


# The Conceptual Framing, Design, and Development of Mobile-Mediated Professional Development for Primary Mathematics Teachers

Ali Gohar Qazi, Institute of Education, University College London, UK & Aga Khan University, Pakistan\*

 <https://orcid.org/0000-0001-7241-9511>

Fredrick Japhet Mtenzi, Aga Khan University, East Africa, Tanzania

## ABSTRACT

This paper examines the design and development of a mobile-mediated professional development program for primary school teachers. It explores learning design frameworks and strategies to offer effective, 24/7, anywhere-anytime PD using mobile technology. The study highlights the significance of design requirements and best practices in mobile-mediated TPD, and presents a conceptual framework incorporating various pedagogical/andragogic approaches and instructional design possibilities enabled by mobile technology. The framework is based on the integrative learning design framework (ILDF), CSAM, RASE, Keller's ARCS, and TPACK framework. The resulting framework enacts evidence-informed and theory-led models, and best practices to cater to instructional design requirements for creating meaningful mobile-based learning experiences for teachers.

## KEYWORDS

Framework, Instructional Design, Mobile Environment, Mobile learning, PD, Professional Competence, Teacher Collaboration, Teacher Effectiveness, Technology-infused Training, Ubiquitous Learning

## INTRODUCTION

Over the last decade, the rapid proliferation of mobile technologies – smartphones, tablets, and other handheld devices - has opened up new avenues and possibilities to extend and enhance learning and education delivery at all levels, including teacher professional development (TPD) (Beauchamp et al., 2015; Gao et al., 2021; Gunter & Reeves, 2017; Mayer, 2020). As a result of these technological advancements, there is a renewed focus on the development and discourse of design-based understanding that aims to create inclusive, engaging pedagogy embedded in technology-rich environments (Gohar, 2022; Grant, 2019; Parsons et al., 2007).

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\*Corresponding Author

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Mobile learning (m-learning) is an emerging trend and assumed even greater importance amidst the COVID-19 pandemic, where the education and training provision has predominantly relied on the use of mobile or portable digital technology whilst maintaining a physical distance (Naciri et al., 2020; Qazi et al., 2023). While these technologies provide greater affordances (Danish & Hmelo-Silver, 2020) and capabilities to deliver education and training in a contextualized, personalized, and geographically unrestricted manner, they have, however, often been matched with a more nuanced understanding of a design for effective learning in a technology-rich environment (Hall et al., 2020; Pishtari & Rodríguez-Triana, 2022).

While much of the research identifies and addresses specific, persistent issues regarding effective design for scalable and sustainable mobile learning in the TPD context (Bano et al., 2018; Baran, 2014; Dallimore & Souza, 2002; Kearney et al., 2012; Koenraad, 2019; Tony et al., 2006), there are still many questions, concerning effective integration of mobile learning experiences in the TPD context, remaining to be addressed. It is, therefore, imperative to offer new perspectives on how technology-mediated, specifically mobile-mediated, TPD programs can be designed and developed effectively to better facilitate teachers' use of mobile technology for their professional development.

The current study attempts to provide a conceptual framework that can be used to plot an effective design for the development of mobile-mediated TPD programs. The framework is conceptualized by enacting theory-led, evidence-informed approaches and models of teacher professional development and mobile learning research and practice. The outcome of this study is expected to serve as a guide, providing essential pedagogical and technological considerations in the instructional design when using mobile-mediated TPD.

## **RELATED WORK**

### **Teacher Learning and Professional Development**

It is widely established that teacher competence or quality is decisive in student learning, given that the variation in student achievement is highly correlated with teacher-related factors (Araujo et al., 2016; Aslam et al., 2019; Azam & Kingdon, 2015; Beteille et al., 2014; Britton & Vignoles, 2017; Chetty et al., 2014; Darling-Hammond & Berry, 2006; de Talancé, 2017; Glewwe et al., 2011; Kyriakides et al., 2009). Endorsing similar findings, the OECD observes that "...the quality of an education system cannot exceed the quality of its teachers since student learning is ultimately the product of what goes on in the classroom" (OECD, 2010, p. 4). Evidence from systematic empirical reviews of well-designed intervention studies also confirmed that the quality of education received by students in schools greatly relies on the quality or competence of teachers (Hopkins & Stern, 1996). Simultaneously, professional development for teachers is widely viewed as the key mechanism or approach for improving teacher quality and effectiveness in the classroom (Desimone & Stuckey, 2014; Desimone & Garet, 2015).

Many existing studies in the broader literature have consistently reported that teacher professional development is one of the critical factors for school-level change and development (Feiman-Nemser, 2001; Guskey, 1986; Hargreaves, 2000; Postholm, 2012). Feiman-Nemser (2001) emphasized, "... if we want schools to produce more powerful learning on the part of students, we have to offer more powerful opportunities to teachers" (p. 1014). Likewise, Guskey (1986) asserted that "...any proposal for improving the quality of education and student learning is not worthwhile unless it incorporates a programme of teacher development." As it currently stands, many reviews of major studies in the areas of teacher development and school change elucidate mixed results; however, it is widely assumed that PD could potentially play a cascading causal role, leading to changes in teachers' beliefs and actions, thereby improving student learning outcomes (König et al., 2017; Montt, 2011).

When well-designed, PD has the potential to not only support the development and effectiveness of teachers but also to raise student achievement and overall school performance (Brutti & Torres, 2022; Elmore & Burney, 1997). Largely, investing in teachers' ongoing PD is considered a cost-effective

policy solution to enhancing teacher quality and levelling up educational opportunities for students (Sheralyn et al., 2012). It stands to reason, therefore, that any reform effort to strengthen teaching must begin with considerations of robust and effective professional development that could provide effective conditions for productive learning and be able to sustain effective classroom practice (Goos et al., 2018; Hennessy et al., 2018).

Teachers, and all those responsible for making education systems as effective as possible, often utilize a series of individual and collaborative PD activities to facilitate teacher attainment and change (Duncan, 1998; Hattie, 2008; Yoon et al., 2007). However, attaining teacher knowledge and improvement is an intricate and subtle process and is necessarily immersed in both practice and actions (Duncan, 1998). For instance, Clarke and Hollingsworth (2002) as cited in Basma and Savage (2018) show that "...teacher change is sometimes evident in certain teachers 'personal domain' following PD activity. And the new knowledge or approach learned in PD is then explored by teachers in their 'domains of practice' and then evaluated for their efficacy there before being adopted more permanently or rejected as ineffective." This suggests that the design of effective professional development necessarily takes into account how teachers learn and improve practice (Darling-Hammond & Richardson, 2009), instead of assuming that teachers integrate new strategies into current practices seamlessly (Snow-Renner & Lauer, 2005).

Such findings are also seen in research (Basma & Savage, 2018; Keay et al., 2019) that establishes teacher learning as a complex and multi-faceted phenomenon, which is recursive and non-linear, involving many processes, mechanisms, actions, and elements. This notion was further supported in a recent study (see e.g. Ehrenfeld, 2022) which asserts that teacher learning happens through a complex web of learning experiences and is not simply the process of linear conceptions of progress carried out through one-shot teacher training session(s) to prompt teacher improvement. Nevertheless, a closer look at the literature reveals that most PD programs do not reasonably utilize complexity thinking and a weblike notion of teacher learning for developing teacher professional growth and tangible change (Taylor, 2020). They employ a linear pathway perspective without considering the thoroughgoing framing of teacher development and how teaching might be improved.

There is ample evidence supporting this argument, revealing that although some PD programs have been shown to impact teacher outcomes (Martin et al., 2010), much of the research has noted that many PD initiatives appear ineffective in supporting long-term changes in teachers' practices and improving the quality of student learning (Power, 2019; Tao, 2016). Besides, teachers also report frustrations with participating in PD sessions that are sub-standard, irrelevant, and decontextualized (Darling-Hammond & Richardson, 2009; Dichaba & Mokhele, 2012). Thus far, we see a disappointing history in the adoption of 'one-shot', 'sit and get', 'top-down', and cascade frameworks for PD provision in various contexts. There exists a broad consensus among sector practitioners and a wide body of literature regarding numerous problems with PD activities conducted on cascade models, including – 'transmission losses' or 'dilution', 'inadequacy of experts', and 'training fatigue'. Borko et al. (2010) argue that PD experiences that are delivered "...in the form of trainings, workshops, and courses away from the classroom and school by outside experts tend not to make teachers able to integrate what they had learned into their practice." Hence, it can be concluded that such PD strategies are offered to achieve outcome-driven, agenda-centric aims for PD - devoid of a basis in a vision of effective teaching – and they predominantly employ simplistic conceptualizations of teacher professional learning (Strom & Viesca, 2021).

Nevertheless, several investigators (Ehrenfeld, 2022; Keay et al., 2019; Opfer & Pedder, 2011; Taylor, 2020) have suggested that teacher learning and development must be viewed through a broad, conceptual lens where the focus of any teacher learning activity may result in outcomes of changed cognition and behavior related to the subject, pedagogy, and overall educational transformation (Bakkenes et al., 2010; Desimone, 2009). In line with this, we argue that TPD programs must consider teachers as complex professional learners and increasingly consider dynamic relationships of teacher learning and outcome, and thus, accordingly operationalize variables of relevance that could potentially influence teacher learning to a great extent.

## Quality Features of Effective TPD

Recent research (Darling-Hammond, Burns, et al., 2017; Kelcey et al., 2019) on teacher professional development establishes the need to shift focus from a top-down approach to a more robust system of continuing education that enables teachers as reflective practitioners, allowing them to take responsibility for their learning to improve the quality of professional performance. It is believed that professional development for teachers should move from ‘replication to reflection’, from ‘learning separately to learning together,’ from ‘one-off workshops outside schools to ongoing and job-embedded, and from ‘centralization to decentralization’. Additionally, PD should place a focus not only on subject matter content but on the way in which students learn that content (Darling-Hammond, Hyler, et al., 2017).

Given this conceptualization, professional development is believed to be more effective and meaningful to teachers when it is designed in view of known traits of effective PD (Desimone, 2009, 2011; von Suchodoletz et al., 2018), which includes – “content focus, active learning, coherence, duration, and collective participation.” These five key characteristics or features have widely been endorsed by the field as being critical components for effective contemporary models of TPD that lead to teacher learning and change (Desimone & Garet, 2015, p. 253), which are illustrated below:

*(a) content focus: activities that are focused on subject matter content and how students learn that content; (b) active learning: opportunities for teachers to observe, receive feedback, analyze student work, or make presentations, as opposed to passively listening to lectures; (c) coherence: content, goals, and activities that are consistent with the school curriculum and goals, teacher knowledge and beliefs, the needs of students, and school, district, and state reforms and policies; (d) sustained duration: PD activities that are ongoing throughout the school year and include 20 hours or more of contact time; and (e) collective participation: groups of teachers from the same grade, subject, or school participate in PD activities together to build an interactive learning community.*

Although the effective PD characteristics illustrated above are derived from a substantial body of research, their adoption does not always guarantee to lead to positive outcomes. Nevertheless, these features provide overlapping recommendations for what an effective teacher PD entails in terms of content and how to design and structure PD programs. In this light, the features of ‘effective PD’ signal the need to re-conceptualize PD provision by aligning it with the needs of teachers and considering how they learn (Darling-Hammond & Richardson, 2009). That is, we need to shift our focus from the ‘one-shot,’ ‘sit and get’ PD approach to one that facilitates teachers to actively engage in altering their teaching, as a part of their daily routine (Hunzicker, 2011).

Essentially, a PD that provides an effective learning environment for teachers to actively control their own professional learning has a strong claim for potential impact (Kalinowski et al., 2020; Kalinowski et al., 2019). Darling-Hammond and Richardson (2009) posed that learning experiences that are intentional and personally insightful for teachers have a significantly stronger association with the content covered, and increase teacher motivation and engagement in PD. Generally, active engagement is claimed to be positively correlated with outcomes (Bakker, 2011; Deci & Ryan, 2000, 2012). Equally, collective participation in PD can be perceived as “...one of the key mediators and indicators of desirable teaching practice” (Darling-Hammond, Hyler, et al., 2017; Ji, 2021). In short, with these features in place, it is anticipated that PD could become more effective, relevant, and authentic, and thus, it could instigate teachers to change their teaching practices, increase their learning, and ultimately improve student learning.

## Using Mobile Learning for Supporting Teacher Professional Development

Mobile learning (or m-learning) is a kind of learning mediated through mobile devices, such as personal digital assistants (PDAs), media players, mobile phones, and tablet computers (Herrington & Herrington, 2007; Kearney et al., 2015; Kukulka-Hulme & Traxler, 2005, 2013; Pachler et al., 2009; Wu et al.,

2012). It is a way to learn anything, anywhere at any time (Ally, 2009; Franklin, 2011; Krull & Duarte, 2017). O'Malley et al. (2005) defined m-learning as "...any learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of learning opportunities offered by mobile technologies" (p.6). These definitions and discourse indicate that mobile learning provides flexibility, empowerment, and the ability for learners to access course material and instructions regardless of time and place (Bano et al., 2018; Crompton & Burke, 2018).

Besides, mobile learning supports individual, collaborative, and contextual learning, as Crompton (2013) explains, in mobile learning, learning happens in a variety of contexts through "social and content interactions, using personal electronic devices." This implies that mobile learning could potentially offer opportunities for teachers to self-direct their professional learning, spark and sustain collaboration with peers, and engage in (formal, informal, and non-formal) learning through exploiting its affordances – including, 'two-way communication, rich audiovisual media capability, ease of access, contextualization, and personalization' (Bernacki et al., 2020; Hwang et al., 2021).

As with other fields of eLearning, mobile learning has quickly grown in less than a decade, showing immense potential in mediating TPD, in terms of extending reach and scalability in remote areas and for providing favorable options for teachers to learn individually and with colleagues – anywhere, anytime – regardless of their geographical, cultural, and/or socio-political differences. By relying on mobile technologies that are widely used, and available, mobile learning could create a paradigm shift for ongoing or continuous professional development by optimizing opportunities for access, for all, to learn. This suggests that teachers from different social backgrounds may benefit equally from PD supported by mobile technology. Particularly, teachers residing in remote rural villages, where teacher training facilities do not exist. Similarly, mobile learning can bridge the educational gender divide that is more pronounced in developing countries by providing anywhere-anytime access in a safe learning environment, particularly for female teachers who are often not allowed to go outside the home to attend face-to-face training.

Because of its multitude of advantages, many policies and practices worldwide recognize technology-mediated approaches as a source of innovation for education and often invoke possible advantages for increasing teacher capacity and for continual TPD provision. Nevertheless, the field of technology-mediated TPD is still growing and identifying promising uses of technology that could potentially enable teachers to capitalize on knowledge development and improve classroom pedagogy (Hennessy et al., 2022). The existing research identifies and addresses specific, persistent issues regarding effective design principles for scalable and sustainable mobile learning design. It is, therefore, imperative to explore technology-mediated (in our case mobile-mediated) TPD to develop a better conceptual understanding to effectively integrate mobile learning experiences in the TPD context; hence this study is a response to this call.

## Supporting Models and Frameworks

Several researchers have suggested that technology-supported PD offers vibrant professional development activities for teachers that are often inaccessible in traditional training settings (Dede, 2006; Hennessy et al., 2022; Richardson, 2001). Many researchers (Baumgartner & Bell, 2002; Kukulska-Hulme & Traxler, 2013) have also pointed out that teaching-learning innovations utilizing (mobile) technology can enhance learning experiences. Arguably, several pedagogical factors and design requirements are crucial for the mobile-enhanced learning environment to be effective.

Our analysis of previous studies (Gantner & Campbell, 2021; Rapanta et al., 2021; Sh, 2022) indicates that the pervasive influence of technology and pedagogy should be significantly considered in the design of mobile-enhanced learning systems. It is, therefore, crucial to structure pedagogical elements of instructional design by enacting and incorporating the best practices and approaches in mobile learning applications, particularly those that promote the use of mobile technology in TPD contexts. In line with this, numerous attempts have been made to conceptualize mobile learning theories and instructional design frameworks for mobile-based learning environments (Ally, 2005; Elias, 2011; Gedik et al., 2012; Levene & Seabury, 2015).

The body of research in the field of technology-supported TPD shows some approaches, models, and frameworks for creating mobile learning content that could reflect essential pedagogical elements in the mobile learning design, such as FRAME (Koole, 2009), CSAM (Power, 2013), Kellers' ARCS model (Keller, 1987, 2013), transactional distance theory, activity theory, and the TPACK framework (Herring et al., 2016; Mishra & Koehler, 2006). Despite this, there is still no consensus on a holistic framework for a mobile-based TPD, as the mentioned models and frameworks are fragmented and their focus remains limited to a few pedagogical considerations, coupled with mobile instructional design. This implies that there is currently no single theoretical framework for a mobile-mediated TPD that can inherently provide principled guidelines for creating effective mobile learning design for teacher development. Thus, there is a need to establish integrated and holistic conceptual/theoretical frameworks that can be used to guide the design of mobile learning experiences for effective PD (incorporating effective PD characteristics) for teachers.

The following sections will present the conceptualization of a mobile-mediated TPD framework in this research study.

### **Conceptualization of a Mobile-Mediated TPD Programme: An Integrative Approach**

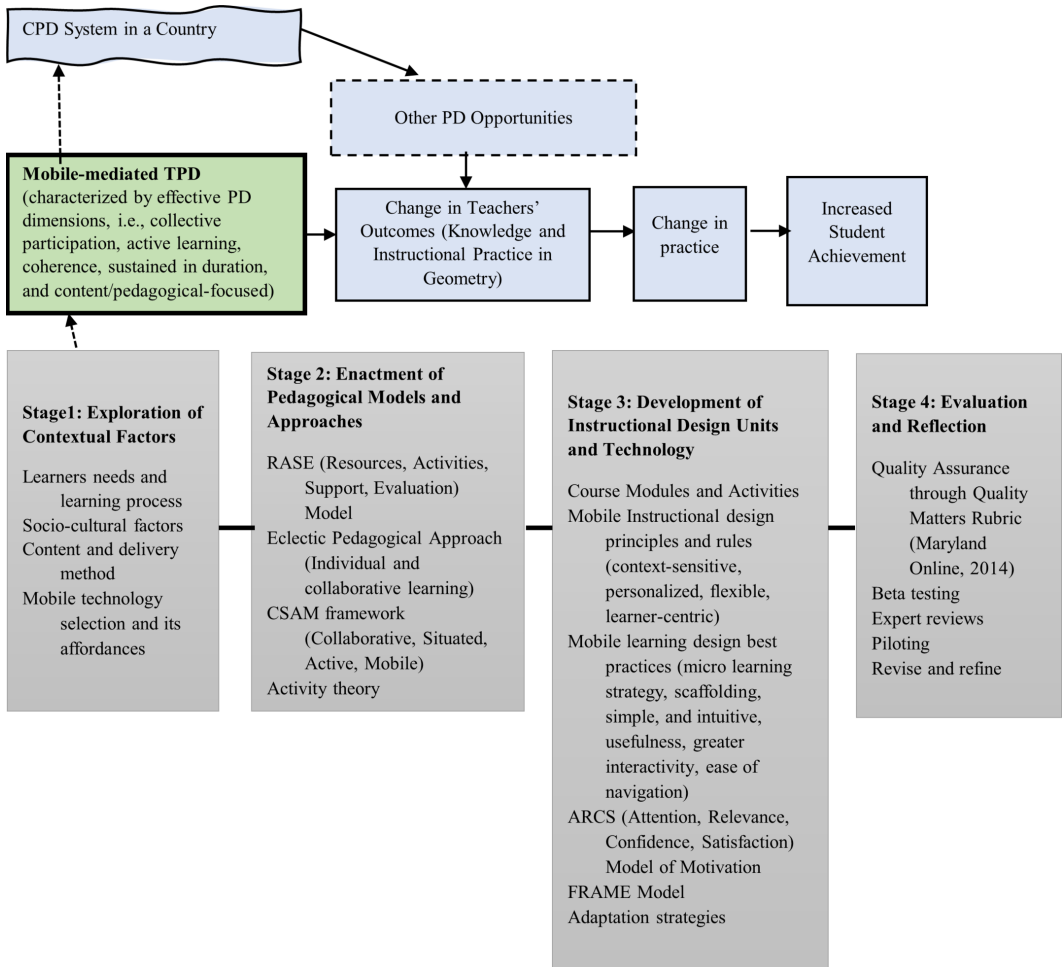
The use and integration of appropriate models and frameworks for mobile-mediated TPD are necessary so that optimal learning results can be achieved. In view of this, this study aims to present the conceptual framing for designing TPD interventions and experiences to optimize their effectiveness in terms of the quality of the instructional design and pedagogy when utilizing mobile technologies.

The mobile-mediated TPD program uses the Desimone (2009) framework as a philosophical underpinning for facilitation and delivery mechanisms. Considering the current literature, the comprehensive theoretical framework synthesized by (Desimone, 2009) is convincing, since it contains: 1) an explanation of effective professional development; 2) the path from effective professional development to student achievement; and 3) contextual factors related to the effectiveness of professional development. In the light of reported literature, it is conceivable that Desimone's framework has been justified by both theoretical and empirical studies (Kang et al., 2013). We have, therefore, underpinned the mobile-mediated TPD based on this framework.

The theoretical underpinning of the mobile-mediated TPD program is that teachers who are provided with tools, strategies, and opportunities to interact, explore, and engage in real-time, active, sustained, collaborative, coherent, and content/pedagogical content-focused PD activities could improve their knowledge and instructional practice for better classroom teaching which in turn improves students' learning outcomes. This implies that the primary pedagogical elements for mobile-mediated TPD involve collaborative interaction and exploration, active engagement with learning content, authentic tasks and activities, mobility to engage in real-time content-focused PD, and effective support and feedback.

To achieve these pedagogical elements, the proposed conceptual framework (see Figure 1) for mobile-mediated TPD considers various pedagogical domains for its learning design. It draws upon the Integrative Learning Design Framework (ILDF) for online learning which allows the development of "...a more flexible, adaptable process of design and development emphasizing specific social and cultural contexts of learning" (Bannan-Ritland, 2003; Bannan, 2009). The ILDF framework provides a blueprint to a) *explore* the contextual factors that may affect the design in terms of the learning process, content, and delivery method, and b) *enact* sound pedagogical models in terms of instructional strategies that may align with the features of the mobile delivery systems, and c) *assess* if the designed intervention is valid and relevant to meet the instructional objectives. Thus, in an attempt to develop conceptual framing, we have integrated ILDF with Desimone's framework for a mobile-mediated TPD program whereby all the stages of ILDF are grounded given the mobile learning process, content and delivery method, and enacted multiple, fragmented pedagogical models and frameworks – including, RASE, CSAM, ARCS, and TPACK for guiding the development of instructional design units and technology adaptations.

Figure 1. The Conceptual Framework for Mobile-mediated TPD



## THE PILOT STUDY

Based on the proposed conceptual framework, a mobile-mediated TPD intervention was developed and implemented among 328 randomly selected primary school mathematics teachers at public and private schools in the Sindh province of Pakistan. The emphasis on primary-level Mathematics teachers is borne out of the need that students' conceptual understanding of basic concepts to be developed in the early years of education; thus, the quality of teaching and learning need to be the best at the primary level to prepare students effectively to learn more concepts at the advanced level. Despite this recognition, when it comes to mathematics, for example, various research studies have identified 'low teacher quality' as the primary factor responsible for low levels of student performance, particularly in the context of Pakistan. While many techniques and reforms have been introduced in Pakistan to uplift the quality of teaching, due to various reasons, they have not yet been successful. What is lacking is the provision of continual, on-the-job professional support available to teachers across Pakistan, including in its most rural areas (Power, 2019).

By focusing narrowly on building a few individual teachers' knowledge and skills, many PD programs have largely ignored quality and equitable access to teachers' development. Contrarily, we have established that continuous PD is a crucial aspect of education systems as it enables teachers

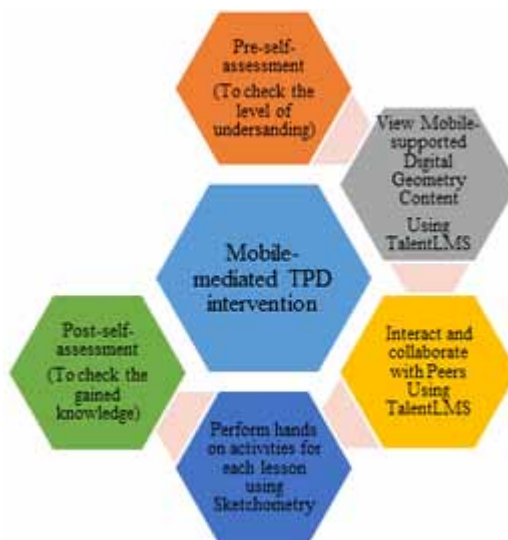
to improve their knowledge, skills, and teaching practice (Cordingley, 2015; Kennedy, 2014). Additionally, it has been widely acknowledged in the literature that continuous access to PD is often limited (Power, 2019), in low- and middle-income countries (LMICs)- including Pakistan, and the traditional PD methods are predominant which are costly and logistically challenging to implement (Singh et al., 2020). Thus, it is essential to find ways to provide PD to teachers in Pakistan and other LMICs in an accessible and cost-effective way. Mobile technology, on the other hand, offers a promising solution to this problem, as it can provide a cost-effective and accessible solution for providing PD to teachers in LMICs (Bano et al., 2018; Hall et al., 2020). With this in mind, we undertook this pilot study to explore and validate the proposed framework in terms of designing effective mobile-mediated PD experiences for teachers.

To effectively create alternative professional learning for the targeted teacher group, the proposed framework was utilized in the design and development of the mobile-mediated TPD program. In our proposed framework, we have placed a significant emphasis on the characteristics of effective professional development, so the design of a mobile-mediated TPD program incorporates these features in place. Moreover, it provides ongoing support and resources for these teachers, with a focus on helping them to improve their instructional practices and better meet the needs of their students. One key aspect of the framework is the use of a four-stage process for the design and development of mobile-mediated TPD interventions, so the mobile-mediated TPD program has undergone these stages (see Figure 2). The following subsequent sections illustrate an overview of the design, structure, and key pedagogical elements of the mobile-mediated TPD program.

### Contextual Factors and Technology Selection: An Overview of the Components of the Mobile-mediated TPD intervention

While exploring the contextual factors and technology selection for the mobile-mediated TPD program, all the guidelines, as illustrated in stage 1, were followed. In terms of understanding learner needs, an extensive literature review and informal interviews with participants were carried out to later accommodate learner needs, interests, and areas of weakness in the design of the mobile-mediated TPD program. On the other hand, sociocultural factors, content delivery methods, and technology selection were carefully considered during this stage. The following mechanisms were selected for the pilot study.

Figure 2. Mobile-mediated TPD Intervention





### *TalentLMS - A Content Delivery Platform*

The mobile-mediated TPD program utilized the TalentLMS (a cloud-based online learning platform) to create, manage, deliver, monitor, and assess the mobile-optimized Geometry course for primary school teachers. The TalentLMS consisted of two separate parts:

- **A cloud-based server component** that performs the core functionality of creating, managing, and delivering a course, authenticating users, serving data and notifications, etc., and
- **A user interface component** through a mobile app (TalentLMS), that was used by the target teachers to - access assigned courses and use them anywhere, anytime; view progress and gamification elements like points, levels, and badges; download courses for offline use and synchronize when online, and read, send and reply to messages, as well as view and attach files from their mobile device.

The selection of TalentLMS was deemed fit for the study and was tested and tallied, as outlined in stage 1 of the proposed framework. The mobile-mediated TPD through using TalentLMS technology brought together groups of primary mathematics teachers to collaborate and share strategies and best practices. Through ongoing communication, teachers supported one another in their professional growth and development. Moreover, the TalentLMS application can function offline, allowing teachers to access the digital learning content without being connected to the internet; however, one-time internet connectivity was required to deliver the content from the cloud server.

In addition to accessing content and assessments (pre- and post-for each lesson), the TalentLMS mobile application captured user data such as frequency and duration of lesson viewing, and teacher performance on embedded (built-in) assessment items (progress monitoring) and presented these at user and administrator levels. This mechanism provided teachers with feedback on their learning progress and usage. Thus, in line with the proposed framework, the mobile-mediated TPD program provided opportunities for individualized and collaborative learning which allow teachers to control their learning – anywhere anytime; receive peer support and guidance as they work to improve their instructional practices and stay on track based on the performance.

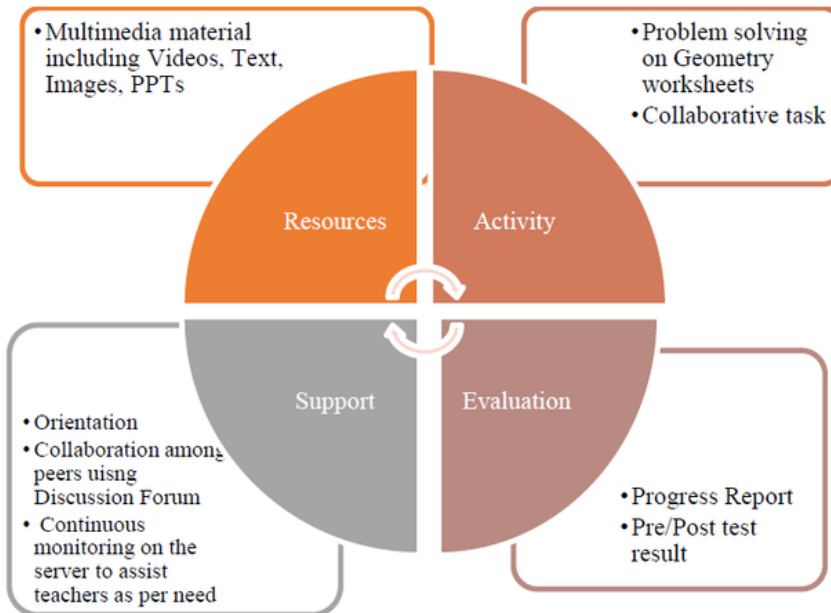
### *Sketchometry – An Interactive Dynamic Geometry Environment*

A Sketchometry application was used to provide the teachers with a dynamic geometry environment (DGE) whereby they autonomously create geometric constructions and manipulate them interactively. Thus, teachers had gone through a multi-stage procedure: a construction stage, an exploration stage, and maintaining a study journal or an exercise book. In the construction stage, teachers had to draw the required sketch or geometric construction with sketchometry. Next, in the exploration stage, teachers had to experiment with the construction they have created. Furthermore, in the last stage, teachers had to write down their observations and findings in their study journals. This way, teachers could actively be engaged in doing hands-on activities or experiments (after the given lesson) to discover geometric relationships, make observations and assumptions, and try to verify them. Thus, the utilization of Sketchometry could suffice the purpose of engaging the target teachers in the active learning process.

### **Instructional Design and Pedagogy of the Intervention through the Enactment of Models and Approaches**

The learning design of mobile-mediated TPD intervention is informed by the RASE pedagogical model (Churchill et al., 2013). This model consists of four components, including - Resources, Activity, Support, and Evaluation (RASE). It is based on the notion that "...content or resources alone are not sufficient for the full achievement of the learning outcomes. In addition to resources, it is necessary to consider activities, support, and evaluation." Figure 3 depicts the implementation of the RASE pedagogical model for the mobile-mediated TPD intervention.

Figure 3. RASE pedagogical model



In addition, the mobile-mediated TPD intervention utilized an eclectic andragogical/pedagogical approach to ensure uniform and predictable learning outcomes in the mobile-based learning environment. This approach puts together both constructivist and behaviourist perspectives. This implies that it will minimize the “transactional distance” as propounded by Moore (Moore, 2013), accommodate learners with “multiple learning styles”, and facilitate learners who are not prepared to learn fully in a “self-directed way.” In addition, this approach is based on the assumption that learners acquire some percentage of their knowledge by themselves (individually) while the remaining percentage of knowledge is through collaboration (Blondy, 2007; Knowles, 1980).

Collaborative learning in the mobile-based environment includes learning elements that are both synchronous and asynchronous. Nonetheless, due to the inherent advantages of mobile learning as being adaptable to anywhere-anytime, much of the focus in this study is on asynchronous components. Synchronous interactions occur in real time when learners are online at the same time and have direct contact (Asgarova et al., 2021). Asynchronous communications, on the other hand, take place at the learners’ own time and convenience. Figure 4 illustrates this approach.

Since the andragogy model asserts “...letting learners know why something is important to learn, how to direct through information, relating the topic to the learners’ experiences, being ready and motivated to learn, and overcoming inhibitions, behaviours, and beliefs about learning” (Knowles et al., 2015; Knowles et al., 2011), the authors deduce that the motivation to learn is internal. Conversely, this study assumes that the motivation to learn is not evident among primary school teachers in Sindh, Pakistan. Because mobile-mediated TPD is a diversion from normal pedagogy; thus, it requires an extra need to motivate teachers for better implementation of the mobile-mediated TPD programme.

To consider the role of motivation in this study, the instructional design of mobile-mediated TPD is informed using the ARCS (Keller, 1987, 2013) model (see Figure 5). The model comprises four components - “attention, relevance, confidence, and satisfaction (ARCS)”. ARCS is an instructional design model that “...finds more effective ways of understanding the major influences on the motivation to learn, and ...identifies and solves problems with learning motivation” (Keller, 1987,

Figure 4. A focus on asynchronous self- and collaborative learning

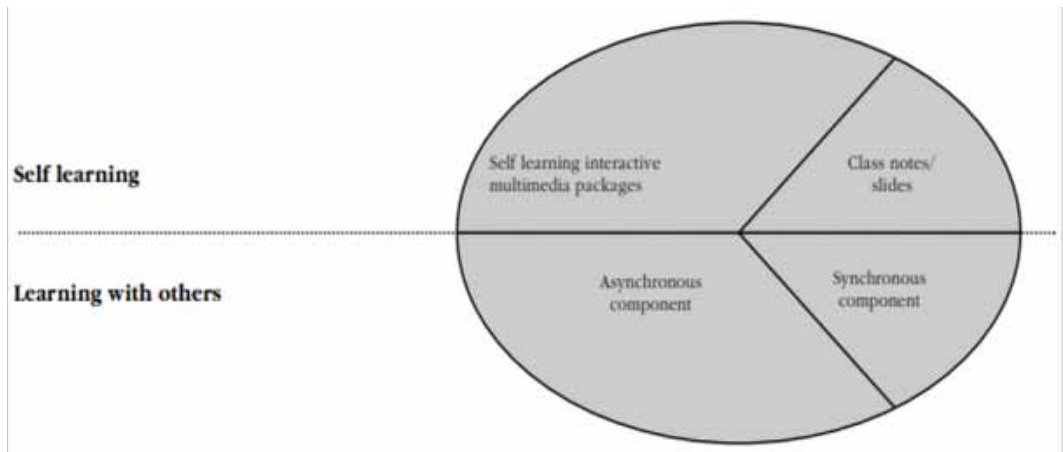


Figure 5. ARCS Model of Motivational Design



p. 2). According to Keller (1987), this model provides the “...method for improving the motivational appeal of instructional materials” (p. 2).

These four categories of motivation can be achieved in this study, as follows:

- Attention gained by offering a new method of content delivery that would maintain interest through exploration, graphics, video, and participation.
- Relevance to the learners maintained by aligning it to curriculum learning outcomes, their familiarity with the mobile devices, and their application towards new learning and study.
- Confidence provided among the learner with personal control and opportunities for meeting learning requirements.
- Satisfaction maintained with a consistent useable resource, positive reinforcement of the topics and videos studied, and discussion around opportunities for this new learning.

Like Keller’s (1987, 2013) ARCS model, the TPACK framework (Mishra & Koehler, 2006) provides a holistic picture of instructional design for mobile-mediated TPD. It emphasizes considering generic technology competencies and placing emphasis to promote teacher self-efficacy (in terms of

confidence to use technology in educational contexts). Thus, the integrative learning design framework for mobile-mediated TPD is consistent with the considerations espoused by both the ARCS model and the TPACK framework.

Regarding the development of mobile-optimized Geometry course modules and units, mobile instructional design and practices were followed as outlined in stage 3 of the proposed framework. Later the developed mobile-optimized course was undergone through an extensive evaluation stage whereby expert reviews were conducted from pedagogical and technical perspectives. Thus, the development of mobile-mediated TPD used the Integrative Learning Design Framework (ILDF) model in terms of exploration, enactment, and evaluation.

To validate the effectiveness of the proposed framework and to investigate the impact of the resultant mobile-mediated TPD program on teacher enhancement, our preliminary analysis shows that teachers who have participated in the mobile-mediated TPD program have made significant gains in their enhancement in subject matter content and instructional practice. Nevertheless, the proposed framework needs to be implemented in a variety of settings to be validated. In summary, our proposed framework is designed to provide primary mathematics teachers with a comprehensive approach to professional development supported with mobile technology; it is anticipated that it could be a powerful tool to design effective technology-mediated, especially mobile-mediated, TPD interventions that can support teachers in their professional development journey.

## **CONCLUDING THOUGHTS AND IMPLICATIONS**

There exists a common misconception that electronic learning materials can be merely transferred into mobile learning courses for teacher development. However, during the transition, it is crucial to rethink and reconsider the entire instructional design, mobile learning process, content, and delivery system. This paper has proposed a conceptual framing of the key design considerations underpinned by pedagogical models for the development of the mobile-mediated TPD program. One of the more significant findings to emerge from this study is that the contemporary design challenges we encounter in mobile-enhanced education and professional development require us to capitalize on integrated approaches by enacting sound pedagogical models and instructional interventions, aligned with the features of the mobile delivery systems. Thus, the present study adds to the growing body of research that indicates the design of mobile-mediated TPDs must draw on best practices identified through research and experience, and it must be consistent with the mode of delivery and effective learning design process for teachers.

## **CONFLICT OF INTEREST**

The authors of this publication declare there is no conflict of interest.

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*Ali Gohar Qazi is a multidisciplinary individual, having demonstrated expertise on technology integration in Education from K-12 to higher studies. Currently, he is a visiting PhD scholar at UCL Institute of Education, London from the Aga Khan University - Institute for Educational Development (AKU-IED), Pakistan. Previously, he holds MS and BS degrees in Innovative Technologies in Education and Information Technology both of these from the NUST, Islamabad. His current focus is on exploring ways to provide professional development to primary-level teachers in rural areas using mobile technologies. He has multiple publications in his research area. His areas of interest include the use of technology in primary and secondary education, ICT-Pedagogy integration, ICT in teachers' professional development, and blended and mobile learning.*

*Fredrick Mtenzi, holds a Master of Management Science and a Doctor of Philosophy Degree in Management Information Systems from the University College Dublin – Ireland. Dr. Mtenzi research interests range from security and digital investigations of online financial transactions, systems compliance, data analytics, privacy, algorithm design and technology integration in education. Dr. Mtenzi has significant experience in managing and securing information systems in healthcare and financial institutions, where he has implemented and managed systems. In the last few years, he has been working on integrating technology in education. Specifically, identifying and customizing Open Source software that can be used in low-cost devices with the view of increasing the acceptability and utility of technology in teaching, learning and research. For example, one of the systems he is currently working on is an Open Source software that is designed to enable children who are out of the formal education system to learn on their own so that they can join the formal education system with their age group.*