

Integrating “Just-in-time” Learning in the Design of Mathematics Professional Development

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This paper describes a professional development (PD) programme design integrating just-in-time learning (JITL) to support teachers to learn about and enact inquiry teaching. Through JITL, teachers are provided with support that is responsive and applicable to their needs. This case study reports on the professional journeys of three teachers who received JITL via online resources, face-to-face meetings, opportunities for community building within and across schools, and reflections on pupils' reactions to learning mathematics through inquiry. Findings indicate that JITL embedded within PD facilitated teacher learning about inquiry enactment, since the PD was responsive to teachers' immediate and contextual needs. We suggest that explicit attention to JITL is given in the design of teacher PD, providing support that is made readily available for teachers to access and utilise.

Keywords: inquiry teaching · just-in-time learning · mathematics education · professional development · zones of enactment

Introduction

Continuing professional development (PD) is an ongoing and long-term process (Loucks-Horsley et al., 2010). Research shows that PD is more effective when it is school-based and involves collaboration, the negotiation of meanings and reflective practice (Bannister, 2018; Stoll et al., 2012). Hence, collaborative opportunities for teachers are increasingly being embedded within PD design programmes as a move away from isolated, off-site workshops (Guskey, 2002; Putnam & Borko, 2000). In this way, PD is enacted through ongoing, collaborative on-site experiences of practice-oriented learning. For this to happen, schools need to combat teacher isolation and instill a collaborative learning culture (Bannister, 2018; Cordingley et al., 2015).

According to Koellner and Jacobs (2015), PD models range on a continuum from highly specified approaches to highly adaptive ones, which attempt to be more responsive to the purposes, resources and conditions of the context in which PD is enacted. While highly specified PD models might be conceived of as focused training being done *on* teachers, *just-in-case* they may want to use the knowledge transmitted, highly adaptive models are more flexibly structured PD experiences that rely on a commitment of ongoing and sustained engagement *with* teachers. The study reported in this paper is based on the design and implementation of an adaptive PD programme aimed at supporting teachers in *Learning to Teach Mathematics through Inquiry* (LTMI). Designed by the first author, LTMI was intended to provide just-in-time learning (JITL) opportunities for secondary school teachers of mathematics in Malta who voluntarily participated in this PD experience. In this paper, we apply the concept of JITL to PD design and

draw parallels with JITL in mathematics education and, in particular, to the support that teachers provide to pupils when working on challenging tasks (Russo & Hopkins, 2019). In other words, just as teacher intervention—for example, through enabling prompts (see Sullivan et al., 2006) – is intended to support pupils in the moment of experiencing difficulty with mathematical tasks, JITL PD opportunities target the specific needs of teachers at that point in time. Thus, by offering tailored and timely support, JITL PD encourages teacher self-directed learning to select what, when and how to use the resources and support structures available.

While literature on PD design focuses on the importance of providing support, collaboration and feedback for teacher learning (Fullan, 2007; Putnam & Borko, 2000), the notion of JITL has not yet featured, even in adaptive approaches to PD designs that combine online and face-to-face learning. In this paper, we extend the concept of JITL to PD design for mathematics teachers. We examine how JITL can be embedded within PD that aims to cultivate social interactions as well as individual reflection. This study draws on data as reported by teachers to explore the effectiveness of JITL in supporting their enactment of inquiry teaching. Hence, this paper addresses the research question: *Within an adaptive PD programme, which JITL opportunities do teachers report as supportive in enacting inquiry?*

In the next sections, we provide literature related to PD, PD design and JITL. This is followed by presenting the theory of zones of enactment that we use to analyse the JITL opportunities that facilitated teacher learning. Next, we outline the study, the PD design and the case study methodology before presenting the research findings. The closing discussion and conclusion shed light on the findings, implications and significance of this study, while also providing suggestions for future designs of PD incorporating JITL.

Related Literature

This section focuses on literature related to PD, the design of effective PD programmes and the concept of JITL in PD.

Teacher Professional Development

There are many definitions of PD. In this paper, we take PD to include “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” (Guskey, 2000, p. 16). Moreover, in PD, targeted support is available to address “the needs, concerns, and interests of individual teachers along with those of the school” (Hunzicker, 2011, p. 177).

From the vast literature of studies on mathematics teachers’ PD, it is clear that there has been a shift towards programmes that model inquiry-based pedagogies (e.g., Back et al., 2009; Garet et al., 2001; Loucks-Horsley et al., 2010; Luft, 2001) and authentic activities; that is, PD programmes that model for teachers the practices that they are encouraged to promote in their classrooms (see Jaworski & Huang, 2014). Indeed, this research shows that PD is effective when the learning activities that teachers engage in are collaborative, reflective, ongoing, supportive and connected to classroom practice.

Researchers interested in teacher professional communities draw on the community of practice perspective to explain the social processes shaping teacher learning (see Jaworski, 2006; Wenger et al., 2002). Wenger and colleagues (2002, p. 4), define a community of practice as a group of individuals “who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis.” The importance of community, collaboration, negotiation, support and feedback in PD is well

documented (e.g., Meirink et al., 2007; Putnam & Borko, 2000; Stoll et al., 2012). Feedback and support are necessary for teachers to persist with PD-promoted practices, and are more effective when provided within teachers’ working contexts and in a timely manner (Goos et al., 2007; Lerman & Zehetmeier, 2008). In other words, learning opportunities arise when support structures, embedded within a PD programme design, are readily available to respond to teachers’ needs, concerns and challenges.

Just-in-time Learning (JITL) in Different Contexts

Just-in-time learning (JITL) draws on learning principles incorporated within games and game-based learning. As Gee (2003) argues, video games give assistance through explicit information provided ‘just-in-time’; that is, when “the learner needs it or just at the point where information can best be understood and used in practice” (p. 138). JITL occurs when the learner pays attention exclusively to the information that can be implemented. This means that the learner applies specific knowledge for the particular challenge encountered. Given this learner-centred structure of JITL, reflection is a critical part of the learning process, as the learner needs to make decisions about what, how much and when to learn. From a socio-constructivist perspective, this implies that the learner needs to be provided with scaffolding when learning outcomes are comprehensible to learners but not easily achievable without support (see Vygotsky, 1978). Learners can be offered this support through interactions with knowledgeable others (see, for example, Sprott, 2019). Through on-site and just-in-time assistance, knowledgeable others stimulate learners to think of alternatives and help them go beyond what they already know.

In planning and teaching through challenging tasks, Sullivan et al. (2006, p. 123) highlight the key role of the teacher in identifying “potential and perceived blockages, prompts, supports and challenges” and then providing pupils with access to enabling and extending prompts. Through prompts, teachers offer support and access to pupils who experience difficulty, but also extend the thinking of those who are successful. According to Russo and Hopkins (2019, p. 763), “enabling prompts can be thought of as a type of ‘reverse scaffold’, in which, rather than support being removed as students become more competent and independent, support can be accessed by students on a ‘just-in-time’ basis when required.” JITL is incorporated into the design and use of challenging tasks to offer accessibility while also retaining the cognitive demand within the task. Similarly, the premise of JITL in PD is that teachers are provided with, and have access to, support when they recognise both the need and its potential use.

Just-in-time Learning (JITL) in Professional Development

JITL is a relatively new concept in education and, as a result, is still under-researched. By definition, when provided just-in-time, PD offers opportunities that are responsive and applicable to teachers’ needs. According to Greenhalgh and Koehler (2017, p. 274), while just-in-time PD is “not a formalised concept built on a foundation of empirical evidence, it is a metaphor of PD organised around flexible structures that emerge when necessary.” In particular, within a JITL framework to PD, responsibility for learning is shifted onto teachers and learning opportunities are strengthened through the availability of support structures.

JITL also involves making content immediately and readily available (usually online) for use at one’s own discretion. Provided that support structures are in place, JITL promotes the self-determination and self-directedness of people engaging in learning when needed (Riel, 2000; Greenhalgh & Koehler, 2017). Within a JITL-driven PD, responsibility for learning is with the teachers to access and request readily available formal and informal support. According to Riel (2000), the just-in-time model of PD is characterised by three key aspects: learner self-

directedness, time-independent learning and materials applicability. With JITL, the learner owns the PD by taking control of what is being learned and determines the particular order in which knowledge is accessed. In addition, since PD materials are provided via multiple formats (e.g., printed and online), learners may access information and tools for learning at any time. The JITL model of PD also encourages a functional process of learning; in other words, it is characterised by an immediate putting to use of the materials to the classroom situations that teachers encounter. As a result, in JITL models learning takes place in variety of ways and at the learner’s own pace.

Theoretical Background

Our approach to analysing teacher learning draws on the theory of zones of enactment. We discuss how looking into teachers’ zones of enactment may enable our understanding of teacher learning as they engage in PD.

Zones of Enactment as a Theoretical Framework

Teachers encounter challenges, constraints and dilemmas in their attempts to change their practices (Anderson, 1996; Dorier & Garcia, 2013). Based on a study comparing teachers who had changed their mathematics practice with those who did not, Spillane (1999) argued that the extent to which teachers reconstruct their practice depends on the characteristics of their *zones of enactment*. Zones of enactment are defined as the space where new initiatives are encountered by teachers and in which teachers “make sense of, and operationalize for their own practice, the ideas advanced by reformers” (Spillane, 1999, p. 159). In Spillane’s (1999) definition, the ‘space’ refers to places where teachers make sense of and enact the reform initiative – such as classrooms, but also other formal and informal meeting places within and beyond the school. For Spillane (1999), teacher change requires rich deliberations about practice and its reform, incorporating: (1) social and collaborative, rather than individual, engagement; (2) support from knowledgeable others; and (3) access to high-quality material resources.

Enactment zones, hence, refer to the space in which PD initiatives and the learning opportunities they offer are encountered, interpreted, constructed and operationalised by teachers. Drawing on the study of Spillane and Zeuli (1999), Spillane (1999) presents a model to account for the ways teachers respond to and enact mathematics classroom practices. This model (see Figure 1) positions the *personal* resources that teachers have for learning about practice – their existing knowledge, beliefs and dispositions – as central to the learning process. Spillane shows that, while influenced by teachers’ personal resources, zones of enactment are also shaped by *pupils* (pupils’ responses to teachers’ practices), the *professional* sector (contact with colleagues in and out of school), the *private* sector (textbook and curriculum publishers), the *public* sector (parents and community), and the *policy* sector (policies, curriculum and assessment practices). Enactment zones are context dependent and vary on a continuum from individual to social.

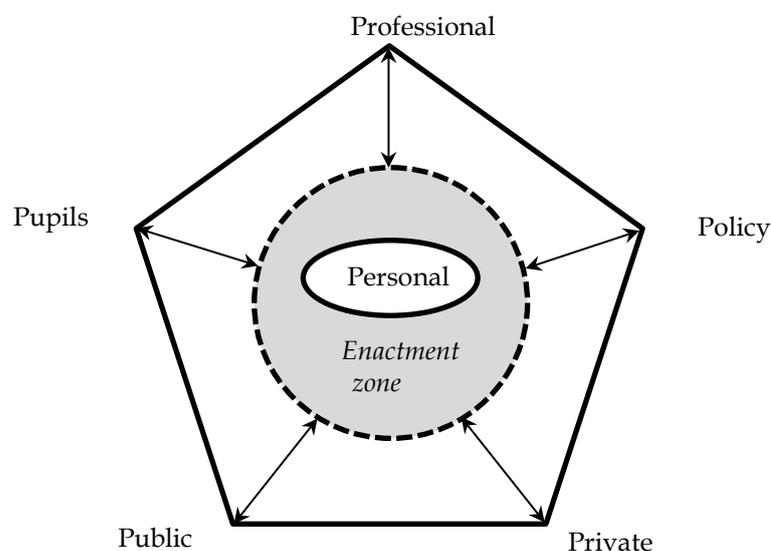


Figure 1. Zones of enactment model, adapted from Spillane (1999)

In this model (Figure 1), the personal is at the centre, as influences from public, pupils, professional, private and policy are mediated through teachers’ personal resources. The policy sector refers to government and school policies including both formal policies and informal policy talk. The professional sector includes formal and informal contacts among educators and professional interactions that may occur among colleagues at and within other schools. The pupils sector refers to the influence that their responses to schooling has on teachers. The public reflects the concerns of parents and community towards reforms, and the private sector includes textbook and curriculum publishers. The two-way arrows linking the personal to the pupils, policy, professional, public and private represent the influence that the environment has on the personal resources of teachers in enacting reform practices, but also on what teachers notice and their influence of practice as mediated through their personal resources.

For teachers to change their practices, their enactment zones need to include a social dimension. Spillane (1999, p. 170) suggests that:

The extent to which teachers’ enactment zones extend beyond their individual classrooms to include rich deliberations about the reforms and practising the reform ideas with fellow teachers and other experts, the more likely teachers are to change the core of their practice.

PD, thus, has an important role to play in facilitating teachers’ social enactment zones. Encouraging and assisting teachers to change the core of their practice depends on an environment that supports ongoing collaborative inquiry about practice and its improvement (see Lotter et al., 2014; Meirink et al., 2007). Enactment zones that are social not only promote changes in the personal resources of teachers, but also, importantly, they promote changes in the ways that teachers enact their learning in practice. JITL PD has the potential to create enactment zones for teachers that recognise teacher agency by placing the teacher at the centre, focusing attention on the extent to which they choose when, where and how they will access JITL support. In this way, the PD experience extends teachers’ agency beyond individual classrooms to include collaborative deliberations between teachers that eventually support learning and the enactment

of the practice being promoted (Spillane, 1999). In this study, JITL is the means to effect these transformations.

Background to the Study

Learning to teach mathematics through inquiry (LTMI)

LTMI is a one-year PD programme offering teachers opportunities to experience, integrate, reflect upon and develop inquiry teaching practices. Offered in Malta to secondary school teachers of mathematics as a voluntary course, LTMI was an intervention programme designed by the first author. The role of the first author was related exclusively to design, while teachers and teacher educators with experience in inquiry practices facilitated the sessions with teachers. During these sessions, the first author adopted a non-participant observer role, gathering field notes and other data to study teacher learning. For this study, 12 teachers enrolled in the programme, seven of whom provided consent for data collection. The data presented in this paper draws on the data from these seven teachers.

LTMI used a practice-based model drawing on research-based principles, namely: a ‘task-first’ approach, engaging teachers in activities through which they could experience learning through inquiry; online access to PD materials; a community of practice experience; and long-term engagement (see Calleja, 2016). As an adaptive PD programme, LTMI provided JITL opportunities through readily available materials, opportunities for reflection, support and feedback. Within LTMI, teachers were also given autonomy to take control over their learning by having access to classroom materials, when needed and at their own learning pace, and the space to engage in practice-based discussions with colleagues over time. To encourage building communities in the participating schools, *pairs* of teachers, rather than individuals, were invited to take part in LTMI.

The content and structure of LTMI

The PD programme was designed to provide LTMI experiences for teachers first through summer workshops, and then by participating in follow-up meetings held during the scholastic year (see Table 1). The four summer workshops focused on four inquiry features: *mathematical tasks*, *collaborative learning*, *purposeful questioning*, and *student agency and responsibility*. These features emerged from research into PD materials used in large scale projects such as PRIMAS (see www.primas-project.eu) and Bowland Maths (see www.bowlandmaths.org.uk), and also from Schoenfeld’s (2013) TRU (Teaching for Robust Understanding) Math scheme, which illustrates fundamental dimensions of powerful mathematics classrooms. Summer workshops followed a consistent pattern of activities: teachers first worked collaboratively to solve a mathematical task through inquiry, then discussed their experience working on the task and later watched a video from a local classroom demonstrating a teacher using the same task with pupils. A subsequent activity included the analysis of a published lesson video (available on YouTube¹) dealing with a particular inquiry feature being discussed (e.g., collaborative learning). Each activity involved pair or small-group work followed by a whole-class discussion intended as an opportunity for teachers to further investigate teaching approaches, clarifying concepts and problematising issues related to inquiry teaching. At the end of each workshop, teachers were encouraged to collaboratively plan a lesson using the activities presented and the ideas generated. The complete PD materials are available online (see www.iblmaths.com).

¹ See www.youtube.com/watch?v=TqBNWEQmBRM as an example of a short video by Dylan Wiliam

Table 1
The LTMI programme

Summer PD Workshops <i>A focus on understanding inquiry</i>		Follow-up PD Meetings <i>Reflecting on classroom practices</i>
1 Session (4 hours) <i>July 2015</i>	3 Sessions (4 hours each) <i>September 2015</i>	10 follow-up meetings (1¼ hours each) <i>October 2015 to May 2016</i>

Follow-up meetings were then intended to provide collaborative, ongoing support for teachers to discuss, evaluate and develop practice-based learning. These meetings followed a structured set of activities led by a facilitator. The opening activity prompted participants to reflect on their just-in-time needs by writing on sticky notes. Reflections included personal strategies for using inquiry, challenging situations encountered and classroom incidents (in which they described the situation, its significance and how this influenced their teaching). This was followed by reporting back and sharing inquiry lessons and tasks. Finally, participants discussed and agreed an agenda for the following meeting. The facilitator’s role was that of a challenger and an intervener – asking questions to support, stimulate and enable participants’ thinking. Over time, this scaffolding was gradually removed to allow for increased teacher autonomy in learning, but also to nurture a self-sustaining learning community (see Calleja, 2016 for a more detailed outline of the LTMI activities).

JITL within LTMI

LTMI was designed to provide JITL that enhance teachers’ enactment zones (see Table 2). The intended benefit was (1) to encourage social interactions, individual reflection and knowledge building, (2) to instill self-directed learning and (3) to provide opportunities for teachers to take ownership of their LTMI experiences. For example, teachers could access the PD materials in any order, rather than necessarily in the order offered in the summer workshops.

Table 2
JITL opportunities embedded within LTMI to enhance teachers’ zones of enactment

PD Tool	JITL Opportunity	Zone of Enactment
Printed materials	Eight PD booklets including a range of inquiry tasks, links to videos of lessons from local classrooms and guidelines for enacting inquiry practices.	Policy
Website	An online platform with access to eight PD booklets, links to inquiry teaching websites and videos, and literature readings.	Policy
Face-to-face meetings	Ongoing occasions bringing teachers from different schools together to share ideas and challenges, while seeking solutions amongst colleagues.	Professional
Knowledgeable facilitators	Teachers with experience in inquiry teaching and teacher PD leading the LTMI sessions and providing support for participants along the course.	Professional
Community building with a school colleague	Pairs of teachers attending the PD programme, intended for participants to connect with a colleague from their own school.	Professional
Reflective journal	Teachers keeping a journal to write post-lesson reflections based on pupils’ responses to inquiry practices.	Pupils

Methodology

This research draws on an interpretivist research paradigm, with the underlying assumption that understanding of reality is embedded within a social construction (see Guba, 1990). A sound understanding of teacher learning could be gained by studying how teachers operate within the community cultivated by the PD, and within their own work-based context. A data-driven, inductive approach (see Boyatzis, 1998) was employed to allow patterns, represented by the teacher voices grounded in the data, to emerge from the ‘realities’ provided by the participants. The goal was to understand multiple ‘realities’ across the various data sources from the teachers’ perspectives, their experiences and views of effective PD.

The Case Study

This research adopted a case study methodology (see Yin, 2003), with the unit of analysis being a small group of Maltese secondary school mathematics teachers as they learned to enact inquiry while participating in a one-year-long PD programme. This case study involved observations and interviews – which took place before, during and at the end of teachers’ participation in LTMI – with seven teachers, of whom three were purposefully selected for an in-depth investigation of teachers’ understanding and enactment of inquiry. This methodology served as an all-embracing strategy to research how participation in PD may support teachers in learning to implement inquiry practices in their classrooms over time. Contextual detail and the representation of teachers’ voices were key elements to focus on within the research design.

Using Teacher Beliefs

The beliefs (about mathematics, teaching and learning) criterion was important as it addressed the personal resources of teachers’ zones of enactment which, according to Spillane’s (1999) model, is central to teacher learning and enactment. Prior to the PD, teachers filled in a questionnaire that sought to categorise teacher beliefs under transmission, discovery and connectionist (see Askew et al., 1997). A transmission belief system views learning as a teacher-led individual activity based on watching, listening and replicating; a discovery belief views learning as an activity based on pupil-led practical exploration and reflection; and a connectionist belief views learning as a social activity where learners are challenged and learn by negotiating meanings with teachers. We used the questionnaire format and the nine statements provided by Swan (2006), asking teachers to position their own beliefs about (i) mathematics, (ii) teaching and (iii) learning by giving each one a percentage weighting (see Appendix 1). The three percentages in each section had to add up to 100. The first statement in each of three sections corresponded to a transmission, the second to a discovery and the third to a connectionist belief. However, teachers were not made aware of this classification. Their ratings were analysed by working out the mean of the percentage weighting for statements under transmission, discovery and connectionist. In addition, the questionnaire included questions related to general information about their school sector, year groups taught, teaching experience and qualifications, teachers’ current teaching practices, their structuring of lessons and their definition of inquiry teaching.

The Participants

At the end of the data collection period, three participants (1 male and 2 females) were purposefully selected from the case study (2 males and 5 females). Given the large data set about each of the seven teachers, the sampling framework presented by Patton (1990) was used. Intensity and maximum variation sampling strategies led to the selection of three differing teachers – Chris, Greta and Sarah (pseudonyms, see Table 3). While the seven teachers provided extensive data about their enactment of inquiry teaching, five of them (Chris, Greta, Sarah, Colin and Jackie) contributed data that specifically focused on JITL and the opportunities it offered in supporting their learning. Of these five, three were selected based on how they varied on their school contexts (both state and non-state), beliefs (spanning two out of three of the pre-CPD belief orientations), different lengths of teaching experience (ranging from 1-5 years to 16-20 years) and the year groups that they were teaching (years 7, 8 and 9). Unfortunately, the only teacher holding discovery beliefs (Tania), was not included as she did not contribute data about JITL and the learning opportunities it provided for her.

Table 3
Information about the participants²

	Teacher	School	Beliefs Pre-PD	Teaching Experience (Years)	Year Group Taught
Purpose-fully selected	Chris	Non-state	Transmission	1 – 5	7
	Greta	Non-state	Connectionist	16 – 20	8
	Sarah	State	Transmission	16 – 20	9
	Colin	Non-state	Transmission	1 – 5	9
	Jackie	Non-state	Connectionist	16 – 20	10
	Tania	State	Discovery	1 – 5	10
	Janet	State	Connectionist	11 – 15	8

Ethics approval for the research was granted by all schools and informed consent was then obtained from all teacher-participants and heads of school prior to conducting the research. Each teacher and head of school was provided with information about the LTMI programme through an information booklet. One-to-one meetings were also held to discuss the research project and their involvement in the research process. The study adhered to the ethical principles of informed consent, confidentiality, anonymity and the right to withdraw at any point (see British Educational Research Association, 2018).

Data Collection

Data collection, spread over a 14-month period, was designed to capture the beliefs, practices, experiences and learning of teachers at different stages during the study – prior, during and after LTMI. Data from the pre-PD teacher questionnaire were used to select the three cases and to gather data about their classroom practices, knowledge about inquiry and the challenges they envisaged encountering. The same questionnaire was also used at the end of the study to identify potential changes in teachers’ views, understanding of inquiry, and their practices and beliefs. During LTMI, four other research instruments were used – semi-structured interviews, lesson observations, teacher lesson journals and a focus group discussion – to contribute data towards understanding teacher enactment of inquiry. The semi-structured interviews and focus group were used to answer the research question: “Within an adaptive PD programme, which JITL opportunities do teachers report as supportive in enacting inquiry?”

Semi-structured interviews (see Fontana & Frey, 2000) were intended to capture data at three critical points during the study: before teacher participation in the PD, following their participation in the summer workshops, and at the end of the PD programme. While the first interview addressed aspects linked to motivations for participation, views, practices and knowledge of inquiry, the second interview investigated what participants gained from involvement in the PD workshops, and what they intended to take into their classrooms. The

² Teachers’ beliefs: classified into transmission, discovery and connectionist (see Askew et al., 1997) using a set of statements asking teachers to position their own beliefs about mathematics, teaching and learning
 Teaching experience: the number of years of teaching after completing their initial teacher education
 Year group age: Year 7 (11 to 12 years old); Year 8 (12 to 13 years old); Year 9 (13 to 14 years old)

third, and final, interview offered teachers a retrospective, reflective analysis to describe potential challenges and learning experiences encountered in their LTMI journey to make changes towards inquiry teaching. For example, questions in the second and third interview asked participants to describe their experiences and identify LTMI activities that they found most valuable in supporting their professional development. Each interview, which took between 40 and 50 minutes, was audio recorded and later transcribed verbatim in Maltese.

As a qualitative method for gathering data, the focus group brought together the researcher and the original seven teachers to discuss their PD experiences and the perceived effectiveness of the PD for their professional learning. The focus group participants were led through the discussion by the researcher, acting as a moderator, using questions as probes and prompts for participants to elicit experiences, meanings and insights into different aspects of the LTMI programme. Through the focus group, participants engaged in discussion about attitudes, perceptions and experiences (Krueger & Casey, 2015) related to their immersion in the PD programme offered. The focus group took 75 minutes and was video recorded. The video recording was later transcribed for analysis.

All interviews and the focus group discussion were held in Maltese and only the quotations included in this paper were translated into English. To ensure translation reliability, once translated into English, the first author asked a colleague (a Maltese teacher of English) to translate them back to Maltese. Upon cross-checking this version with the original, any minor modifications needed were addressed.

Data Analysis

Data analysis was guided by the research question and conducted using a hybrid approach to qualitative thematic analysis using staged iterative coding (see Braun & Clarke, 2006), and incorporating both a data-driven inductive stage (see Boyatzis, 1998) and a deductive stage. A thematic approach involves pattern recognition within the data, and emerging themes become the categories for analysis. Themes emerge from the data as a result of the active engagement that the researcher plays in coding, identifying patterns and themes, selecting these and eventually reporting them (Patton, 1990).

Inductive coding (see Boyatzis, 1998) began with close reading of the text and consideration of possible multiple meanings. Each interview and the focus group transcript were then divided into chunks – usually short paragraphs of between 20 and 60 words – applying an open-ended coding technique to label comments and assign codes in the margins. Initial codes focused on significant statements, comments and actions that reflected teachers’ thoughts, judgements and expectations of PD. These codes and comments were then compared and grouped to create themes. Codes generated included “targeted feedback”, “mindfulness”, “classrooms”, “collaboration”, “availability of materials”, “support”, “identity” and “self-directed learning”.

The deductive coding drew on zones of enactment (Spillane, 1999) as a sociocultural theoretical framework. For example, descriptions relating to pupils’ experiences, responses and reactions were coded as “pupils”. The other deductive codes used were “policy”, “professional”, “public” and “private”.

The analytical process involved comparing inductive and deductive codes that eventually complemented the emergence of themes that served to answer the research question (see Table 4). The full set of codes obtained is available at figshare.com/articles/figure/JITL/9751694.

Table 4
Inductive and deductive codes generated from the data

Inductive code	Deductive code	Theme
Mindfulness Classrooms	Pupils	Teacher mindfulness of classroom situations creates JITL
Collaboration Support Targeted feedback Identity	Professional	Collaboration provides support and targeted feedback that enhance teachers’ identity
Availability of materials Self-directed learning	Policy	Availability of PD materials provide self-directed learning for just-in-time knowledge about teaching

In reporting findings, we attempted to capture as faithfully as possible the views narrated by teachers. Member check (see Koelsch, 2013, p. 12), which involves presenting transcripts to participants and asking for correction and clarifications, was used as a means to validate what was captured (Lincoln & Guba, 1985). This member checking was also intended to serve as a reflective exercise for both researchers and participants. Hence, participants were provided with a document of the transcript for each interview and the focus group discussion and asked to comment on how accurately the transcript captured what they described. Comments from two of the three purposefully selected participants were received. Each of these were further discussed and amended following an online conversation, via email, asking participants to add further detail. Suggested changes included clarity about descriptions of classroom situations and insight into teachers’ PD experiences.

Results

Below, we present data from the three selected teachers in the case study outlining how each of these three sectors—pupils, professional and policy—provided JITL opportunities for enacting and learning about inquiry teaching.

Pupils: Teachers’ Mindfulness of Classroom Situations Creates JITL About Inquiry Enactment

Learning opportunities for teachers necessitated reflections and actions as a result of the demands from pupils’ initial and ongoing encounters with inquiry teaching. In implementing inquiry, these three teachers (Chris, Greta and Sarah) were aware of pupils’ prior experiences learning mathematics, which were mainly characterised by transmission teaching. For them, building pupils’ trust and lines of communication with pupils, while integrating inquiry, was critical. As a result, they were receptive to classroom situations related to issues about pupils’ participation, reactions and dispositions to inquiry teaching.

You need to show students that you respect their ideas and can learn from them. If this communication and trust is missing, then it is unlikely for the teacher to improve his teaching.

(Chris: Interview 3)

This “mindfulness”, which Brown and Ryan (2003, p. 822) define as the “state of being attentive and aware of what is taking place in the present,” opened up opportunities for just-in-time feedback and reflection for teachers.

Students struggled with inquiry. Hence, I reflected on this and adapted tasks and lessons to offer gradual challenges that they could manage.

(Sarah: Interview 3)

Being open to listen to and take on board students’ suggestions and ideas helped me develop as a teacher. I learned a lot about inquiry teaching from my students.

(Chris: Interview 3)

As much as possible, I listened to what students had to say ... what they liked and disliked about their inquiry experiences. I took these into consideration to improve my lessons.

(Greta: Interview 3)

Sarah, Chris and Greta developed their teaching by engaging in a reflective exercise to learn from classroom experiences. Their mindfulness to ongoing critical incidents happening in their classrooms offered JITL opportunities for teachers to develop their inquiry practices based on the pupils’ experiences. Pupils were, hence, an important stimulus for teachers to improve on their personal resources for teaching through inquiry. For example, pupils’ evolving positive responses to inquiry tasks helped teachers to believe more in their pupils’ capabilities to undertake challenging work. It appears that the shift to a more collaborative and inquiry-based approach was sustained by teachers’ mindfulness to listen to and observe pupils closely. This allowed for direct feedback that enabled teachers to recognise just-in-time elements of PD—accessing online resources, writing down reflections in their journal and then sharing these during face-to-face meetings—that were useful in improving their inquiry practices.

The three teachers also sought to gain insights from situations during which pupils struggled or commented on the difficulties encountered. For example, Sarah had initially taken up the idea of using tasks involving matching cards or discussion statements to engage pupils in inquiry. However, she observed that most groups were rushing through these activities in order to finish within the time assigned, usually 10-12 minutes. Through her mindfulness in observing, reflecting and eventually sharing it with others during one of the follow-up meetings, Sarah came to an important conclusion. Given the limited 35-minute lesson time available, rather than extending the time on the task, she decided to reduce the number of cards or discussion statements assigned. Sarah found that, by reducing the quantity of material for discussion, pupils eventually engaged themselves in more focused, in-depth discussions, and she found more opportunities to challenge their reasoning.

A key element contributing to teacher learning was the teachers’ capacity to develop their reflective practices by considering and valuing pupils as a major resource for improving their inquiry practices. In enacting inquiry, the pupils sector appeared to contribute to developing teachers’ personal resources, and data showed that their ongoing personal reflections on classroom situations provided JITL. Through JITL, the three teachers were mindful of critical incidents and acted in ways to address these. Feedback from pupils appeared to prompt reflection, sharing and thinking, and opened up possibilities for redesigning teaching that addressed pupils’ learning needs.

Professional: Collegial Support Generates Targeted Feedback That Shapes Teachers’ Identities

For these three teachers, the social learning opportunities encountered during LTMI enhanced the “professional” sector of their zones of enactment. Besides the opportunities for feedback and reflection arising from their classrooms, teachers’ learning about inquiry teaching was concurrently supported by the ongoing opportunities for interaction with colleagues during the LTMI meetings. In the focus group discussion, Greta mentioned that the LTMI environment provided “*the opportunity to demonstrate*” their work and practices. The collaborative PD environment appeared to allow agency and freedom for teachers to make as many contributions as they liked.

The meetings helped me improve on the strategies I was using, getting tips from what was discussed. Meeting others was for me crucial in persisting with inquiry.

(Sarah: Focus Group Discussion)

Coming for the meetings was not imposed, there was no-one checking on what I was doing ... that made the difference. This was something I wanted to do for myself and if there was a time when I could not contribute as much, there was nothing wrong with that ... so I was free and in control of my own professional development.

(Chris: Focus Group Discussion)

Collegiality was valued, and meetings were not viewed as merely a way to share experiences. Rather, they offered teachers ongoing opportunities to listen to and provide their own reflections on each other’s experiences, while appreciating the diverse working contexts framing their respective workplaces and classrooms. Chris, for example, felt that LTMI offered him the opportunity to take responsibility for his own professional learning. Apparently, this promoted his self-determination and self-directedness to engage in learning when and as needed.

Opportunities for interactions, arising from LTMI, also provided teachers with targeted feedback on their understanding and enactment of inquiry. Sarah and Greta both mentioned the community as an essential feature of the PD, as this generated feedback targeted towards the challenges that they were facing and, thus, helped them to persist in using inquiry. For Greta, this community represented a “*support group*” (Interview 3), with opportunities to exchange ideas with others. Similarly, Sarah mentioned the learning opportunities offered by the PD facilitators, acting as knowledgeable others, to discuss the inquiry tasks and improve the strategies she used. LTMI meetings offered the space where teachers could share their dilemmas, seek support and develop their knowledge of inquiry teaching over time. In particular, they valued the JITL knowledge and experiences shared by knowledgeable others. For instance, Sarah appreciated that knowledgeable others “*were teachers themselves*” and so she “*could easily relate to what they were saying*” (Interview 3). However, knowledgeable others “*did not provide solutions straight-away but challenged us to think, discuss and try things out*” (Greta: Interview 3).

Engagement in the LTMI community eventually shaped the identity of teachers; that is, their self-perception of their own role in learning about teaching, their agency and relationship with others.

I am finding myself doing things and acting in ways that are not typical of the ways I used to act in class before. I am also more open to challenges, to critique from colleagues and, hence, feel better prepared to change.

(Chris: Focus Group Discussion)

I feel more confident now to accept and take on new challenges. I am more aware of my own needs and in control of my own learning.

(Greta: Focus Group Discussion)

I really feel changed this year. Now I believe more in students’ capabilities and learn a great deal from their learning experiences.

(Sarah: Focus Group Discussion)

Sarah, Greta and Chris spoke about developing themselves as teachers through their engagement and the support received within the collaborative approach of LTMI. Sarah changed in her self-perception of her role as a teacher and those of her pupils. She experienced a change from being a transmission teacher (see Askew et al., 1997) to one who was now more receptive to employ inquiry learning strategies with pupils. Similarly, through his PD experience, Chris learned to gradually shift more responsibility onto pupils; for instance, he readily pursued pupils’ lines of thinking rather than imposing his own. In the same way, Greta revealed more confidence in taking challenges that she would not have done previously.

For these teachers, however, learning about inquiry within the school context was characterised by isolation. Sarah declared that no teacher at her school used inquiry to teach mathematics and, hence, she could not seek any assistance there. This was the same for Greta, who described a rather competitive atmosphere between teachers as a “*race to cover the exam syllabus*” (Interview 2). Chris, on the other hand, occasionally discussed tasks and lessons with a colleague who also attended the LTMI meetings and who consistently used inquiry. Despite this experience, Chris still felt that what Krainer (2001, p. 274) describes as a “lone-fighter culture” prevailed within his school:

You become aware that your ideas are not recognised. It feels like they [school colleagues] are telling me to keep my ideas to myself because they fear that these might be liked and imposed on them by the school. In a subtle way, you learn not to seek colleagues for help.

(Chris: Interview 3)

Within their schools, these teachers felt isolated in their journeys to innovate their practices. While LTMI sought to create within-school JITL by having pairs of teachers from different schools join the PD, occasions for just-in-time collaboration between teachers within their schools turned out to be rare. School administrations did encourage groups of teachers to participate in LTMI and undertake innovative practices. However, collaborative supporting structures and a school learning culture of sharing and support were lacking.

Within the professional sector of teachers’ zones of enactment, these isolated practices often saw teachers retreating into their own classrooms and keeping professional exchanges with school colleagues to a minimum. It appeared that the social aspect of JITL was lacking in schools and limited to the LTMI community component of the PD. Social enactment zones that extended beyond teachers’ individual classrooms were sustained by ongoing deliberations with LTMI colleagues and supported by knowledgeable others.

Policy: Availability of PD Materials Provide Self-directed Learning for Just-in-time Knowledge About Teaching

Within the policy sector of teachers’ zones of enactment, an important element for inquiry enactment was that teachers’ deliberations were enabled by the resources they created, and the materials provided in the PD.

Within the adaptive approach of LTMI, teachers were offered teaching resources but also had opportunities to collaboratively create their own. The summer workshops provided teachers with access to a set of eight PD booklets and a bespoke LTMI website. While these materials were important to provide knowledge about inquiry teaching, they enabled conversations about not just *what* to use but *how* to use resources effectively. These teachers learned about inquiry by accessing and critically analysing PD materials. Hence, they did not just put into practice the PD material offered; they questioned the material, adapted and evaluated it—on their own and during meetings. Teachers’ enactment zones were both individual and social, mediated by deliberations about material resources that supported conversations on mathematics teaching, eventually enabling them to change elements of their practice over time. For example, Greta struggled to see how inquiry teaching could be aligned within the policy context focusing on high-stakes examinations.

Perhaps my mindset is what has changed ... rather than saying that inquiry is not for my Year 11 students, I now consider that some elements of inquiry can be incorporated in my teaching.

(Greta: Interview 3)

The opportunities Greta had, to look into the materials, adapt and use them, appeared to enable her to widen her perspective and see possibilities that went beyond her initial perceptions. For example, she identified the use of challenging tasks and more open questioning as aspects that she could transfer to her teaching in the Year 11 classes.

Access to the LTMI website resources offered opportunities for learning that influenced teachers’ views about policies, curriculum, and assessment in the mathematics class. This was particularly important for those teachers operating within school systems that emphasised examinations, transmission teaching and summative assessment.

Now I encourage and expect students to think, to share their thinking and to ask questions.

(Chris: Interview 3)

I give students a problem and let them come up with ideas. I am using more group work, challenging students and helping them to correct their own mistakes.

(Sarah: Interview 3)

LTMI also offered JITL opportunities by supporting teachers to pay attention to the material that they could implement in their classrooms. All teachers reported that they mostly accessed, adapted and used inquiry tasks. However, teachers also watched lesson videos and accessed websites “to obtain knowledge about a specific dilemma encountered” (Sarah, Interview 3). These teachers also reported that access to resources was helpful, particularly when opportunities to consult others were limited. Greta, for example, stated that she found “*new ideas, strategies and materials and adapted these*” (Interview 3) for her class. Data indicate that, while enactment zones were positively influenced by ongoing deliberations between teachers from different schools, they were supported by teachers’ self-directed access to a range of PD materials, and the adaptations that these teachers eventually made.

Discussion

Data analysis shows that teacher learning about inquiry teaching was facilitated by JITL opportunities influencing different sectors within teachers’ zones of enactment. In particular, the teachers developed their inquiry practices through the “pupils”, “professional” and “policy” sectors.

This adaptive PD had no effect on the “public” and “private” sectors of teachers’ zones of enactment. Initially, teachers were concerned and expressed frustration about the potential of using the mathematics textbooks for inquiry teaching and the pressure parents would put onto them once they deviated from the more transmission-oriented style of teaching. They perceived the textbooks tasks as “*limiting in the inquiry teaching approach*” that they were expected to promote in class (Sarah, Interview 1). According to these teachers, pupils were “*oriented to practise mathematics using the textbook because they think in terms of examination success*” (Chris, Interview 1). These teachers overcame this challenge by integrating the textbook as a teaching tool within the PD classroom materials available and the resources they created. Additionally, Chris deemed that “*parents would object to inquiry because they are so demanding of teachers to focus on drill and practice*” (Interview, 1). However, over the course of the PD, teacher overcame these dilemmas, because parents “*did not complain*” (Greta, Interview 3) and “*did not report any negative feedback about my teaching*” (Chris, Interview 3). In other words, the public and private sectors appear detached, as teachers saw no constraints arising from these two sectors.

Evidently, JITL opportunities embedded in PD provided teachers with ongoing support through targeted feedback and community engagement. This study suggests that teachers are likely to rely on those JITL opportunities that facilitate and enable their understanding of inquiry practices. The JITL opportunities, supporting teachers’ enactment of inquiry, were related to the pupils, professional and policy sectors, and we will now discuss each of these in turn.

With regard to the pupils sector, an important finding is that teachers learned about inquiry through their mindfulness of pupils’ engagement with inquiry. As direct recipients of their teaching, pupils provided teachers with reliable, telling and just-in-time feedback that they could reflect and act upon. Pupils’ responses to inquiry and their development in thinking and communicating mathematics were highly powerful motivators for teachers to improve and persist with inquiry teaching. This finding echoes research by Sprott (2019) on the central role that pupils play in teachers’ professional development. When teachers are receptive to pupils’ responses about classroom practices, teacher reflection is enabled and, as a result, this supports their professional learning.

Within the professional sector of teachers’ zones of enactment, privacy has been found to be a dominant feature in Maltese schools (see Attard Tonna & Shanks, 2017). LTMI, hence, sought JITL opportunities through (1) within-school communities (pairs of teachers from schools attended the PD), and (2) community building across schools (the LTMI community). It appears that school systems did not facilitate teacher collaboration, and this led to individual rather than social enactment zones. During this period, teachers could engage in ongoing communications with the LTMI community and PD facilitators who helped them focus on their specific needs. Interactions with PD facilitators, who acted as knowledgeable others, and colleagues offered more flexible structures for teacher learning. Evidence shows that PD meetings, enabled by PD facilitators who were also practitioners themselves, and driven by ongoing deliberations about practice-based experiences using a range of material resources, served as a transformative learning experience for teachers. Similar to the findings reported by Spillane (1999), Hodgen and Johnson (2003), and Golding (2017), data from this research shows that teachers’ enactment zones that are social were indispensable for their learning. Moreover, these social enactment zones allowed for ongoing feedback and collaboration that enabled teachers’ learning to teach through inquiry.

In LTMI, the policy sector, which incorporates policies, curriculum, and assessment practices, was enhanced by material resources available to teachers which they could access freely together with targeted support by PD facilitators. The highly adaptive JITL PD provided access to support that was offered when necessary and as requested by teachers. The availability of online support materials offered JITL that could respond to teachers’ immediate questions and concerns. In

addition, teacher learning was enhanced by creating flexible environments that allowed teachers to connect with colleagues and knowledgeable others who could help them with their immediate needs, doing this at their own pace. As Greenhalgh and Koehler (2017) contend, through JITL, the teachers in this study took control of the destiny of their own learning by pursuing the specific knowledge and resources that met their specific needs.

We have seen how JITL opportunities enacted in PD can offer design principles that can inform high quality PD enactment. With the ongoing need to improve the quality and effectiveness of PD for mathematics teachers, PD designers need to plan and provide PD that will help teachers understand, reflect upon, and enact the pedagogies being promoted. According to Spillane (1999), enactment zones that have strong social connections are an indispensable condition for profound teacher change. For the teachers in this study, learning spaces with opportunities for negotiation, reflection, collaboration, support, and feedback were critical. We have seen that when these learning opportunities are available, just-in-time, they appear to support teachers to recognise the pedagogical benefits of a new initiative and facilitate their learning and enactment of it. In embedding JITL, PD designs need to be flexible and responsive to teachers’ needs, they need to reach and nurture close alliances with schools, and they need to offer face-to-face and online collaborative opportunities to adequately support teachers’ professional learning journeys.

Within an adaptive PD, JITL enables professional growth (Vavasseur & MacGregor, 2008; Glazer et al., 2009), as it responds to teachers’ immediate needs through support structures that may include: access to resource material available online; systematic and ongoing observation of and interaction with pupils; individual and collaborative reflective practices leading to research; formal and informal discussions with colleagues and outside experts; and opportunities to share learning with a wider community. Approaches to collaborative PD offer possibilities for professional encounters and community building that have an important influence on teachers’ practices (Jaworski, 2003; McLaughlin & Talbert, 2001). The study we have described suggests that the ‘professional’ sector of teachers’ zones of enactment, which incorporates both formal and informal encounters that teachers have with other educators in and outside the school, is an important factor in creating JITL opportunities. For teachers, JITL opportunities may arise through formal encounters, such as whole-school and departmental meetings and PD opportunities offered by the school or by other education institutions. Informal encounters include participating in online groups and researching teaching material, or having discussions with colleagues during break, generally in staff rooms, corridors, and the school yard.

Conclusion

There is widespread consensus that effective PD needs to address the challenges teachers face in their classrooms, provide access to resources and expertise, and offer support through long-term engagement within a community of practice (Bannister, 2018; Cordingley et al., 2015; Loucks-Horsley et al., 2010; Stoll et al., 2012). These design principles focus on the importance of social resources in the development of teaching, in which access to other material and human resources and support are fundamental aspects. To this we add that PD needs to create opportunities through which teachers may obtain assistance when and where they need it. Through JITL, learning about practice occurs individually and collaboratively as teachers take responsibility for setting their own goals, collaborating, and systematically reflecting on practice in and beyond their own classrooms.

This study contributes to our knowledge on PD design by introducing the concept of JITL in teacher education through a set of design principles, drawing on the ‘pupils’, ‘policy’ and

‘professional’ sectors of teachers’ zones of enactment. Hence, the concept of JITL has implications for PD design, and integrating JITL can make PD more robust. In particular, PD integrating JITL is responsive to teachers’ professional contexts and embraces that learning about practice occurs at teachers’ own pace. Admittedly, PD needs to transform teacher learning from being just-in-case and instead creating just-in-time opportunities (Schrum, 1999). Teachers value practice-based learning that offers new forms of discourse communities with opportunities for just-in-time conversations and feedback on current matters. Through engagement in within-school professional networks (Goos et al., 2017), teachers may transform their insular work environments to address their just-in-time needs. Schools, as organisations, need to support this ongoing learning by strategically creating adequate time for collaboration, and time that is purposefully directed and structured for teacher learning (Garet et al., 2001).

Teachers, at all levels, need just-in-time assistance as they struggle to adapt new curricula and new instructional practices to their unique classroom contexts. Within an environment promoting social learning experiences, teachers may accumulate knowledge not only from their personal reflections on classroom practices but also from co-learning experiences (Jaworski, 2006) with colleagues and knowledgeable others. In these ‘expert to novice’ conversations, teachers should be the ones involved in talking about their teaching and learning experiences. The “knowledgeable other” has a key role in enabling teachers to take a critical stance to practice by stimulating thinking while providing timely support. Creating “critical friendship” (see Stoll et al., 2012) requires establishing positive co-learning relationships and agreements (Jaworski, 2003), where both parties respect the expertise of the other. The role of the knowledgeable other can serve to stimulate just-in-time thinking in pursuit of engaging teachers in exploring and inquiring about their practice, rather than merely describing it.

Hence, PD providers should give explicit attention to JITL at the design phase. We encourage PD designers to be reflective of the potential that support structures have in providing teachers with JITL that is responsive to their immediate professional needs. For example, PD providers need to devise ways in which JITL can support teachers to revisit, think critically about and refine their personal resources for learning. In other words, we think that teachers may develop their knowledge, beliefs, and disposition to reform their practices when PD designs consider and incorporate JITL opportunities that enhance teachers’ zones of enactment.

Research shows that teacher practices are more likely to be transformed by PD that is sustained, coherent and intense (Guskey, 2002; Supovitz et al., 2000); this study adds that teachers may improve their practices when they engage in a personally transformative experience. Professional learning needs to be conceptualised as authority and responsibility that is bestowed upon teachers to own it and lead it with others. PD needs to be enacted to offer networking opportunities for teachers to participate actively, take ownership and feel safe to attempt changes (Bryk & Schneider, 2002). This is the transformative purpose (see Kennedy, 2014) that PD designers should seek. PD with a transformative purpose sees teachers as inquirers creating opportunities for themselves to address their own professional development needs. Just as pupils enhance their learning of mathematics within an inquiry environment through just-in-time assistance (Mercer, 1995; Russo & Hopkins, 2019), this shifting of responsibility of PD onto teachers requires structured support that is made readily available for teachers to access and make use of.

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Appendix 1: Beliefs Statements

You are presented with three statements about mathematics, learning and teaching. For each statement give a percentage (%), so that the three percentages in each section add up to a 100.

Mathematics is...

- . a given body of knowledge and standard procedures. A set of universal truths and rules which need to be conveyed to students.
- . a creative subject in which the teacher should take a facilitating role, allowing students to create their own concepts and methods.
- . an interconnected body of ideas which the teacher and the student create together through discussion.

Learning is...

- . an individual activity based on watching, listening and imitating until fluency is attained.
- . an individual activity based on practical exploration and reflection.
- . an interpersonal activity in which learners are challenged and arrive at understanding through discussion.

Teaching is...

- . structuring a linear curriculum for the students; giving verbal explanations and checking that these have been understood through practice questions; correcting misunderstandings when learners fail to 'grasp' what is taught.
- . assessing when a student is ready to learn; providing a stimulating environment to facilitate exploration; avoiding misunderstandings by the careful sequencing of experiences.
- . a non-linear dialogue between teacher and learners in which meanings and connections are explored verbally. Misunderstandings are made explicit and worked on.