and individual reflection also significantly predicted their TPACK self-efficacy.

Furthermore, one-way ANOVA and the Kruskal-Wallis H tests were used to assess whether statistically significant differences existed in math teachers' participation in informal learning activities (colleague interaction, media interaction, stakeholder interaction, and individual reflection) based on their career stage (beginning, mid-career, or experienced teacher). The results of the analysis showed that there were no statistically significant differences in math teachers' participation in informal learning activities and their career stage.

Qualitative findings from the analysis of open-ended survey responses, survey-based journaling of teachers' everyday informal learning experiences, and case analysis were used to inform the quantitative findings (research question one). The analysis of the open-ended responses identified five distinct categories of informal learning activities that mathematics teachers engage in: consulting information sources (e.g., reading professional literature, social media), interaction and discussion with others (e.g., sharing, collaboration with others), learning from others without interaction (e.g., written feedback, observation), practicing and testing (e.g., experimenting), and reflection in and on action (reflecting on issues of practice). The most frequent informal learning activity that math teachers engage in was found to be consulting information sources as 64.1% of survey quotes bordered on it. This is followed by interaction and discussion with colleagues in second place (30.9% of survey quotes). While the numbers focus on categories; overall, the single most frequent informal learning activity that math teachers reported engaging in was using social media (34.3% of survey quotes).

The analysis of the open-ended survey responses further found three categories or levels of factors that affect teachers' informal learning: personal, interpersonal, and school level factors. An overwhelming majority (70.3% of survey quotes) of issues that math teachers mentioned were school level factors. In fact, school level factors accounted for twice the

percentage of personal and interpersonal factors that math teachers described combined.

Additionally, there were three areas of perceptions of the contributions of informal learning identified from the analysis of the open-ended responses: content, technological, and pedagogical knowledge as well as support for practice. In other words, teachers gave different instances of how informal learning has contributed to their knowledge in these TPACK domain and supported their professional practice. Support for practice was in the form of motivation and emotional wellbeing and unspecified learning and resources (sometimes teachers mentioned accessing resources without specifying the nature of those resources, that is, whether they relate to content, pedagogy, technology, etc.).

The analysis of data from the survey-based journaling that teachers (the four teachers purposefully selected from the first phase of the study) completed and the case analysis found that even though formal and informal learning experiences constitute math teachers' everyday or continuous learning; informal learning experiences were more frequent. Also, there were five main informal learning activities that teachers frequently engaged in: referencing web-based resources, collaboration with colleagues (mostly discussions), reading professional literature, using social media, and discussing with persons outside school. Of these five, referencing web-based resources and collaboration with colleagues were the most frequent informal learning activities teachers engaged in; they were also perceived as the most useful.

Whereas referencing web-based resources and collaboration with colleagues were the most frequent informal learning; teachers mentioned other forms of informal learning activities that contributed to their professional learning and practice. This includes experimenting, observation, and individual reflection. Overall, teachers judged the usefulness of their informal learning engagements on the basis of how well it supported their practice; especially as it relates

to teaching and student learning. The contributions of informal learning that teachers mentioned in the interviews was mostly in the area of their pedagogical knowledge followed by their technological knowledge. There was hardly any mention of informal learning contributing to their content knowledge. Furthermore, the instances of informal learning contributing to teachers' motivation and emotional wellbeing during the interviews were in the context of their interaction with persons outside school. Also, the specific informal learning activities that teachers engaged in depended on different factors including their personal and school context, and preference.

This chapter explained the quantitative and qualitative findings of this study and presented a summary of key findings. The next chapter, Chapter 5, will discuss these findings and specifically answer the research questions based on meta-inferences from the quantitative and qualitative findings.

CHAPTER 5: DISCUSSION, LIMITATIONS, IMPLICATIONS, AND CONCLUSIONS

This chapter discusses this study's findings based on the research questions obtained from the analysis of multiple data sources (quantitative and/or qualitative)- data from closed-ended survey, interviews, and teachers' survey-based journaling of their daily informal learning experiences. The limitations of the study and its implications for research, practice, and policy are also discussed.

To recap, the purpose of this study was to examine math teachers' perceptions of the effects of informal learning on teacher knowledge and practice. Specifically, this study: 1) identified the types of informal learning activities that math teachers engage in as part of their continuous professional learning in the course of their daily work; (2) examined math teachers' perceptions of the factors that support or hinder their informal learning in the workplace; (3) examined math teachers' perceptions of the effects of informal learning on their knowledge and practice; and (4) explored how math teachers' participation in informal learning relate to their self-reported efficacy in select TPACK domains (CK, TK, PK, and TPACK), as well as differ based on teacher career stage.

To address the purpose of the study, an explanatory sequential mixed methods approach was employed to address the following research questions (RQ):

1. How do math teachers' participation in informal learning activities relate to their self-reported efficacy in select TPACK domains and differ based on teacher career stage?
 - a. Do relationships exist between math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) and their self-reported efficacy in select TPACK domains (CK, TK, PK, and TPACK)?

- b. Do math teachers' participation in informal learning activities (learning through media, colleague interaction, individual reflection, and stakeholder interaction) differ based on teacher career stage?
2. What informal learning activities do math teachers engage in during their everyday practice?
3. What are math teachers' perceptions of the factors that affect their informal learning?
4. What are math teachers' perceptions of the effects of informal learning on their knowledge and practice?

Key Findings

RQ 1: How Math Teachers' Participation in Informal Learning Activities Relate to their Self-reported Efficacy in Select TPACK Domains Respectively and Differ Based on Teacher Career Stage.

Relationships between Participation in Informal Learning and TPACK Self-efficacies

The correlation analysis in this study found significant positive relationships between math teachers' participation in informal learning activities (learning through media, colleague interaction, stakeholder interaction, and individual reflection) and their self-reported efficacy in specific TPACK domains (CK, TK, PK, TPACK). Although the study found that all four variables for teachers' levels of participation in informal learning activities were positively correlated with each of the four TPACK self-efficacy variables; the results of the multiple regression analysis conducted to lend support to the correlation results suggested that not all the relationships between the variables in question were predictive.

Except for math teachers' participation in stakeholder interaction, their participation in the remaining three informal learning activities (learning through colleague interaction, media,

and individual reflection) were predictors of one or two of the self-efficacies in TPACK domains that this study focused on. To be specific, controlling for gender, career stage, school level, and certificate type; the regression results showed that math teachers' frequency of participation in colleague interaction and media were significant predictors of their content knowledge self-efficacy. Math teachers' frequency of participation in media was also a significant predictor of their technological knowledge self-efficacy. Similarly, math teachers' participation in colleague interaction and individual reflection were significant predictors of their pedagogical knowledge self-efficacy. Additionally, math teachers' participation in colleague interaction and individual reflection also significantly predicted their TPACK self-efficacy.

Although this study found that teachers' frequencies of participation in the four informal learning activities considered were positively related to their TPACK self-efficacies, not all of them are predictors of teachers' TPACK self-efficacies. However, together, these findings provide some evidence to support my initial proposition that teachers' informal learning engagements or experiences inform their TPACK self-efficacies. The qualitative analysis (the case analysis to be precise) also provided some evidence in support of these findings as teacher' informal learning was found to influence their self-efficacy. For example, Jane, one of the participants, suggested that having opportunities to informally observe a national board-certified teacher colleague contributed to her pedagogical knowledge self-efficacy: her confidence in her ability to teach a math class by herself for the first time.

The quantitative analysis was based on teachers' frequencies of participation in informal learning as predictor variables and TPACK self-efficacy variables as dependent variables. As such, the quantitative results did not address the second part of my proposition that suggested that teachers' self-efficacy beliefs inform their informal learning experiences. The qualitative

results provided some evidence suggesting that the second proposition is also true as the interviews revealed that participants' self-efficacy beliefs determined the aspects of learning (content, pedagogy, technology, etc.) or practice that their informal engagements focused on, and the extent to which they participated in specific informal learning activities. The case analysis also revealed that all four participants were pretty confident about their content knowledge, and this was possibly the reason why there very few references to engaging in informal learning in relation to content knowledge. However, quantitative analysis is required to further explore this claim.

These findings are supported by previous research which identified self-efficacy as a personal factor related to teachers' informal learning (Runhaar et al., 2010; Van Daal et al., 2014; Huang et al., 2020). Furthermore, Choi and Jacobs (2011) highlighted different studies that found self-efficacy as a predictor of workplace learning related variables such as trainee learning and performance and critical reflective working behavior.

This study also treated teachers' self-efficacy in the TPACK domains considered as proxies for teacher knowledge in those domains. As such, the qualitative results which captured specific instances of how teachers' participation in interaction with colleagues, media, and individual reflection combined with the quantitative results contribute to the literature highlighting the contributions of teachers' informal learning to teacher knowledge and practice.

There is considerable evidence from extant research that show that teachers' engagement in informal learning activities such as learning through media, interaction with colleagues, interaction with stakeholders, and individual reflection positively influence teachers' beliefs and contributes in improving their practice (McNally et al., 2009; Verberg et al., 2013; Kyndt et al., 2016; Louws et al., 2017; Huang & Wang, 2021). Although this study showed that teachers'

engagement in stakeholder interaction was not a predictor of any of the TPACK self-efficacies; there is some evidence from the qualitative results to suggest that such interaction, particularly conversations with family, contribute to teachers' emotional wellbeing. Interaction with stakeholders, when it focused on school issues, was mostly general. This could be a pointer to why such interactions barely contributed to teachers' knowledge.

Research has also shown that besides engaging in informal learning to grow their practice, teachers also engage in informal online spaces to avoid feeling isolated, and support each other emotionally (Carpenter & Linton, 2016). This study's interview questions focused primarily on teachers' perceptions of the contributions of informal learning to their knowledge. As a result, it is not surprising that the contributions of informal learning engagements that teachers reported for the case analysis barely touched on issues of motivation and emotional wellbeing. However, there were a couple of survey quotes that touched on motivation and wellbeing.

Participation in Informal Learning Activities and Teacher Career Stage

This study used the one-way ANOVA and Kruskal-Wallis H tests to assess whether statistically significant differences existed in math teachers' participation in informal learning activities (learning through interaction with colleagues, media, stakeholder interaction, and individual reflection) based on their career stage (beginning, mid-career, or experienced teacher). The results of the analysis showed that there were no statistically significant differences in math teachers' participation in informal learning and their career stage.

Research has linked veteran teachers to the tendency to resist change (Orlando, 2014; Snyder, 2017; Monteiro et al., 2020). Richter et al. (2014) also associated teachers' uptake of formal and informal learning opportunities to their career stage, suggesting that teachers tend to

collaborate more at the beginning of their career than at the middle or towards the end of their careers and that veteran teachers tend to be more drawn to self-directed learning e.g., reading professional literature as a means of professional learning. As such, it was interesting to find no significant differences in teachers' level of participation in all the informal learning activities this study focused on; particularly their media interaction. However, there are a number of explanations that can be advanced for this finding, especially as it pertains to teachers' media interaction which includes reading professional literature, social media, browsing the internet in search of educational materials, etc.

Findings from research that focus on the connection between teachers' use of social networks, including social media are mixed. For example, Hunter and Hall (2017) found a negative relationship between teachers age and teaching experience and their level of comfort using social media respectively. This suggests that that the older and more experienced a teacher is, the less likely they are to be comfortable with using social networks. In the same vein, a 2000 survey by the National Center for Education Statistics (NCES) found a similar relationship between teachers' age and teaching experience and the use of social networking applications. However, more recent studies appear to be showing that the increase or growth in social media use may be driven by older users (Lenhart et al., 2010). This is corroborated by the 2018 MDR Teachers and Social Media Survey which found that veteran teachers in the U.S seem to be heavier users of social media than beginning teachers. Their study was based on a sample of 732 teachers across the U.S.

Additionally, Bexheti et al. (2014) found that teachers use social media for both personal and educational purposes. Assuming the beginning teachers in this study used social media more than teachers in other career stages, it may be the case that they use it more for personal purposes

compared to their more experienced colleagues. The survey items about their media interactions focused on their use of social media and other forms of media for educational purposes. It may also be that the COVID-19 pandemic pushed a lot of veteran teachers out of their comfort zone, and that one of its impact is a greater willingness of veteran or the more experienced teachers to commit to professional learning through informal engagements.

The case-analysis results also supported the finding that there was no statistically significant difference between teachers' level of participation in informal learning activities based on career stage. This is because there was no clear pattern that distinguished the four teachers in this study in terms of their informal learning engagements. Each teachers' commitment to specific informal activity was largely based on preference, their personal and school contexts, and their perception of different informal learning sources. Furthermore, Kyndt et al. (2016) found no difference between beginning and experienced teachers in terms of their informal learning engagements.

RQ 2: Informal Learning Activities and Teachers' Everyday Learning and Practice

Overall, this study identified five distinct categories of informal learning activities that mathematics teachers engage in: consulting information sources (e.g., reading professional literature, social media), interaction and discussion with others (e.g., sharing, collaboration with others), learning from others without interaction (e.g., written feedback, observation), practicing and testing (e.g., experimenting), and reflection in and on action (reflecting on issues of practice).

Although the quantitative analysis found that reflecting on issues of practice was the most frequent informal learning activity teachers engage in on average; the single most frequent informal learning activity that math teachers reported engaging in, based on the analysis of the

open-ended survey responses was using social media (34.3% of survey quotes). This is followed by others including collaboration with colleagues (29% of survey quotes), online courses and web-based resources (15.1% of survey quotes) and reading professional literature (14.7%). The analysis of the interview data and data from teachers' two weeks journaling of their informal learning experiences suggested that teachers engaged in some of these and other informal learning activities such as observing practice from time to time. However, some of the activities, especially collaboration with colleagues (mostly discussions), referencing of web-resources, using social media, reading professional literature, and discussion with persons outside seemed to be the most common informal learning activities in teachers' day-to-day practice. These activities belong to two of the aforementioned categories: consulting information sources and interaction with others.

In their review of 74 articles focusing on teachers' informal learning, Kyndt et al. (2016) identified 129 unique learning activities which they further grouped based on seven categories. The informal learning activities reported in this study are largely based on seven of these categories except two: engaging in extra-curricular activities and encountering difficulties. Beyond just identifying the types of informal learning activities teachers reported like many of the studies described in Kyndt et al. (2016), this study goes further to identify the extent to which they are part of math teachers' day-to-day practice.

RQ 3: Perceptions of Factors Affecting Math Teachers' Informal Learning

This study identified three levels or categories of factors affecting math teachers' informal learning- personal, interpersonal, and school level factors. Personal factors involve individual level factors such as teachers' attitude, self-efficacy, lack of time due to personal commitments, experience, and perceptions or beliefs about formal and informal learning

opportunities which affect teachers' experiences of informal learning. Interpersonal factors refer to issues bordering on teacher collegiality and rapport, for example, teacher collaboration and support, the presence of trade unions, and so on. School level factors refer to issues at the wider policy and administrative level teacher informal learning. Examples include admin attitude, school characteristics (e.g., size, location), school policy/culture and the likes.

This study, particularly the case analysis, found that teachers' school context was central to their experience of informal learning. Thus, it is no surprise that an overwhelming majority (70.3% of quotes) of issues affecting teachers' informal learning depended on their school context, twice the percentage of personal and interpersonal factors that math teachers described combined. This is followed by interpersonal and personal factors which accounted for 18.5% and 11% of survey quotes respectively. It is also noteworthy that time and scheduling accounted for up to 36.9% of all survey quotes, teacher attitude accounted for 11%, while teacher collaboration and support accounted for 8.6%.

While the analysis of the open-ended responses gave an overall picture of how frequently teachers mentioned these factors, the interview data provide additional context by addressing how they specifically hinder or support teachers learning. On the personal factors level, for example, the interview data showed that teachers' self-efficacy beliefs spurred them to seek out informal learning opportunities. They engaged in informal learning in areas where they felt less confident about their abilities. Teachers in this study were mostly confident about their content knowledge and it appears that is a possible explanation for why they barely mentioned anything about content knowledge as it relates to informal learning.

Teacher attitude, especially the willingness to learn so as to be able to solve problems of practice was a major motivator of the informal learning of the teachers described in the case

analysis. While their informal learning was driven by problems of practice most of the time, at other times it was driven by love of learning. The specific types of informal learning teachers engaged in also depended on a variety of factors including their personal context, preference, and perceptions of the usefulness of such informal learning opportunities.

With regards to school level factors, school culture, policies, or practices were found to be important factors that supported teachers' informal learning. A school vision or year theme which communicated support for teacher collaboration was identified as a factor which fostered interaction among teacher colleagues. This finding corroborates Jurasaitė-Harbišon and Rex (2010) who suggested that the mission and tradition of an organization (the school in this case) supports informal learning. School administrators also reportedly supported teachers' informal learning by pointing them to other teachers they could talk to about problems of practice besides supporting class projects for which these teachers engaged in research to execute. Difficulty in accessing funds to buy resources like books due to school policy was also perceived as a factor that affected teachers' informal learning.

Collaboration with colleagues was also found to be a given for schools with inclusion classes as teachers had to co-teach. Expectations about use of technology was another school level factor that drove teachers to seek out informal learning opportunities. For example, Carlos taught in an online school where there was a big push to engage students with technology, leading him to seek out informal learning opportunities such as discussing with a more experienced colleague and observing practice to improve student engagement.

Formal learning opportunities also contributed to teachers' informal learning. For example, teachers sometimes made better sense of, and built on or enhanced things they learnt from formal PD using informal learning sources. This finding, in part, supports Lai (2011) and

Theisinger (2017) who found a reciprocal relationship between teachers' formal and informal learning opportunities. In general, the school level factors identified in this study highlight the important role that the workplace context (the school context in this case) plays in teachers' informal learning. The impact or role of context in teachers' informal learning is well established in extant literature (Lohman, 2006; Burns and Schaefer, 2008; Schei and Nerbø, 2015; Theisinger, 2017).

Closely related to school level factors were issues that bordered on teachers' interpersonal relationships and collegiality- interpersonal factors. Having supportive and cooperative colleagues contributed to help seeking and teacher collaboration in general. All the teachers in the case analysis reported having colleagues who were available and willing to support their practice. Most interactions that teachers reported learning from involved a more knowledgeable colleague. Being comfortable or close with a more capable colleague made it easier for teachers to engage share their practice-related challenges and get feedback from them. This corroborates Holley et al. (2016) who suggested that having close ties with more capable colleagues contributed to informal learning.

RQ 4: Math Teachers' Perceptions of Effects of Informal Learning on Teacher Knowledge and Practice

This study found that teachers' engagement in informal learning contributed to their knowledge and practice. Informal learning contributed to some extent to math teachers' content knowledge (math content knowledge and knowledge of math curriculum and standards). For example, one of the study participants, Natasha, noted how she struggled with a scale factor problem and had to reach out to a more knowledgeable colleague for help. Another teacher pointed out how using social media has contributed to their knowledge of calculus - "I am part of

Facebook groups for calculus and that helps me hone calculus skills specifically in preparing students for the AP test”. However, content knowledge was the least of the three knowledge domains that informal learning contributed to. This was obvious from all the qualitative data sources this study was based on, especially results from the analysis of the open-ended responses which showed that the content knowledge category accounted for only 7% of all survey quotes.

The contributions of informal learning that teachers mentioned mostly focused on their pedagogical knowledge, followed by their technological knowledge. Teachers noted that informal learning contributed to their professional practice in different ways, including the adoption of new teaching practices, improvement of extant practices, lesson planning, and classroom management. While most of the informal learning experiences that participants described helped address immediate or momentary needs (e.g., feedback on lesson planning), a few others point to more enduring changes born out of informal learning engagement (e.g., adopting new practices to promote equity). For example, Debbie, one of the participants how reading professional literatures and following math educators on social media have brought about greater student engagement and also transformed her class to a more equitable space.

Similarly, Carlos, another participant noted how talking with colleagues and purchasing resources on teachers-pay-teachers to help engage students in interactive activities such as *escape room* have helped to address some of the challenges he encountered with student engagement when he first began teaching. The analysis of the open-ended responses showed that survey quotes related to the contributions of informal learning in the area of pedagogical knowledge accounted for 51.6%. In the same vein, technological knowledge accounted for 9.1% of all survey quotes. The qualitative analysis showed that informal learning contributed to

teachers' knowledge and use of technology. For example, Natasha, noted how a teacher colleague helps her with coding in Desmos from time to time while planning lessons.

Together, these findings speak to the important role that informal learning plays in teachers' professional learning. Kyndt et al.'s (2016) review of 74 studies on informal learning identified 20 studies which examined informal learning outcomes. They found that seven of these studies indicated that teachers acquired subject matter knowledge through their engagement in informal learning activities. This suggests that informal learning contributes to teacher content knowledge as this study found. Most of the studies (n=13) also showed that the learning outcomes which teachers reported bordered on pedagogical knowledge. This corroborates the finding that most of the contributions of informal learning that teachers reported was in the area of their pedagogical knowledge.

Overall, Kyndt et al.'s (2016) review situated informal learning outcomes under three areas: subject knowledge, pedagogical knowledge and skills, and professional attitudes and identity. The results of this study touches on two of these areas; however, it also captured outcomes related to teachers' technological knowledge. Besides the contributions of informal learning to teachers' knowledge, this study found that informal learning also contributed to teachers' motivation and emotional wellbeing to some extent.

Research has shown that apart from gaining professional knowledge to grow their practice, teachers also engage in informal learning (sometimes in online spaces) to avoid feeling isolated, and to support each other emotionally. Anderson et al. (2022) also highlighted, through their analysis of interactions within a Facebook group, how informal learning supported mathematics teachers in tackling the detrimental impact of tracking while seeking help to more effectively implement mixed ability learning. These aspects of the contributions of informal

learning could have been explored further during the interviews, except that it was not the primary focus of this study. Although smaller (2005) found that most teachers prefer informal learning to formal learning, this study suggests that teachers consider both as equally important but different; they were also divided in regard to their preferences. While teachers engaged in informal learning more frequently, this study found that both formal and informal learning opportunities form part of their continuous or everyday learning.

Limitations of the Study

In spite of efforts aimed at conducting a good study, limitations are inevitable. Thus, this study has its own limitations. While there are inherent advantages attached to the mixed methods design employed in this study, there are a couple of limitations associated with the design that are worth mentioning.

To start with, convenience sampling was employed in the quantitative phase of the study. As such, it is difficult to say with certainty, that the sample is representative of the population of interest- secondary math teachers (Creswell, 2002; Ivankova, 2002). The fact that there are many secondary math teachers that do not use Facebook and Twitter or even belong to the specific Facebook groups the survey link was posted add to the challenge of representativeness. Also, all the study variables except for one were not normally distributed. Consequently, analyses were based on non-parametric tests which are known to have lesser statistical power compared to their parametric alternatives. Additionally, the results of this study are not generalizable to all math teachers, especially the results from the case analyses which is based on the experience of only four participants (Leung, 2015).

This study is based on survey (the larger survey with close and open-ended items and a micro-survey of teacher everyday/continual learning experiences over a two-week period) and

interview data. These data sources are self-reported and prone to bias as respondents may not have been honest about their perceptions of informal learning. Subsequent research can consolidate on this by integrating elements of observation like Jurasaitė-Harbison and Rex (2010) in their study which examined how school cultures support or hinder opportunities for teacher informal learning in an elementary school in Midwestern United States, an elementary school in Russia, and a secondary school in a large city in Lithuania.

Although the qualitative analysis hinted on the contribution of informal learning to teachers' motivation and emotional wellbeing, the interviews primarily focused on teachers' perceptions of the effects of informal learning in the area of content, pedagogy, use of technology. Also, teachers did not fill out the micro-survey capturing their daily informal learning experiences in the evening while at home every time as the researcher expected. This may have limited the extent to which stakeholder interaction, particularly interaction with family and other non-teacher colleagues was reported.

Lecat et al. (2020), Kyndt et al. (2016) and several other studies on teacher informal learning clearly point out that there is no consensus among researchers with regards to the definition of informal learning, making measuring informal learning problematic. This further compounds the irregularity and misalignment in the extant educational literature. Consequently, it is possible that the definition of informal learning adopted in this study leaves out certain aspects of informal teacher learning that could contribute to the field. For example, the definition of informal learning adopted in this study did not include professional learning communities (PLC). Although it was sometimes difficult to separate when teachers were collaborating in the context of a PLC which is school-led or mandated and when they were not, a distinction was made between the two where obvious.

This study also used teachers' TPACK self-efficacies as proxies for teacher knowledge in the specified domains. It is possible that there are other more representative and reliable measures out there. For example, White et al. (2013) used the Learning Math for Teaching (LMT) instrument to investigate the extent to which participating in a four to five-day intensive Math Teacher Circles (MTC) workshop, an informal learning opportunity, impacted teachers' mathematical knowledge for teaching. Lastly, although the researcher was reflexive throughout the research process, the interpretive nature of qualitative research gives room for bias in the interpretation of results. The researcher's positionality may have also affected some teachers' openness about their informal learning experiences.

Implications

This study contributes meaningfully to extant research on teacher informal learning. Among other things, it focuses on the outcomes of informal learning and uses a mixed methods approach, two areas of need in teacher informal learning research. Kyndt et al. (2016) and Lecat et al. (2020) in their reviews both noted that a mixed methods approach is most suitable for capturing teachers' informal learning. Overall, the study identified the types of informal learning activities that math teachers engage in, the extent to which these activities form part of teachers' everyday learning, factors affecting their informal learning, as well as the effects of such learning on their professional development and practice. This study has implications for mathematics teachers, school leadership, and future research.

Implications for Mathematics Teachers

The results of this study demonstrate the fact that informal learning is an authentic source of professional learning which teachers can capitalize on for their continuous professional development. Consequently, there is a need for teachers to maximize the affordances of informal

learning opportunities both within school spaces and online even when they have access to formal learning opportunities. As this study and similar studies such as Theisinger (2017) show, there is a reciprocal relationship between teachers' formal and informal learning. As such, teachers can explore informal learning sources to make better meaning of, extend, and enhance the things they learn during formal training. The converse is also true as the agenda or focus for formal PD can stem from teachers' informal learning experiences.

The call for math teachers to take advantage of informal learning experiences is especially important when we consider the fact that teachers do not necessarily have equal access to formal PD opportunities. For example, rural schools sometimes face challenges related to funding and budgetary constraints which can make accessing effective professional development difficult (Franz et al., 2007; Sundeen, 2013; Kalonde, 2017). This situation may even be worse in developing countries. Teachers in settings where access to formal PD is limited or ineffective can take advantage of informal learning opportunities to further their professional learning.

This study identified different personal and interpersonal factors that affect math teachers' experiences of informal learning. Notable among personal factors is teachers' attitudes and beliefs about formal and informal learning opportunities. There is a need for teachers to pay attention to how their attitude or certain deeply held beliefs about informal learning or learning in general may be limiting their professional growth and make appropriate adjustments. For example, research has documented veteran teachers' resistance to change (Orlando, 2013). This study also found that teachers informal learning thrives better within a supportive and cooperative environment. This speaks to the need for teachers to pay attention to investing in developing interpersonal relationships with colleagues within their schools and networking with other teachers or math educators outside their schools to access support for practice.

Implications for School Leadership

This study found that the school context is central to teachers' experience of informal learning. This suggests the fact that school leaders can do a lot to positively influence teachers' experience of informal learning. Unfortunately, even though about 80% of workplace learning takes place informally. However, only about "...20 percent of what organizations invest in learning is dedicated to enhancing informal learning" (Berg & Chyung, 2008, p. 230). Although this statistic is not specific to schools; nonetheless, it still suggests the need for more support for informal learning.

This study showed that teacher collaboration is important for teachers' continuous professional development. Consequently, schools need to really allow teachers collaborate. Educational leaders, by virtue of their positions, can establish norms or create policies that foster a culture of collaboration among teachers. As this study found, a school vision (or year theme) and clearly stated expectations, for example, expectations regarding the use of technology, can set the tone for teachers' informal learning in an area and promote teacher collaboration. Opportunities can be created for struggling teachers, for example, to observe the teaching of veteran teachers or just more experienced teachers who model best teaching practices. An extension of this could also involve creating opportunities for new teachers to be mentored by more experienced capable colleagues.

Most teachers identified time and scheduling issues as the most common factor affecting teachers' informal learning during school hours. Consequently, there is a need for school administrators to deliberately make efforts towards freeing up teachers' time and being strategic about scheduling planning times so teachers can pay more attention to their personal professional learning and have opportunities to collaborate with colleagues. When teachers are overworked

and saddled with extra-responsibilities, there is a high chance of teacher burnout. The result is that they may have little or no time left for informal learning. School administrators can also pay attention to making resources available to support teachers' learning. Teachers may be discouraged if they have to resort to paying for resources like textbooks out of pocket. Also, a lack of proximity to colleagues or not having colleagues that teach the same courses or grade level can limit teachers' informal learning opportunities (Desimone et al., 2014). For example, Carlos, one of the participants in this study complained about being the only teacher that teaches the course that he teaches. Hence, schools can support teacher informal learning by providing physical infrastructures such as a common room and teacher lounge to encourage teacher interaction where such facilities do not already exist.

Findings from this study suggests that some teachers may be more inclined towards informal learning than others. Thus, as Cerasoli et al. (2018) suggests, it will be helpful for school leaders to consider how to support such teachers to be better informal learners by exposing them to useful tips and insights that foster informal learning behaviors through formal training sessions or one-to-one coaching. Cerasoli et al. (2018) went on to list skills that these tips and insights can focus on. They include becoming better at asking questions, listening actively, recognizing patterns, soliciting feedback, and observing experts.

The researchers further suggested the need for an informal needs assessment similar to a traditional needs assessment and argued that while the traditional needs assessment may ordinarily focus on what teachers need to know by the end of a formal training, an informal needs assessment will capture what teachers need to or can learn on the job. The results of such analysis when communicated to teachers can help them better use their learning time. These implications clearly speak to the need for school leaders to embrace the fact that teachers learn

though multiple pathways (formal and informal) in this case and think of creative ways to support teachers' learning through both means.

Implications for Future Research

Although there is a growing interest in teacher informal learning, there is need for more studies that explore the outcomes of informal teacher learning (Eraut, 2004); informal teacher learning is largely qualitative as well (Kyndt et al., 2016; Lecat et al., 2020). This study contributed to extant informal teacher learning research by focusing on both the outcomes of informal learning and employing a mixed methods approach, and future research can provide further insight into different issues relevant to this study.

Firstly, informal learning is difficult to measure and as such there is a need for reliable instruments. The need for validated instruments has been repeatedly expressed in different studies (Cerasoli et al., 2018; Kukenberger, Mathieu, & Ruddy, 2015; Sitzmann & Ely, 2011). Although the instrument used in this study is a validated instrument, it was developed and validated for primary school teachers in China. Future research can look into re(validating) the instrument for the purpose of establishing further validity evidence for its use and interpretation in the United States for secondary math teachers similar to the work Smith and Zelkowski (2022) did in coming up with the TPACK-M-US instrument.

Secondly, although this study found positive correlation between math teachers' participation in informal learning (learning through media, colleague interaction, stakeholder interaction, and media) and their TPACK self-efficacies (CK, TK, PK, TPACK), a cause-and-effect relationship could not be established for all the variables concerned. Future research can explore the use of more robust techniques in exploring possible relationships between teachers' participation in informal learning and outcome variables. For example, Huang et al. (2020)

explored relationships between five different kinds of informal teacher learning activities (learning through media, colleague interaction, stakeholder interaction, student interaction, and individual reflection) and teacher emotion.

Furthermore, teachers' TPACK efficacies were used as proxy for teacher knowledge. Subsequent research can explore other measures or proxies of teacher knowledge. This study is also based on self-reported data. Subsequent research can incorporate elements of observation. Although Huang et al. (2020) suggests that teachers also learn from their interactions with students, this study did not specifically capture the role students in teachers' informal learning. Future research can extend this work by paying attention to the effects of interaction with students.

This study found no significant difference between teachers' participation in informal learning activities based on career stage. However, results from studies of teacher learning based on career stage suggest possible changes in teachers' motivation and attitude at different career stages (Kyndt et al., 2016). Thus, there is a need for more studies that capture possible differences based on career stage and other relevant factors such as gender and leadership roles. This study is unique in a sense because it focuses specifically on the experiences of math teachers. Studies of teacher informal learning more often than not, tend to focus on multiple subject areas. To relate some of the findings from these general studies specifically to math teachers, there is a need for more studies that specifically capture the experiences of math teachers.

Finally, considering that this is the first study (as far as I know) that explored possible relationships between teachers' participation in informal learning activities and their TPACK self-efficacies, there is a need for additional studies to consolidate the results. Furthermore, this

study is based on the experiences of math teachers with a temporary or permanent teaching certificate. As such, there is a need for studies that will capture the experiences of teachers, their certification status notwithstanding.

REFERENCES

- Akiba, M. (2012). Professional learning activities in context: A state-wide survey of middle school mathematics teachers. *Education Policy Analysis Archives*.
- Akiba, M., & Liang, G. (2016). Effects of teacher professional learning activities on student achievement growth. *The Journal of Educational Research*, 109(1), 99-110.
- Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish journal of emergency medicine*, 18(3), 91-93.
- Alexopoulos, E. C. (2010). Introduction to multivariate regression analysis. *Hippokratia*, 14(Suppl 1), 23.
- Anderson, R. K. (2019). *Professional Development Across Communities: Investigating Teacher Learning Networks Online and Beyond*. Stanford University.
- Appova, A. K. (2009). Teacher opportunities to learn: responses and recommendations of grades 6-12 mathematics teachers from one district (Doctoral dissertation, University of Missouri--Columbia).
- Bandura, A. (1997). *Self-efficacy: The Exercise of Control*. New York, NY: Freeman.
- Bexheti, L. A., Ismaili, B. E., & Cico, B. H. (2014, March). An analysis of social media usage in teaching and learning: The case of SEEU. In *Proceedings of the 2014 International Conference on Circuits, Systems, Signal Processing, Communications and Computers* (pp. 90-94).
- Bill & Melinda Gates Foundation. (2014). *Teachers Know Best: Teachers' Views on Professional Development*. ERIC Clearinghouse.
- Billett, S. (2004). Workplace participatory practices: Conceptualising workplaces as learning environments. *Journal of workplace learning*, 16(6), 312-324.

- Boston Consulting Group (2014), Teachers know best: Teachers' views on professional development, report commissioned by The Bill & Melinda Gates Foundation, Seattle, WA.
- Carpenter, J. P., & Linton, J. N. (2016). Educators' perspectives on the impact of Edcamp unconference professional learning. *Teaching and Teacher Education, 73*, 56-69.
- Cofer, D. A. (2000). Informal workplace learning. Retrieved June 16, 2005, from <http://www.cete.org/acve/docs/pab00019.pdf>
- Cox, S. (2008). A conceptual analysis of technological pedagogical content knowledge. Doctoral Dissertation, Brigham Young University, Provo, UT.
- Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into practice, 39*(3), 124-130.
- Cseh, M. (1998). *Managerial learning in the transition to a free market economy in Romanian private companies*. University of Georgia.
- Darling-Hammond, L., Hyler, M. E., Gardner, M. (2017). Effective teacher professional development. Palo Alto, CA: Learning Policy Institute.
- Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational researcher, 38*(3), 181-199.
- Desimone, L. M. (2011). A primer on effective professional development. *Phi delta kappan, 92*(6), 68-71.
- DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2011). Developing and using a codebook for the analysis of interview data: An example from a professional development research project. *Field Methods, 23*(2), 136-155.
<http://doi.org/10.1177/1525822X10388468>.

- DeVellis, R. F. (2011). *Scaled development: Theory and applications*. Thousand Oaks, CA: Sage Publications.
- Guskey, T.R. (2000). *Evaluating professional development*. Thousand Oaks, CA: Corwin Press.
- Hervey, L. G. (2015). Between the notion and the act: Veteran teachers' TPACK and practice in 1: 1 settings. In *Technological pedagogical content knowledge* (pp. 165-189). Springer, Boston, MA.
- Hightower, A. M., Delgado, R. C., Lloyd, S. C., Wittenstein, R., Sellers, K., & Swanson, C. B. (2011). Improving student learning by supporting quality teaching. *Retrieved on, 3, 14*.
- Hill, J. E., & Uribe-Florez, L. (2020). Understanding Secondary School Teachers' TPACK and Technology Implementation in Mathematics Classrooms. *International Journal of Technology in Education, 3*(1), 1-13.
- Hoekstra, A., Brekelmans, M., Beijaard, D., & Korthagen, F. (2009). Experienced teachers' informal learning: Learning activities and changes in behavior and cognition. *Teaching and teacher education, 25*(5), 663-673.
- Huang, X., Lee, J. C. K., & Frenzel, A. C. (2020). Striving to become a better teacher: linking teacher emotions with informal teacher learning across the teaching career. *Frontiers in psychology, 11*, 1067.
- Huang, Y., & Bentler, P. M. (2015). Behavior of asymptotically distribution free test statistics in covariance versus correlation structure analysis. *Structural Equation Modeling: A Multidisciplinary Journal, 22*(4), 489-503.
- Hunter, L. J., & Hall, C. M. (2018). A survey of K-12 teachers' utilization of social networks as a professional resource. *Education and Information Technologies, 23*, 633-658.

- Jacobs, R. L., & Park, Y. (2009). A proposed conceptual framework of workplace learning: Implications for theory development and research in human resource development. *Human Resource Development Review*, 8(2), 133–150.
<https://doi.org/10.1177/1534484309334269>.
- Jeong, S., Han, S. J., Lee, J., Sunalai, S., & Yoon, S. W. (2018). Integrative Literature Review on the Antecedents of Informal Learning in the Workplace: A Conceptual Framework for Future Research. *Human Resource Development Review*.
- Jones, W. M., & Dexter, S. (2014). How teachers learn: The roles of formal, informal, and independent learning. *Educational Technology Research and Development*, 62(3), 367-384.
- Jurasaitė-Harbison, E., & Rex, L. A. (2010). School cultures as contexts for informal teacher learning. *Teaching and teacher education*, 26(2), 267-277.
- Kyndt, E., Gijbels, D., Grosemans, I., & Donche, V. (2016). Teachers' everyday professional development: Mapping informal learning activities, antecedents, and learning outcomes. *Review of educational research*, 86(4), 1111-1150.
- Lecat, A., Spaltman, Y., Beusaert, S., Raemdonck, I., & Kyndt, E. (2020). Two decennia of research on teachers' informal learning: A literature review on definitions and measures. *Educational Research Review*, 30, 100324.
- Lehtinen, A., Nieminen, P., & Viiri, J. (2016). Preservice teachers' TPACK beliefs and attitudes toward simulations. *Contemporary Issues in Technology and Teacher Education*, 16(2), 151-171.
- Liljedahl, P. (2020). *Building thinking classrooms in mathematics, grades K-12: 14 teaching practices for enhancing learning*. Corwin press.

- Little, J. W., Gearhart, M., Curry, M., & Kafka, J. (2003). Looking at student work for teacher learning, teacher community, and school reform. *Phi delta kappan*, 85(3), 184-192.
- Lohman, M. C. (2005). A survey of factors influencing the engagement of two professional groups in informal workplace learning activities. *Human Resource Development Quarterly*, 16(4), 501–527.
- Louws, M. L., Meirink, J. A., Van Veen, K., and Van Driel, J. H. (2017). Teachers' self-directed learning and teaching experience: What, how, and why teachers want to learn. *Teach. Educ.* 66, 171–183. doi: 10.1016/j.tate.2017.04.004.
- Macià, M., & García, I. (2016). Informal online communities and networks as a source of teacher professional development: A review. *Teaching and teacher education*, 55, 291-307.
- Mannix, J.P. (2022). Exploring characteristics and experiences of secondary mathematics teachers with math anxiety. [Unpublished doctoral proposal]. North Carolina State University.
- Marsick, V. J., & Watkins, K. E. (2001). Informal and incidental learning. *New directions for adult and continuing education*, 2001(89), 25-34.
- Marsick, V. J., & Watkins, K. (2015). *Informal and incidental learning in the workplace (Routledge Revivals)*. Routledge.
- Martin, W., Strother, S., Beglau, M., Bates, L., Reitzes, T., & McMillan Culp, K. (2010). Connecting instructional technology professional development to teacher and student outcomes. *Journal of research on technology in education*, 43(1), 53-74.
- Mayring, P. (2015). Qualitative content analysis: Theoretical background and procedures. *Approaches to qualitative research in mathematics education: Examples of methodology and methods*, 365-380.

- McNally, J., Blake, A., & Reid, A. (2009). The informal learning of new teachers in school. *Journal of workplace learning*, 21(4), 322-333.
- MDR Marketing Team (2018, November 6). We asked teachers about their social media use. Some of their answers surprised us. MDR
- Mishra, P., & Koehler, M. J. (2008, March). Introducing technological pedagogical content knowledge. In *annual meeting of the American Educational Research Association* (pp. 1-16).
- Noe, R. A., Tews, M. J., & Marand, A. D. (2013). Individual differences and informal learning in the workplace. *Journal of vocational behavior*, 83(3), 327-335.
- Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. *Review of educational research*, 81(3), 376-407.
- Orlando, J. (2014). Veteran teachers and technology: Change fatigue and knowledge insecurity influence practice. *Teachers and Teaching*, 20(4), 427-439.
- Richter, D., Kunter, M., Klusmann, U., Lüdtke, O., & Baumert, J. (2014). Professional development across the teaching career: Teachers' uptake of formal and informal learning opportunities. In *Teachers' professional development* (pp. 97-121). Brill Sense.
- Schmidt, K., Köhler, A., & Moldenhauer, W. (2009). Introducing a Computer Algebra System in Mathematics Education--Empirical Evidence from Germany. *International Journal for Technology in Mathematics Education*, 16(1).
- Scribner, J. P. (1999). Professional development: Untangling the influence of work context on teacher learning. *Educational Administration Quarterly*, 35(2) 238-266.

- Slama, R., Moussapour, R. M., Benoit, G., Anderson, N., & Reich, J. (2021). The Future of Math Teacher Professional Learning.
- Sleeter, C. (2014). Toward teacher education research that informs policy. *Educational Researcher*, 43(3), 146-153.
- Snyder, Richard R. "Resistance to Change among Veteran Teachers: Providing Voice for More Effective Engagement." *International Journal of Educational Leadership Preparation* 12.1 (2017): n1.
- Sowder, J. (2007). The mathematical education and development of teachers. In F.K. Lester (Eds.), *Second handbook of research on mathematics teaching and learning* (pp. 157-225). Charlotte, NC: Information Age Publishing.
- Stake, R. E. (2005). Qualitative case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *The sage handbook of qualitative research* (3rd Edition) (pp. 443-466). Thousand Oaks, CA: Sage Publications, Inc
- Trust, T. (2017). Motivation, Empowerment, and Innovation: Teachers' Beliefs About How Participating in the Edmodo Math Subject Community Shapes Teaching and Learning. *Journal of Research on Technology in Education*, 49(1-2), 16-30.
- Villegas-Reimers, E. (2003). *Teacher professional development: an international review of the literature*. Paris: International Institute for Educational Planning.
- Watkins, K. E., & Marsick, V. J. (1992). Towards a theory of informal and incidental learning in organizations. *International journal of lifelong education*, 11(4), 287-300.
- Wei, R. C., Darling-Hammond, L., Andree, A., Richardson, N., & Orphanos, S. (2009). Professional learning in the learning profession. *A status report on teacher development in the United States and Abroad*. Dallas, Tx: National Staff Development Council.

- White, D., Donaldson, B., Hodge, A., & Ruff, A. (2013). Examining the Effects of Math Teachers' Circles on Aspects of Teachers' Mathematical Knowledge for Teaching. *International Journal for Mathematics Teaching & Learning*.
- Wu, H., & Leung, S. O. (2017). Can Likert scales be treated as interval scales? - A Simulation study. *Journal of Social Service Research*, 43(4), 527-532.
- Yoon, K. S., Duncan, T., Lee, S. W. Y., Scarloss, B., & Shapley, K. L. (2007). Reviewing the evidence on how teacher professional development affects student achievement. issues & answers. rel 2007-no. 033. *Regional Educational Laboratory Southwest (NJ1)*.
- Zelkowski, J., Gleason, J., Cox, D. C., & Bismarck, S. (2013). Developing and validating a reliable TPACK instrument for secondary mathematics preservice teachers. *Journal of Research on Technology in Education*, 46(2), 173-206.

APPENDICES

Appendix A

Main Study Survey

Start of Block: Consent

You are being asked to complete a survey for research purposes. The survey is about math teachers' perceptions of informal learning. Completing this survey is voluntary and you can stop at any time by closing the browser tab.

You must be 18 years of age or older, reside in the United States, and be a current teacher of middle or high school mathematics in the United States to participate in this study.

There are minimal risks associated with your participation in this survey. If you are willing to participate in two paid but optional one-hour follow-up interview sessions and a short five-minute micro-survey (to be completed each workday over a two-weeks period after the first interview) about your perceptions and experiences of informal learning, you will be required to provide your email address at the end of this survey.

If you choose to participate in the follow-up interviews and five-minute micro-survey, you will receive a 75 dollars Amazon Gift card for your time commitment.

If you have any questions about this survey, how it is implemented, or survey compensation, please contact Jerome Amedu at jzamedu@ncsu.edu. His Phone number is 984-242-8284. You may also contact his supervisor, Dr Karen Hollebrands at 919-513-0505 or kfholleb@ncsu.edu. Please reference study number 24971 when contacting anyone about this project.

Also, if you have questions about your rights as a participant or are concerned with your treatment throughout the research process, please contact the NC State University IRB Director at IRB-Director@ncsu.edu, 919-515-8754, or fill out this confidential form online. If you consent to complete this survey, please click Yes on question 1 below.

Q1 1. After reading the consent form above, do you consent to participate in this study?

- Yes (1)
- No (2)

Skip To: End of Survey If 1. After reading the consent form above, do you consent to participate in this study? = No

Q2 2. Are you a middle or high school math teacher here in the United States of America?

- Yes (1)
- No (2)

Skip To: End of Survey If 2. Are you a middle or high school math teacher here in the United States of America? = No

Page Break

Demographic information. Please answer the following questions about your academic background and experiences.

Q3 3. What level of mathematics do you teach?

- Middle school (Grades 6-8) (1)
 - High school (Grades 9-12) (2)
-

Q4 4. Which of the following best describes you in terms of your teaching experience?

- Beginning teacher (0-5 years) (1)
 - Mid-career teacher (6-15 years) (2)
 - Experienced teacher (16 years or more) (3)
-

Q5 5. What is your gender?

- Male (1)
 - Female (2)
 - Prefer not to say (3)
 - Others (Please specify) (4) _____
-

Q6 6. Please indicate your highest level of education.

- Bachelor's degree (1)
 - Master's degree (2)
 - Specialist/Doctoral degree (3)
 - Others (Please specify) (4) _____
-

Q7 7. Please indicate your degree major.

- Mathematics Education (1)
 - Mathematics (2)
 - Others (Please specify) (3) _____
-

Q8 8. Please indicate your teaching certificate type.

- Permanent (1)
 - Temporary (2)
-

Q9 9. Which of the following best represents the region of the United States where the State you teach in is located?

- West (1)
 - Northeast (2)
 - Midwest (3)
 - Southwest (4)
 - Southeast (5)
 - Very well (6)
-

Q10 Technology is a broad concept that can mean a lot of different things. For the purpose of this questionnaire, technology is referring to digital technology/technologies—that is, the digital tools we use, such as computers, laptops, iPods, handhelds, interactive whiteboards, computer software programs, graphing calculators, etc.

Q11 Respond to the following prompts using the five-point scale where 1 means 'strongly disagree' and 5 means 'strongly agree.'

	1 (Strongly disagree) (1)	2 (Disagree) (2)	3 (Neither agree nor disagree) (3)	4 (Agree) (4)	5 (Strongly agree) (5)
10. I know how to solve my own technical problems (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I can learn technology easily (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I keep up with important new technologies (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I frequently play around with technology (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I know about a lot of different technologies (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I have the technical skills I need to use technology (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I have sufficient knowledge about mathematics (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. I have various strategies for developing my understanding of mathematics.
(8)

18. I know about various examples of how mathematics applies in the real world (9)

19. I have a deep and wide understanding of algebra
(10)

20. I have a deep and wide understanding of geometry
(11)

Q28 Respond to the following prompts using the five-point scale where 1 means 'strongly disagree' and 5 means 'strongly agree.'

	1 (Strongly disagree) (1)	2 (Disagree) (2)	3 (Neither agree nor disagree) (3)	4 (Agree) (4)	5 (Strongly agree) (5)
10. I know how to solve my own technical problems (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I can learn technology easily (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I keep up with important new technologies (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I frequently play around with technology (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I know about a lot of different technologies (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I have the technical skills I need to use technology (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I have sufficient knowledge about mathematics (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. I have various strategies for developing my understanding of mathematics.
(8)

18. I know about various examples of how mathematics applies in the real world (9)

19. I have a deep and wide understanding of algebra
(10)

20. I have a deep and wide understanding of geometry
(11)

Q27 Respond to the following prompts using the five-point scale where 1 means 'strongly disagree' and 5 means 'strongly agree.'

	1 (Strongly disagree) (1)	2 (Disagree) (2)	3 (Neither agree nor disagree) (3)	4 (Agree) (4)	5 (Strongly agree) (5)
10. I know how to solve my own technical problems (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I can learn technology easily (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I keep up with important new technologies (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I frequently play around with technology (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I know about a lot of different technologies (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I have the technical skills I need to use technology (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I have sufficient knowledge about mathematics (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. I have various strategies for developing my understanding of mathematics. (8)

18. I know about various examples of how mathematics applies in the real world (9)

19. I have a deep and wide understanding of algebra (10)

20. I have a deep and wide understanding of geometry (11)

Q25 Respond to the following prompts using the five-point scale where 1 means 'strongly disagree' and 5 means 'strongly agree.'

	1 (Strongly disagree) (1)	2 (Disagree) (2)	3 (Neither agree nor disagree) (3)	4 (Agree) (4)	5 (Strongly agree) (5)
10. I know how to solve my own technical problems (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I can learn technology easily (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I keep up with important new technologies (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I frequently play around with technology (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I know about a lot of different technologies (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I have the technical skills I need to use technology (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I have sufficient knowledge about mathematics (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. I have various strategies for developing my understanding of mathematics.
(8)

18. I know about various examples of how mathematics applies in the real world (9)

19. I have a deep and wide understanding of algebra
(10)

20. I have a deep and wide understanding of geometry
(11)

Q26 Respond to the following prompts using the five-point scale where 1 means 'strongly disagree' and 5 means 'strongly agree.'

	1 (Strongly disagree) (1)	2 (Disagree) (2)	3 (Neither agree nor disagree) (3)	4 (Agree) (4)	5 (Strongly agree) (5)
10. I know how to solve my own technical problems (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I can learn technology easily (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I keep up with important new technologies (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I frequently play around with technology (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I know about a lot of different technologies (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I have the technical skills I need to use technology (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I have sufficient knowledge about mathematics (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. I have various strategies for developing my understanding of mathematics.
(8)

18. I know about various examples of how mathematics applies in the real world (9)

19. I have a deep and wide understanding of algebra
(10)

20. I have a deep and wide understanding of geometry
(11)

Q29 Respond to the following prompts using the five-point scale where 1 means 'strongly disagree' and 5 means 'strongly agree.'

	1 (Strongly disagree) (1)	2 (Disagree) (2)	3 (Neither agree nor disagree) (3)	4 (Agree) (4)	5 (Strongly agree) (5)
10. I know how to solve my own technical problems (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
11. I can learn technology easily (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
12. I keep up with important new technologies (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
13. I frequently play around with technology (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
14. I know about a lot of different technologies (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
15. I have the technical skills I need to use technology (6)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
16. I have sufficient knowledge about mathematics (7)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

17. I have various strategies for developing my understanding of mathematics.
(8)

18. I know about various examples of how mathematics applies in the real world (9)

19. I have a deep and wide understanding of algebra
(10)

20. I have a deep and wide understanding of geometry
(11)

Q12 Respond to the following prompts using the five-point scale where 1 means 'strongly disagree' and 5 means 'strongly agree.'

	1 (Strongly disagree) (1)	2 (Disagree) (2)	3 (Neither agree nor disagree) (3)	4 (Agree) (4)	5 (Strongly agree) (5)
21. I know how to assess student performance in a classroom (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
22. I can adapt my teaching based upon what students currently understand or do not understand (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
23. I can adapt my teaching style to different learners (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
24. I can assess student learning in multiple ways (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
25. I can use a wide range of teaching approaches in a classroom setting (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

26. I can use strategies that combine mathematics, technologies, and teaching approaches in my classroom
(6)

27. I can choose technologies that enhance mathematics for a lesson
(7)

28. I can select technologies to use in my classroom that enhance what I teach, how I teach, and what students learn
(8)

29. I can teach lessons that appropriately combine mathematics, technologies, and teaching approaches
(9)

30. I can teach lessons that appropriately combine geometry, technologies, and teaching approaches (10)

31. I can teach lessons that appropriately combine algebra, technologies, and teaching approaches (11)

Q24 Informal learning is any form of teacher-led, unstructured, or unplanned activities (e.g., interacting with **colleagues**, connecting with educators on **social media**, reading journals, etc.) that teachers intentionally or unconsciously engage in to acquire knowledge and skills related to their practice.

Q13 Please indicate your frequency of engaging in the following informal learning activities **over the last 6 months** by choosing never (1), rarely (2), sometimes (3), often (4), or always (5).

Q13 In the past 6 months,	1 (Never) (1)	2 (Rarely) (2)	3 (Sometimes) (3)	4 (Often) (4)	5 (Always) (5)
32. I have browsed educational materials (e.g., educational papers or reports) on the internet (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
33. I have browsed teaching materials (e.g., lesson plans, videos of public lessons) on the internet (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
34. I have read education-related posts on social media platforms such as Facebook, Quora, etc. (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
35. I have read hard-copy educational materials (e.g., teaching reference books, journals) (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

36. I have sought out materials (e.g., newspapers, movies) that could provoke me to think about education (5)

37. I have communicated with my colleagues about curricula and teaching (6)

38. I have communicated with my colleagues about student learning (7)

39. I have communicated with my colleagues about teaching problems (8)

40. When my teaching has not met my expectations, I have considered possible reasons why (9)

41. I have thought about or learned from my teaching successes (10)

42. I have thought about how to continue to improve my teaching (11)

Q14 In the past 6 months,

	1 (Never) (1)	2 (Rarely) (2)	3 (Sometimes) (3)	4 (Often) (4)	5 (Always) (5)
43. I have communicated with parents about educational issues (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
44. I have communicated with my family or friends about educational issues (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
45. I have discussed educational issues in online communities (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
46. I have communicated with university scholars about educational issues (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q15 47. Please give examples of the informal learning activities that you engage in as a teacher and describe how engaging in any of these informal learning activities have contributed to your professional learning or practice (possible areas of professional learning include math content knowledge, teaching practices, use of technology in the classroom, etc)?

Q16 48. Based on your personal experiences or the experience of teachers in your school, please describe some factors that support or hinder teachers' informal learning in the school?

Q17 49. Are you interested in participating in two sessions of **paid** optional interviews via zoom and completing a number of short 5-minute surveys of your continual informal learning experiences?

- Yes (1)
- No (2)

Skip To: End of Survey If 49. Are you interested in participating in two sessions of paid optional interviews via zoom and... = No

Q18 50. What is your email address?

Q19 51. What is your preferred first and last name?

End of Block: Consent

Appendix B

Semi-structured Interview Protocol

Before you start video-recording

1. Introduce myself.
2. Thank participants for accepting to participate in your study and ask how they feel today and if they have any questions before the interview.
3. Remind them of their rights to stop the interview, to not answer a particular question, and that they are going to be audio-recorded as was specified in the recruitment email.

Start video-recording

1. How long have you been teaching? What grade level do you teach?
2. Let's start with your perceptions and experience of teaching with technology
 - a. Do you use technology in your teaching?
 - b. If no, why not? If yes, what types of technologies do you use in your classroom?
 - c. How do you learn about new technologies and how to use them?
 - d. What are your views about how and when technology should be used in teaching math
 - e. Tell me a little about the expectations of administration and colleagues to use technology in your classroom.
3. Tell me about your informal learning experiences.
 - a. Do you find the PD workshops or formal professional development opportunities you have had useful for improving your knowledge of math content, using technology, and teaching in general? If no, how do you make up for possible gaps in your knowledge in these areas?

- b. Apart from attending professional development workshops, how do you continue to learn about math content, technology or just teaching in general?
 - c. Tell me about people within or outside your school that you discuss issues related to your teaching with? (This could be students, teacher colleagues, parents, etc)
 - d. Do you find such interactions useful for your own professional learning? If so, can you give specific examples of how such conversations have contributed to your teaching (including your content knowledge and use of technology in the classroom)?
 - e. Do you use social media, e.g., Facebook, Twitter, YouTube? Do you find social media useful for your professional learning in the areas of content, use of technology and teaching?
 - f. At the individual level, what type of learning activities do you engage in on your own to continue learning?
 - g. What has been the most significant learning experience(s) that you have had at this school? That you have had as a professional educator?
4. Tell me about your perceptions of informal learning.
- a. Are there specific views or beliefs you have about learning stuff on your own, from others, or from social media?
 - b. Do you have any thoughts about learning informally (learning on your own or through interaction with others) versus learning from formal professional development?
 - c. When you take your school setting into consideration, are there issues or factors that you know of that support or hinder your informal learning or that of others? If

you could change a few things to make it easier for teachers at your school to learn from each other, what might that be?

- d. What personal factors or characteristics support or hinder your informal learning?

What other factors do you know of that support or hinder teachers' informal learning?

- e. What other ways would you say informal learning (could be individual, in-person or online) has affected or contributed to your learning and practice as a teacher?

5. Is there anything else you would like to share?

Thank you again for your participation!

END recording

Appendix C

Mini survey (for participants' survey-based journaling)

Start of Block: Default Question Block

Demographics inform. This mini survey is meant to capture your daily informal learning experiences both within and outside the school environment. Please answer the following questions:

Q1 1. Who did you talk to today about issues related to teaching mathematics?

- Colleague(s) (1)
 - Persons outside your school setting (family, friends, students' parents, educators in online communities e.g., Facebook, Twitter) (7)
 - Others (please specify) (8) _____
 - I did not talk to anyone today about teaching mathematics (9)
-

Display This Question:

If 1. Who did you talk to today about issues related to teaching mathematics? = Colleague(s)

Q2 What topic(s) did you discuss with your colleague(s)?

- Assessment practices (1)
 - Facilitating classroom discussions (2)
 - Scope & sequence of your subject Classroom management (3)
 - Mathematical content knowledge (4)
 - Interpreting student work (5)
 - Unit/lesson design (plans, tasks, activities, etc.) (6)
 - Group work strategies (7)
 - Math games (8)
 - Strategies for interacting with stakeholders (parents, community, administration, etc.) (9)
 - Technology ideas (10)
 - Supporting second language learners (11)
 - Grading practices (12)
 - Supporting students with special needs (13)
 - Classroom routines (14)
 - Questioning (15)
 - Mindset/Brain science (16)
 - Others (please specify) (17)
-

Display This Question:

If 1. Who did you talk to today about issues related to teaching mathematics? = Colleague(s)

Q3 Please provide any details on the interaction with your colleague(s) that would help researchers understand the learning opportunity (This question is optional and provided just in case you want to share more).

Display This Question:

If 1. Who did you talk to today about issues related to teaching mathematics? = Colleague(s)

Q4 How useful was your interaction with your colleague(s)?

- Extremely useful (2)
- Moderately useful (4)
- Slightly useful (3)
- Neither useful nor useless (6)
- Slightly useless (7)

Display This Question:

If 1. Who did you talk to today about issues related to teaching mathematics? = Persons outside your school setting (family, friends, students' parents, educators in online communities e.g ,Facebook, Twitter)

Q5 What topic(s) did you discuss with persons outside your school setting (family, friends, students' parents, educators in online communities e.g., Facebook, Twitter) today?

- Assessment practices (1)
- Facilitating classroom discussions (18)
- Scope & sequence of your subject (19)
- Classroom management (20)
- Mathematical content knowledge (21)
- Interpreting student work (22)
- Unit/lesson design (plans, tasks, activities, etc.) (23)
- Group work strategies (24)
- Math games (25)
- Strategies for interacting with stakeholders (parents, community, administration, etc.) (26)
- Technology ideas (27)
- Supporting second language learners (28)
- Grading practices (29)
- Supporting students with special needs (30)
- Classroom routines (31)
- Questioning (32)
- Mindset/Brain science (33)

Other (please specify) (34) _____

Display This Question:

If 1. Who did you talk to today about issues related to teaching mathematics? = Persons outside your school setting (family, friends, students' parents, educators in online communities e.g., Facebook, Twitter)

Q6 Please provide any details on your interaction with persons outside your school setting that would help researchers understand the learning opportunity (This question is optional and provided just in case you want to share more)

Display This Question:

If 1. Who did you talk to today about issues related to teaching mathematics? = Persons outside your school setting (family, friends, students' parents, educators in online communities e.g., Facebook, Twitter)

Q7 How useful was your interaction with persons outside your school setting (family, friends, students' parents, educators in online communities e.g., Facebook, Twitter)?

- Extremely useful (1)
- Moderately useful (5)
- Slightly useful (6)
- Neither useful nor useless (7)
- Slightly useless (8)

Q8 What did you reference today about teaching mathematics?

- Books/journals/newsletters (1)
- University course/online MOOC (4)
- Website (wolfram-alpha, teachers-pay-teachers, Desmos, curriculum website). Please specify website name(s) (5) _____
- Online networking community (Facebook, Twitter, Pinterest, etc.). Please specify social media provider (e.g., Facebook) (6)

- I did not reference anything today about teaching mathematics (7)

Display This Question:

If What did you reference today about teaching mathematics? I did not reference anything today about teaching mathematic

Q9 Please provide any details on the resources you referenced that would help researchers understand the learning opportunity (This question is optional and provided just in case you want to share more)

Display This Question:

If What did you reference today about teaching mathematics? I did not reference anything today about teaching mathematics

Q10 How useful was the resource you referenced?

- Extremely useful (1)
 - Moderately useful (4)
 - Slightly useful (5)
 - Neither useful nor useless (6)
 - Slightly useless (7)
-

Display This Question:

If 1. Who did you talk to today about issues related to teaching mathematics? = Others (please specify)

Q12 How useful did you find your interaction with the other persons you talked with today?

- Extremely useful (1)
 - Moderately useful (4)
 - Slightly useful (5)
 - Neither useful nor useless (6)
 - Slightly useless (7)
-

Q13 Please write your name below. This is just to help differentiate your responses from others.

End of Block: Default Question Block

Appendix D

Email for Member-checking

Good morning.

I hope you are having a good weekend.

Thank you so much for your help once again. I am reaching out for two main reasons:

1. I wanted to double-check that your gift card has been sent. I have already forwarded your details to the research office.
2. As part of the research process, I am sharing transcripts of our conversation with you. This is to allow you a chance to double-check that I have correctly captured what you shared with me. It can also be an opportunity to point out anything you may not feel comfortable about me reporting. I doubt this applies in your case but feel free. In any case, there is no way the data can be traced to you because none of your personal details will appear in my report.

I have attached transcripts of our interview. You don't have to spend time on them, just briefly skim through. It's totally fine if you are not able to do that because of time constraints. Please find the transcripts attached and let me know if you have any questions or concerns.

Have a great weekend.

Regards,

Jerome

Graduate Teaching Assistant

Science, Technology, Engineering and Mathematics (STEM) Department

NCSU

Appendix E

Coding scheme for factors affecting informal learning

Category	Sub-category	Example Quotes
<p><u>Personal factors</u></p> <p>refers to issues that could affect informal learning at the individual level. These are specific to the teacher as a person or individual</p>	<p><u>Teacher characteristics:</u> attributes of individual teachers as they relate to their informal learning engagements or experiences (e.g., teaching experience, age)</p>	<p><i>I find many veteran teachers are less willing to try new things. They have "always done it this way and it works for me" and when I suggest new ideas, it's always "that won't work on our kids" even though it does.</i></p>
	<p><u>Teacher attitude:</u> teachers' way of thinking or feeling about informal learning activities and/or issues related to informal learning (e.g., interest or willingness to learn, resistance to change)</p>	<p><i>Teachers may have a disinterest in bettering themselves or commitment to education. Many of my colleagues do not want extra work or to change what they do.</i></p>
	<p><u>Knowledge:</u> refers to the skills, facts, experiences, and information related to informal learning that teachers possess</p>	<p><i>I think there are many teachers who don't realize the value of social media when it comes to improving as a teacher. They might use FB, for example, but only to connect to family and friends - and not realize the immense opportunities that are offered.</i></p>
	<p><u>Perception:</u> views, beliefs, and opinions about teaching and learning (e.g., teaching philosophy) as they affect teachers' experiences of informal learning</p>	<p><i>Lack of time, different philosophy about teaching sometimes hinders general conversation or interest in learning about new research-based strategies...</i></p>
	<p><u>Time (personal):</u> refers to issues bordering on personal commitments outside school hours that affect time available for informal learning</p>	<p><i>Time, of course and "brain space." Teaching takes so much brain power, I often save a lot of articles to read over the summer because I am so tired at the end of the day.</i></p>

Appendix E (Continued)

	<p><u>Teacher burnout:</u> Issues related to stress due to unrelenting work demands</p>	<p><i>Lack of Time and high stress level are two factors that hinder informal learning.</i></p>
<p>Interpersonal/group level factors issues related to teacher interaction, rapport, or collegiality within a school either at the individual (teacher to teacher) or group level as they affect teachers' informal learning experiences</p>	<p><u>Admin Attitude:</u> issues bordering on how the attitude of school leaders or administrators support or hinder teachers' opportunities for and/or experience of informal learning</p>	<p><i>I think it is key to have a supportive administration as well as at least one colleague (not necessarily in your building / district) that is willing to share the load and talk math. Without my administration and colleagues, I would not have been able to coordinate the conferences and meetups I've been involved in.</i></p>
	<p><u>Networking:</u> Issues related to interaction with teachers and other educators outside one's school or social media (e.g., Facebook).</p>	<p><i>I teach at a small private school, and so have fewer opportunities to learn and share with my colleagues. I rely on learning networks outside of my school for more varied input.</i></p>
	<p><u>Teacher collaboration & support:</u> refers to issues around teachers' interpersonal relationship with each other, collegiality, willingness to relate, support, and collaborate etc.</p>	<p><i>If teachers do not work well with their grade level teachers that can prohibit informal learning. Also if teachers are not feeling supported within a building they tend to withdraw and not learn</i></p>
<p>School-level factors refers to broader organizational level (cultural, institutionalized, and systemic) issues that affect informal learning</p>	<p><u>School features:</u> refers to factors such as school size, school location, buildings, and other school attributes which affect opportunities for informal learning</p>	<p><i>Our school is tiny so we all know each other and know all the students. We interact casually all the time.</i></p>

Appendix E (Continued)

	<p><u>Work tools and Resources:</u></p> <p>This relates to issues of access or the lack to resources such as internet access and books that support teacher informal learning</p>	<p><i>Rural communities in my area may not have access to internet or wifi to participate in online settings due to geographical pitfalls. For example, my personal Wi-Fi is very limited because I live in a rocky and heavy tree populated area with a small number of data towers so data signal of any kind is weak.</i></p>
	<p><u>Time:</u></p> <p>issues bordering on the amount of time teachers expend in carrying out their job duties and how that may affect their informal learning experiences</p>	<p><i>Lack of time, too much paperwork or non-teaching duties.</i></p>
	<p><u>School Policy/Practices/Culture:</u></p> <p>refers to issues related to school policy, practices or way of doing things as they affect informal learning</p>	<p><i>Most (referring to teachers) do not have the opportunity to visit outside of their own classroom and many are hesitant to have others come visit because they fear administrators are actually evaluating them</i></p>
	<p><u>Teacher Workload:</u></p> <p>Issues around the amount of work teachers have to complete in their day to day activities. This may or may not be directed connected to their primary role</p>	<p><i>Lack of time, too much paperwork or non-teaching duties</i></p>

Appendix F

Coding Scheme for Effects/Contributions of Informal learning

Category	Sub-category	Example Quotes
<p><u>Content Knowledge</u> contributions/effects of informal learning related to subject matter knowledge (mathematics) and related issues</p>	<p><u>Math content knowledge:</u> Focused on contributions to knowledge of math content</p>	<p><i>Speaking with colleagues, online groups...interacting with colleagues and these groups has grown my math content knowledge</i></p>
	<p><u>Curriculum and standards:</u> Captured contributions to math curriculum/standards, vertical alignment, etc.</p>	<p><i>Visiting (going to observe colleagues) has given me an opportunity to understand more about how and what my students at levels below and above my classroom</i></p>
<p><u>Pedagogical Knowledge</u> contributions/effects of informal learning related to pedagogy and related issues</p>	<p><u>Teaching ideas and strategies:</u> Focused on contributions to teaching practices</p>	<p><i>Talking with colleagues from other schools, I learn a lot about how they teach concepts that I struggle to teach</i></p>
	<p><u>Grading practices:</u> Captured contributions to issues related to grading and student assessment</p>	<p><i>Through informal learning, I have adopted... more equitable grading practices.</i></p>
	<p><u>Lesson planning:</u> contributions related to planning/developing lessons</p>	<p><i>I recently bought a book about planning effective and engaging math lessons...it helped me tweak my lesson planning.</i></p>

Appendix F (Continued)

	<p><u>Classroom management:</u> contributions relevant to managing student behavior and related issues</p>	<p><i>I participate in a number of teacher groups on Facebook...through these groups, I have learnt about various methods of classroom management</i></p>
<p><u>Technological Knowledge</u> contributions/effects of informal learning related to subject matter knowledge (mathematics) and related issues</p>	<p><u>Tech tools and ideas:</u> Contributions to ideas for tech tools. This is strictly at the level of ideas or knowledge</p>	<p><i>I've really gotten a lot of ideas from the Desmos group on Facebook</i></p>
	<p><u>Technology implementation:</u> This sub-category captures contributions related to actual implementation of technology in the classroom</p>	<p><i>Through informal learning, I have adopted...desmos integration, Geogebra integration...</i></p>
<p><u>Support for practice</u> This category focuses on contributions of informal learning that touch on issues of practice and learning not captured by previous categories</p>	<p><u>Motivation and emotional wellbeing:</u> Captures contributions to teachers' professional drive and ability to adapt to change and difficult situations</p>	<p><i>...our conversations have inspired me to stick with new ideas even when they are challenging</i></p>
	<p><u>Resources and unspecified learning:</u> Focuses on contributions that do not fall into any of the aforementioned sub-categories.</p>	<p><i>Collaboration with colleagues across the world through various Facebook groups has given me resources I may never have discovered on my own</i></p>

Appendix G

Coding Scheme for Informal Learning Activities that Math Teachers Engage in

Category	Sub-category	Example Quotes
<p><u>Interaction and discussion with others</u> Refers to informal learning activities that involve interaction between teacher colleagues or between teachers and non-colleagues</p>	<p><u>Collaboration with colleagues</u> Interaction is solely between teacher colleagues</p>	<i>Met with colleagues at happy hour and discussed issues</i>
	<p><u>Non-colleague interaction</u> Interaction between teachers and non-colleagues e.g., family</p>	<i>I have many conversations with family and friends</i>
<p><u>Consulting information sources</u> Focused on informal learning activities involving media (both print and social media) and the internet in general</p>	<p><u>Reading professional literature</u> Involves reading educational books, journal articles, etc.</p>	<i>I read books like “building thinking classrooms”, “limitless mind” ...</i>
	<p><u>Social media</u> This sub-category focuses on the use of Facebook, twitter, and other social media platforms</p>	<i>I participate in several social media groups that are education related</i>
	<p><u>Online courses and web-based resources</u> Involves accessing courses and materials on the internet</p>	<i>I learn through open courseware (MIT)</i>

Appendix G (Continued)

Category	Sub-category	Example Quotes
<p><u>Learning from others without Interaction</u></p> <p>Informal learning activities that do not involve interaction with others</p>	<p><u>Feedback (written)</u></p> <p>Informal learning activities involving written feedback from others</p>	<p><i>Student reflection on quizzes/exams</i></p>
	<p><u>Observation</u></p> <p>Watching colleagues teach</p>	<p><i>I've been able to visit other math classrooms in-person and online</i></p>
<p><u>Practicing and Testing</u></p> <p>Informal learning activities that involve trying out new things or just experiencing the old</p>	<p><u>Experimenting</u></p> <p>Informal learning activities involving exploring new ideas</p>	<p><i>I always try new technology from the student viewpoint before assigning it to my classes</i></p>
<p><u>Reflection in and on Action</u></p> <p>Involves reflection on issues of practice</p>	<p><u>Reflection</u></p> <p>Reflecting on teaching and other issues of practice</p>	<p><i>...did a lot of self-reflection and some modification of my teaching for that</i></p>

Appendix H

Facebook/Twitter Post

Hello everyone! I am a doctoral candidate at NC State University looking for secondary math teachers to participate in my dissertation study which focuses on math teachers' perceptions of informal learning. Participants should be over 18 years and currently teach in the United States to meet the study criteria. The study's reference number is 24971.

If you are interested in taking part, or wish to read more about the study, please click here: [link](#).

The survey should take approximately 10 to 15 minutes to complete.