

Article

From Online Video-Based Professional Development to Differentiated Teaching: A Case Study of Mathematics Teacher

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Abstract

Video-based teacher professional development (TPD) offers teachers structured opportunities to examine their classroom practice, yet its role in supporting differentiated instruction (DI) in fully online formats remains underexplored. This longitudinal case study investigates how participation in a facilitated, fully online video-based TPD was associated with changes in the cognition and classroom practice of one lower-secondary mathematics teacher, with a specific focus on DI. Drawing on Major and Watson's four-dimensional model of teacher cognitive change, we analyse developments in the teacher's self-efficacy, self-evaluation, knowledge of teaching, and instructional beliefs, and link these to observable changes in differentiated classroom practice. Data were collected through six classroom observations, as well as a semi-structured interview focused on DI. The findings show that sustained engagement in structured video reflection and online professional learning community discussions supported a shift from predominantly teacher-centred instruction to more adaptive, student-centred teaching characterised by tiered tasks, embedded scaffolding for struggling students, enrichment for advanced learners, and increased collaborative problem solving.

Keywords: differentiated instruction; mathematics teacher; video-based teacher professional development; teaching practice

1. Introduction

Teacher professional development (TPD) plays a central role for increasing teachers' instructional competencies and improving student learning outcomes (Borko, 2004; Avalos, 2011). Despite extensive research, no single framework for effective TPD has achieved universal consensus. Desimone (2009) emphasises subject specificity and active learning, Kennedy (2016) categorises TPD approaches according to their underlying assumptions about knowledge and practice, and Sims et al. (2023) highlight the importance of integrating motivation, techniques, and sustained practice. Although these frameworks offer valuable insights, they tend to pay less attention to the role of structured reflection in supporting teachers as they navigate complex instructional challenges.

Differentiated instruction (DI) is one such challenge, as it addresses students' different levels of readiness, interests, and learning profiles (Tomlinson, 2017). While DI has been linked to increased engagement and achievement, math teachers frequently report difficulties in implementing it effectively. These challenges are caused by insufficient pre-service and in-service preparation, resource constraints, and the complexity of teaching



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in mixed-ability classrooms (Meutstege et al., 2023). To support DI, teachers need professional development that not only teaches them new ways to teach but also encourages them to think about and change how they teach. This allows teachers to change how they give assignments, interact with students, and grade them in ways that are responsive. Video-based TPD has emerged as a promising strategy in this regard. Teachers can analyse interactions, examine student responses, and reflect on their own pedagogical decisions by using video-recordings in structured and collaborative settings (Gaudin & Chaliès, 2015). Those processes are especially important for DI, which relies on teachers' ability to recognise differences in student understanding and respond flexibly.

While the benefits of video-based TPD for teacher learning are well documented, there is still limited understanding of how fully online video-based TPD supports the cognitive processes that enable teachers to implement DI in practice. In particular, there is insufficient research examining how participation in such professional development is associated with changes in teacher cognition and teaching practice over time. The present study partly addresses this gap by investigating how a teacher's cognition and classroom practice develop over time during participation in an online video-based TPD.

2. Literature Review

2.1. *Effective Use of Video in TPD*

Using classroom video in TPD promotes teacher learning because a mere narrative exchange of teaching experiences cannot mediate complex classroom interactions (de Jong & Lazonder, 2014). Videos present these interactions in a tangible, visual form, facilitating an in-depth analysis of different classroom situations (Borko et al., 2011). Classroom video has numerous positive outcomes in TPD. To begin with, the ability to rewatch videos allows teachers to concentrate on distinct aspects of the classroom environment, as well as on their own and students' moves. This possibility is important for gaining a deeper understanding of teaching and learning in the classroom and for improving one's observational skills. Sharing and accessing these videos via different online platforms also makes both asynchronous and synchronous learning possible. Established classroom observation protocols can be used to examine the video, providing a systematic and comprehensive framework for evaluation (Kang & van Es, 2019). However, the availability of classroom videos in TPD does not inherently imply that teachers have improved their observation or teaching skills. Engaging with the video content in a deliberate and thoughtful way is key to getting the most out of these classroom resources (Koellner et al., 2018; Marsh & Mitchell, 2014). Teachers benefit from reflection because it enables them to consider and internalise what they have observed. Collaborative analysis enriches this experience by integrating diverse perspectives and insights, thereby fostering a culture of collective learning. By engaging in these types of activities, teachers can discover their students' strengths and realise what they need to improve on in future lessons (Borko, 2004; Sherin & Han, 2004; Koellner et al., 2018; Marsh & Mitchell, 2014).

The use of classroom video in TPD can be analysed not only through the lens of teaching practice but also through the perspective of teacher cognition, which includes teachers' thoughts, knowledge, and beliefs. Previous learning experiences, teacher education programmes, classroom teaching experience, and educational policy all influence teacher cognition, which is resistant to change (Lunn Brownlee et al., 2017). However, research indicates that teacher education has the potential to strengthen, broaden, and transform teacher cognition: self-efficacy, self-evaluation, knowledge of teaching, and challenging beliefs (Major & Watson, 2018). Classroom video allows learning through examples of both effective and ineffective practices, offering valuable insights in the instructional moves employed by oneself or other teachers. Teachers' engagement in video-based TPD has the potential to bring about modifications in teaching practices, as well as in teachers'

dispositions towards their profession. This engagement can result in an enhanced level of teachers' content, general pedagogical knowledge, and pedagogical content knowledge, leading to improved learning outcomes for students and their heightened enthusiasm for the subject matter (van der Linden et al., 2021; Kiemer et al., 2014).

A key factor of effective video-based TPD is the iterative learning cycle, where teachers continuously engage in lesson observation, reflection, adaptation, and refinement (Koellner et al., 2018). This cyclical nature ensures that cognitive developments are successfully translated into sustained effective mathematics teaching practices.

2.2. Characteristics of Effective Mathematics Teaching

One of the goals of TPD is to assist teachers in improving their teaching skills and implementing changes in their lessons (Krille, 2020). This investigation focuses on whether a mathematics teacher participating in an online video-based TPD programme contributed to effective mathematics teaching. Therefore, it is important to understand the key components underpinning the effectiveness and quality of mathematics instruction. There are three dimensions that encompass effective mathematics teaching: (1) the level of cognitive demand required by tasks, (2) the provision of learning support through diligent monitoring of student progress, personalised feedback, and adaptive instruction, and (3) the implementation of efficient time management and effective teaching strategies (Praetorius et al., 2018). In effective mathematics instruction, the teacher acknowledges students' prior knowledge and uses it as a foundational basis for both student learning and their own teaching approach (NCTM, 2014; M. Smith et al., 2017). Effective teaching practices encourage the building of students' conceptual and procedural knowledge, as well as the development of collaborative learning skills and a sense of responsibility for both their academic achievement (Hattie, 2012; NCTM, 2014; M. Smith et al., 2017). In such teaching practice, students should also engage in self-reflection, drawing insights from their errors and autonomously arriving at conclusions regarding the underlying causes of these mistakes. To increase their chances of achieving success, students should not only be provided with feedback from their teacher but also from their peers (Hattie, 2009; M. Smith et al., 2017). However, one of the important aspects of effective mathematics teaching is creating equitable learning opportunities for all students, regardless of their readiness or learning profile (Le Fevre et al., 2016; Tomlinson et al., 2003; M. Smith et al., 2017). Such opportunities include adapting to students' needs through DI, which will be discussed in the following subsection.

2.3. DI in Mathematics Education

DI is a pedagogical strategy used to design instruction in mixed-ability classrooms in accordance with students' readiness, interests, needs, and learning profiles (e.g., Hunter et al., 2019; Tomlinson, 2017). While the precise definition and unambiguous operationalisation of DI are still lacking in the literature, there has been a growing understanding of its attributes. Deliberateness and adaptability are identified as shared characteristics among teachers who address the differences among students in a heterogeneous classroom (Jager et al., 2022). Teachers must identify the learning needs of their students and modify curriculum content, learning tasks, instructional strategies, learning objectives, and continuing assessments of students' progress (Prast et al., 2015; Van Geel et al., 2019). Effective DI leverages the varied backgrounds and skills students bring to the classroom, optimising learning opportunities for each individual (Parsons et al., 2018).

Mathematics teachers report being aware of the need for DI in mixed-ability classrooms and state their confidence in their ability to provide such instruction (Shayshon et al., 2014). However, Mellroth (2018) found that a substantial number of teachers are unfamiliar with DI strategies. Moreover, teachers frequently face challenges in effectively addressing the diverse range of mathematical aptitudes present in the classroom (e.g., Leikin & Stanger, 2011;

Mhlolo, 2017). Those include a lack of time and resources for teacher preparation, the need for collaboration within and across schools (Smit & Humpert, 2012), and an imbalance between teachers' understanding and implementation of DI (Whipple, 2012). Continuous PD is essential for in-service teachers to effectively address the learning requirements of their students (Van Geel et al., 2019). According to a recent systematic review by Langelan et al. (2024), effective TPD programmes for DI include design and classroom practice, collaboration, reflection, mentoring, and the utilisation of feedback. This review found that in such TPDs, the real-world examples of differentiated lesson plans and differentiated teaching practice helped teachers identify patterns and make more informed instructional decisions regarding DI. Moreover, the review detected that collaboration among teachers was beneficial and influential, and it enhanced the participants' comprehension of their own pedagogy, as well as student learning. Collaborative approaches, such as Lesson Study or professional learning communities (PLCs), afforded teachers the chance to share insights and participate in collective knowledge acquisition. Even though DI has shown promising outcomes not only in enhancing students' academic achievement but also in nurturing their social and emotional growth, international research highlights a concerning gap: many teachers feel ill-equipped to effectively employ DI in their classrooms. This underscores the need for comprehensive TPD programmes (Meutstege et al., 2023). Through such initiatives, teachers can cultivate a more inclusive and effective learning environment, contributing to enhanced student learning outcomes and holistic development. Implementing DI requires changes in teacher's beliefs, self-efficacy, self-evaluation and knowledge for teaching. Therefore, it is useful to investigate whether video-based TPD, known for its impact on teacher cognition, can support the development of DI.

3. Model for Integrating Video-Based TPD and DI

The present study draws on the four-dimensional model of teacher cognitive change proposed by Major and Watson (2018), which conceptualises how video-based TPD can influence teachers' cognition and classroom practice. The model emphasises four interrelated dimensions of cognitive change: self-efficacy, self-evaluation, knowledge of teaching, and challenging beliefs. Together, these dimensions describe how teachers develop confidence, reflect on their practice, expand their instructional knowledge, and reconsider their pedagogical assumptions through engagement with video-based professional learning. While the original model provides a comprehensive explanation of how video-based TPD influences teacher cognition, it does not explicitly address how these cognitive changes relate to specific pedagogical approaches. In this study, we extend the model by linking each dimension to DI in mathematics, providing a framework for analysing how cognitive change may support more adaptive and responsive classroom practice.

Self-Efficacy: Self-efficacy refers to a teacher's belief in their ability to implement effective instruction. Video-based TPD enhances self-efficacy by allowing teachers to observe successful differentiation strategies, analyse their own instructional choices, and build confidence in making pedagogical decisions (Sherin & Han, 2004).

- **Instructional impact:** Mathematics teachers with higher self-efficacy are more likely to experiment with DI, trust their instructional decisions, and persist in refining DI practices even when faced with challenges (Coles & Brown, 2021; Mellroth et al., 2021). Increased confidence in instructional decision-making is also consistent with research showing that reflective, design-oriented professional learning can support shifts in teachers' professional identity (Lambert et al., 2021).

Self-Evaluation: Video-based TPD promotes self-evaluation by enabling teachers to critically analyse their own lessons, recognise strengths and weaknesses in their teaching, and identify areas for improvement through structured reflection and collaborative analysis (Lambert et al., 2021; van der Linden et al., 2021).

- **Instructional impact:** Mathematics teachers with strong self-evaluation skills are better able to articulate and implement differentiation strategies, leading to more intentional modifications in lesson design, scaffolding approaches, and formative assessment practices. Through reflective processes and collaborative inquiry, teachers refine their instructional decisions to better support diverse learners (Herner-Patnode & Lee, 2021; Mellroth et al., 2021).

Knowledge of Teaching: Video-based TPD supports the development of teachers' knowledge of teaching by expanding their instructional repertoire, including strategies related to task design, scaffolding, and targeted differentiation.

- **Instructional impact:** As mathematics teachers deepen their knowledge of teaching mathematics, they are more likely to implement structured and purposeful differentiation, ensuring that instructional materials and learning activities align with students' diverse needs and levels of understanding (Coles & Brown, 2021; Langelaan et al., 2024). Design-oriented professional learning may further support this process by positioning teachers as active designers of instruction rather than passive implementers (Lambert et al., 2021).

Challenging Beliefs: Teachers often hold firmly established beliefs about instruction that can hinder the adoption of innovative practices such as DI. Video-based TPD can challenge these beliefs by exposing teachers to alternative perspectives, highlighting effective differentiation practices, and promoting a shift from teacher-centred to student-centred instruction (Lunn Brownlee et al., 2017).

- **Instructional impact:** Mathematics teachers are more likely to incorporate student-led learning, collaborative problem-solving, and individualised support structures into their lesson plans as instructional beliefs change. Studies on reflective and empathy-driven professional learning show how such processes can disrupt deficit-oriented beliefs and support more inclusive instructional practices (Fitzgerald et al., 2021; Lambert et al., 2021).

Research Focus

There is limited understanding of how fully online, video-based TPD contributes to changes in teachers' cognition and classroom practices over time, especially concerning differentiated mathematics instruction (Koellner et al., 2018; Lambert et al., 2021). Studies have usually examined either the benefits of video for teacher learning or DI as a classroom strategy in its own right. Using the model presented above, this study investigates how changes in teacher cognition are connected to observable shifts in teaching practice. Rather than measuring the effectiveness of DI using student achievement data, the study focuses on how participation in a facilitated, fully online video-based TPD may support cognitive and pedagogical change over time. The study is guided by the following research questions:

- (a) How does participation in an online video-based TPD influence a mathematics teacher's cognition regarding DI?
- (b) How does participation in an online video-based TPD influence changes in the teacher's practice, particularly with respect to DI?

4. Methods

4.1. Study Design

To answer the research questions, case study methodology was applied. The strength of case study research lies in its ability to ask important questions about educational practice, such as why and how (Yin, 2014). If a case study is conducted over an extended period of time (at least one year for social studies and nine months for educational projects),

it represents a longitudinal case study (Saldaña, 2003). Longitudinal case study designs permit researchers to investigate a phenomenon in greater depth over time using a variety of methods, such as repeated interviews and observations, document analysis, and small-scale questionnaires (Mills et al., 2010). The aim of the case study is not to generalise findings to a wider population, but to examine the phenomenon in depth within its specific context (Stake, 2008). In our study, the focus is on tracing developmental processes within a single case rather than on evaluating the general effectiveness of the whole TPD.

4.2. Study Context

This study was conducted within the SURFPRIMA research project, in which an online video-based TPD for mathematics teachers was designed and implemented (Filipov, 2023). The project aimed to explore how video-based reflection within an online PLC may support changes in mathematics teachers' instructional practice. The present paper focuses on a single-case study of one teacher participating in this TPD in order to examine in detail how engagement in the professional development process was reflected in classroom practice over time.

4.3. Description of the TPD

The TPD brought together seven mathematics teachers and six members of the research team (mathematics teacher educators and researchers) to form an online PLC. The group met biweekly via Zoom over the course of one school year. All participating teachers worked in lower secondary schools. Among them, two worked in rural schools and the others worked in urban schools across different geographical districts. None of the participants were novice teachers; their teaching experience ranged from 8 to 25 years. The first five sessions focused on theoretical principles of effective mathematics teaching. In the subsequent sessions, teachers analysed video recordings of their own lessons in which these principles were implemented. Each meeting centred on the analysis of a 20 min classroom episode and followed a structured performance feedback protocol that included introductory reflection, positive and corrective feedback, suggestions for future lessons, and concluding reflections (Hemmeter et al., 2011). Discussions were facilitated by members of the research team. In this study, facilitation refers to structuring the conversation rather than providing directive coaching. Facilitators organised the flow of discussion, selected video episodes, and posed open questions encouraging teachers to articulate and examine their instructional reasoning. Responsibility for interpreting classroom events and making pedagogical conclusions remained with the teachers.

During each session, teachers first discussed selected video segments in small groups together with the experts and then shared their insights in a plenary discussion. Additional reflection took place asynchronously through written analyses posted on Moodle forums, allowing teachers to engage with one another's observations outside scheduled meetings. This combination of synchronous discussion and asynchronous reflection created a continuous online professional learning environment centred on the analysis of classroom practice. Over time, responsibility for initiating lesson analysis gradually shifted from the experts to the teachers whose lessons were being discussed. Teachers began each session by presenting their own reflections and identifying key instructional moments for discussion, while peers and experts contributed additional perspectives. Because all discussions were grounded in classroom video recordings, the focus remained on teachers' interpretations of their own and their colleagues' practice.

The TPD itself did not focus on the use of specific digital tools. Instead, it centred on analysing classroom practice through video recordings and collaborative reflection. During the project, the participating teacher independently introduced several digital tools while experimenting with instructional ideas that emerged from these discussions. The

tools functioned as enactment resources rather than as components of the professional development intervention.

All participants provided informed and voluntary consent after being briefed on the study's objectives and procedures. Approval was obtained from the Ministry of Science and Education of Croatia, the Education and Teacher Training Agency, school principal, and students' parents or guardians (URBROJ: 533-05-19-0004). Students without parental consent were excluded from recordings, ensuring their rights were protected. Participants retained the right to withdraw from the research at any time.

4.4. Participant

The case study participant was one female mathematics teacher in lower secondary school (grades 5–8). For the purpose of anonymity, the teacher is referred to as Ms. Maddie. She was one of seven mathematics teachers who participated in the same online video-based TPD. Her mathematics advisor recommended her for participation in TPD based on her strong motivation to improve her teaching practice and her openness to innovative approaches, like DI. However, she was not selected for the case study in advance. Instead, the case emerged during the project. Although several teachers participated in the TPD, Ms. Maddie was the only participant who consistently attempted to implement DI in her classroom. For this reason, her case provided the most suitable opportunity to examine the development of DI practices within the TPD context.

Ms. Maddie worked in a rural school where opportunities for subject-specific professional development were relatively limited and had fewer colleagues teaching the same subject. Thus, the online TPD provided an important space for her professional exchange and reflection that would otherwise have been difficult to sustain. At the time of the study, Ms. Maddie had eight years of teaching experience. She held a Bachelor's degree in Mathematics and a Master's degree in Mathematics Education. At the beginning of the project, she expressed concerns about low student motivation and disengagement in mathematics, which motivated her to implement DI.

4.5. Data Collection

The data collection process encompassed both classroom observations and interviews with the teacher. Since the teacher chose to incorporate differentiation into her lessons as a key aspect of effective mathematics teaching, an online semi-structured interview was conducted related to this topic (Table 1).

Table 1. Interview protocol.

Prior experience with DI	
1.	How did you approach differentiation in your teaching before participating in this TPD program?
2.	How has your approach to DI changed during your participation in the TPD program compared with your previous teaching practice?
3.	Which aspects of implementing DI in your teaching have been most successful?
4.	What challenges or difficulties have you encountered when implementing DI?
5.	How did students respond to the introduction of DI in your lessons?
TPD focused on DI	
1.	What prior professional development experiences have you had related to DI outside this program?
2.	In what ways, if any, has this TPD program supported your implementation of DI?
3.	Were there any aspects of the program that you found less helpful or missing?
4.	What recommendations would you offer for designing professional development programs that support mathematics teachers in implementing DI?

There were six classroom observations spread out over one school year. The lessons were recorded with two cameras: one at the back of the classroom and the other carried by a researcher who moved around the room to film what the students were doing and saying. This placement enabled the researchers to observe Ms. Maddie's teaching strategies, her engagement with the students, and the interactions that occurred among the students. The first lesson was recorded at the start of the TPD, and all other lessons were recorded after the theoretical part of the TPD was over.

Student achievement was not measured through tests. Student-related observations (e.g., collaboration, participation, metacognitive talk) are interpreted as indicators of classroom participation rather than direct evidence of learning outcomes.

4.6. Data Analysis

Data analysis combined qualitative and quantitative methods to comprehensively explore changes in teacher cognition and practice within above described video-based TPD. The analysis focused on two primary sources: classroom observation data and interview data, both analysed using systematic protocols and frameworks.

4.6.1. Classroom Observations

Teaching Observation Form (TOF) (Bezinović et al., 2012) was used to evaluate teaching practices across three dimensions: lesson structure, individualisation and differentiation, teaching metacognitive skills and learning strategies and feedback. To ensure consistency in data interpretation, TOF scoring followed a three-tier scale:

- Not Implemented (NI): The teaching practice was absent or inconsistently applied.
- Emerging Implementation (EI): The teaching practice was present but inconsistently or partially integrated.
- Fully Implemented (FI): The teaching practice was consistently and effectively integrated into instruction.

Each observation was accompanied by qualitative descriptions, providing deeper insights into specific instructional behaviours.

The COPUS protocol (M. K. Smith et al., 2013) was used to code and analyse classroom activities in two-minute intervals. The protocol captures observable behaviours of both teachers and students, allowing researchers to characterise how classroom time is distributed across different instructional and learning activities. These included teacher activities (e.g., lecturing, providing feedback, and moving around the classroom) and student activities (e.g., group work, answering questions, and whole-class discussions; see Figure 1). To examine how lesson dynamics changes during the intervention, the frequencies and percentages of time allocated to each activity were calculated. Multiple behaviours could be coded within the same two-minute interval, as COPUS is designed to capture all actions occurring during that interval. The protocol is descriptive rather than evaluative and does not assess instructional quality; instead, it records the occurrence of specific observable actions. For analytical purposes, each code was treated as a frequency of occurrence across all intervals in a single lesson. The number of intervals in which a specific behaviour appeared was divided by the total number of coded intervals, yielding the percentage of time that behaviour occurred. Because the codes are not mutually exclusive, percentages do not sum to 100%; rather, they reflect overlapping instructional and learning activities. Although COPUS was originally developed and validated for undergraduate STEM classrooms, its focus on observable, content-neutral behaviours makes it applicable across educational levels. The protocol's coding categories, such as lecturing, group work, and whole-class discussion, reflect instructional and learning activities that are not specific to higher education and are equally relevant to lower-secondary school contexts.

Two independent coders analysed the TOF and COPUS data to ensure coding reliability. Cohen's Kappa was calculated, yielding scores of 0.82 for TOF and 0.87 for COPUS, indicating strong inter-rater agreement. Any discrepancies in coding were resolved through collaborative discussion, ensuring consistency and rigour in the analysis.

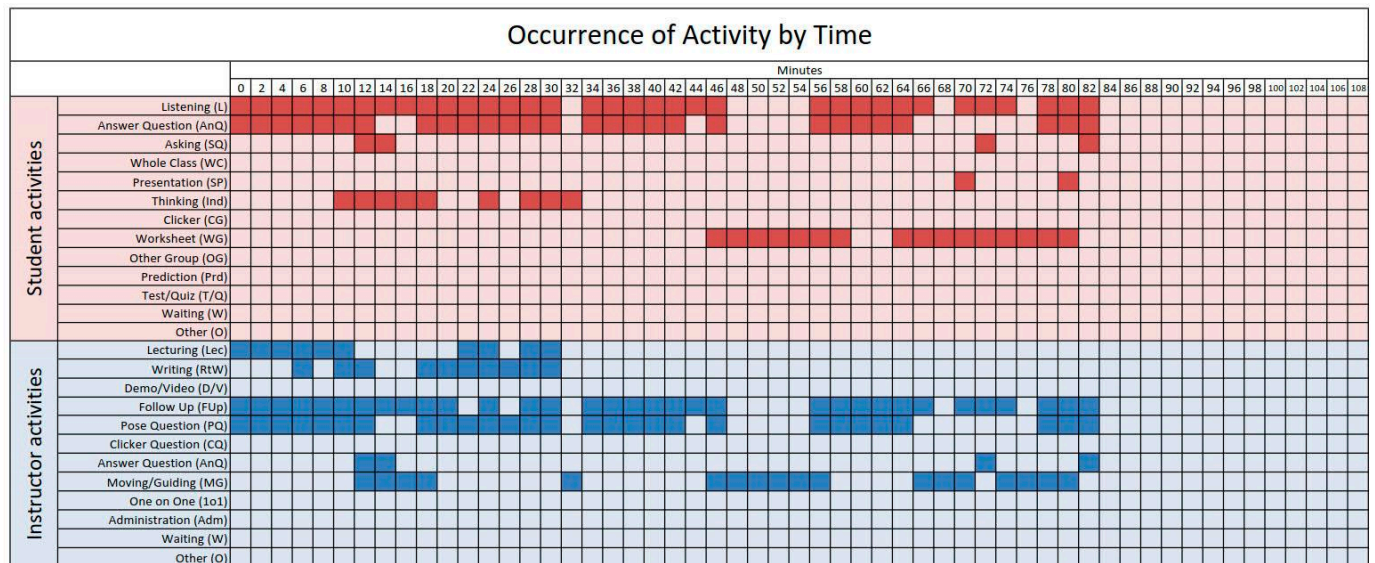


Figure 1. Example of coding a recorded lesson using COPUS protocol. The colors follow the standard COPUS convention: instructor activities are shown in blue, while student activities are shown in red, enabling clear visual differentiation of classroom dynamics over time.

4.6.2. Thematic Analysis of Interview Data

Interview data were analysed using thematic coding, guided by [Major and Watson's \(2018\)](#) model, which focuses on changes in teacher self-efficacy, self-evaluation, knowledge of teaching, and beliefs about teaching (for example, see [Table 2](#)):

- teacher self-efficacy: gaining confidence in ability to help students learn; affirming choices made in own practice; gaining in interpretive self-confidence over time;
- teacher self-evaluation: aid on reflection/critique on own practice; critiquing own performance; recognising when something learnt previously was not applied, but should have been; identifying directions for improvement;
- knowledge of teaching: learning new techniques; observing others' practice (both exemplary and warranting improvement); noticing events not apparent during teaching; sharing and developing pedagogical content knowledge; collaborative reflection (highlighting one is not alone in their struggles);
- challenging beliefs: positively disrupting beliefs of practice; contrasting espoused philosophy and beliefs with reality.

Table 2. Example of coding.

Excerpt from Interview	Code	Theme
This program helped me build myself up, regaining lost self-confidence.	Confidence, empowering	Teacher's self-efficacy
I started noticing some things that I hadn't even noticed before.	Reflection on own practice	Teacher's self-evaluation

4.6.3. Integration of Quantitative and Qualitative Data

The qualitative and quantitative data were integrated to interpret changes in teacher cognition and classroom practice. Observation protocols (TOF and COPUS) provided indicators of observable instructional behaviour, while interview data captured the teacher's interpretations of these changes. Rather than serving as independent forms of evidence, the two data sources were analytically compared. For example:

- TOF ratings related to differentiation and feedback were interpreted together with the teacher's descriptions of designing project-based differentiated tasks.
- COPUS frequencies (e.g., increased group work and questioning) were examined alongside qualitative themes of student-centred instruction and reflective decision-making.

Claims about change were made only when reported experiences were consistent with observed classroom practices. This triangulation allowed the findings to describe a coherent developmental process within the video-based professional learning context.

5. Results

In the following sections, we present findings on the change in mathematics teachers' cognition and teaching practices, highlighting key changes and their implications for teaching.

5.1. Changes in Teacher Cognition

In the following sections, we present findings on changes in Ms. Maddie's cognition and teaching practices, highlighting key developments and their implications for instruction within the context of TPD.

5.1.1. Self-Efficacy: Strengthening Confidence in Teaching and Differentiation

At the beginning of the study, Ms. Maddie struggled with self-doubt about her ability to implement DI effectively. Although she was committed to improve her teaching practice, she found differentiation overwhelming and difficult to manage, particularly when she engaged students with varying levels of readiness. One of her greatest frustrations was that, despite spending hours preparing differentiated materials, her lessons often did not unfold as she had envisioned. Some students remained actively engaged, while others were disengaged, leading her to question whether her efforts were making a meaningful impact. She described her frustration, explaining:

"I would prepare materials for hours, trying to engage students at different levels, but in the end, only some students were working while others were disengaged. It felt like my effort was wasted."

Taking part in the video-based TPD seems to have changed Ms. Maddie's self-efficacy. At first, watching recordings of her lessons made her feel uncomfortable because it showed her gaps in her teaching that she had not noticed before. But after a while, with the help of cycles of analysis and feedback, she started to see patterns in how students were engaged and figure out what worked for them. As she described:

"I started to notice some things that I had not noticed before, and I started to analyse them on the fly. (...) This started happening after seeing the videos and engaging in the discussions."

Her self-efficacy was greatly enhanced by peer discussions. She discovered that many of her difficulties were typical of teachers using differentiation after discussing her experiences with colleagues. Her self-doubt was reduced by this insight, which also helped her feel more a part of the learning community as a professional. By the final phase

of the study, Ms. Maddie expressed a renewed sense of confidence and enthusiasm for teaching, stating:

“This program helped me build myself up, regaining lost self-confidence, restoring my enthusiasm, and transforming me into a person who encourages other colleagues.”

This increase in self-efficacy was also reflected in changes in how lessons were planned and carried out. Ms. Maddie became more confident in implementing adaptive tasks and scaffolded learning, which was reflected in higher TOF scores for differentiated task design, student engagement strategies, and clarity of instructional delivery (Table 3).

Table 3. TOF Results on differentiation, instructions and student engagement.

TOF Dimension	Lessons 1–2 (Beginning)	Lessons 3–4 (Midway)	Lessons 5–6 (Final Phase)
Clear instructional delivery	NI (unclear instructions)	EI (partially structured)	FI (well-structured, clear transitions)
Differentiated task design	NI (uniform tasks)	EI (limited adaptation, for struggling students)	FI (adaptive tasks, tiered tasks)
Student engagement strategies	NI (mostly passive)	EI (some structured engagement)	FI (active student-led learning)

5.1.2. Self-Evaluation: Developing Reflective Teaching Practices

Before participating in this TPD, Ms. Maddie’s instructional decisions were mainly intuitive, with minimal intentional consideration of lesson pacing, student engagement, or the efficacy of differentiation. She knew that some lessons were better than others, but she did not know what needed to be better or what she could do to make her teaching better. Through video-based TPD, she was able to change this: she was able to observe teacher-student dynamics, lesson clarity, and engagement levels while watching recordings of her teaching. Peer discussions and comparative analyses with colleagues enhanced this process, facilitating opportunities for constructive feedback. When she reflected on this process, she noted:

“I started noticing things I hadn’t even realised before. Watching and discussing videos made me rethink my teaching approach and refine my lessons.”

By the end of the study, Ms. Maddie had fully accepted reflective teaching as an important component of her work. This new approach to reflective teaching led to a more responsive teaching style. Data in Table 4 supports this change, showing a clear progression in differentiation strategies from minimal to more consistent implementation. Improved formative assessment strategies (Table 4, Figure 2) also enabled real-time instructional adjustments based on diverse student needs.

Table 4. TOF Results on differentiation strategies and feedback.

TOF Dimension	Lessons 1–2 (Beginning)	Lessons 3–4 (Midway)	Lessons 5–6 (Final Phase)
Differentiation strategies	NI (no strategies)	EI (limited adoption)	FI (various strategies)
Use of formative feedback	NI (minimal feedback, general comments)	EI (inconsistent feedback, some input)	FI (targeted formative feedback)

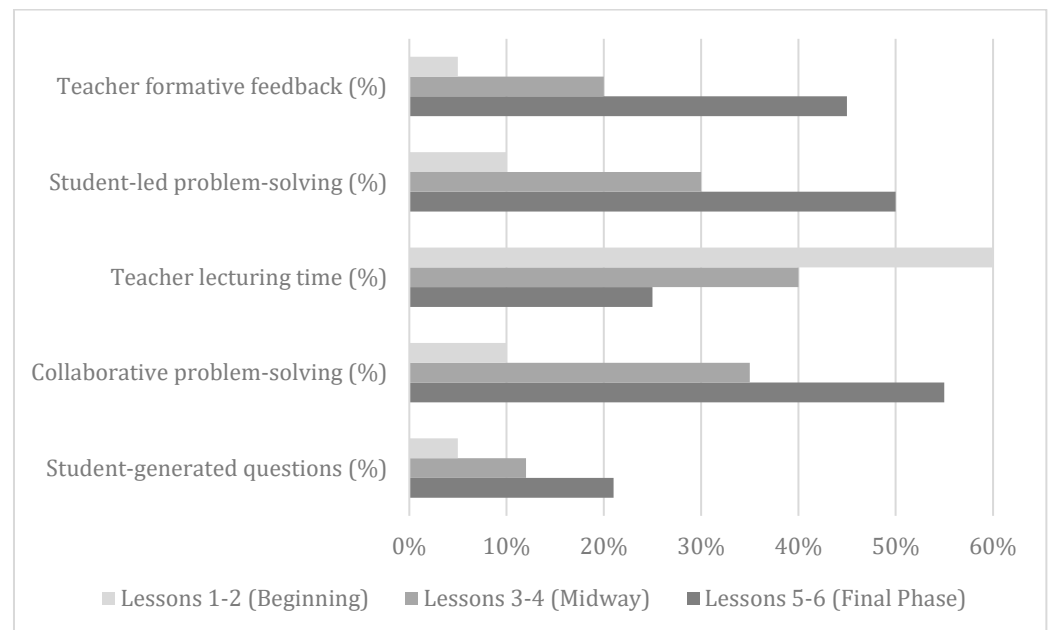


Figure 2. Prevalence of observed behaviours across the lesson. Percentages indicate how often each behaviour occurred across 2 min intervals. Multiple behaviours could occur within the same interval; categories were not mutually exclusive, and therefore percentages do not sum to 100%.

5.1.3. Knowledge of Teaching: Expanding Pedagogical Content Knowledge

Ms. Maddie's participation in video-based TPD allowed her to broaden her instructional strategies, particularly in DI and formative assessment. Initially, she struggled to scaffold content for struggling learners while keeping advanced students engaged, which resulted in uneven participation and inconsistent outcomes. Her teaching style was primarily lecture-based, with few opportunities for student-led inquiry and collaboration. Over the course of TPD, she started using adaptive and tiered tasks with multiple entry points, formative assessments to adjust lesson pacing, and scaffolded problem-solving to encourage students to try out solutions without immediate teacher intervention.

When she reflected on this shift, she noted: "Now, I plan tasks ensuring that every student [struggling students and high achievers] is meaningfully engaged in the lesson."

COPUS data show a change in teaching where teacher lecturing decreased from 60% (beginning) to 25% (final phase) while student-initiated activity increased (Figure 2). This shift reflects a movement from teacher-centred practice toward guided student activity, with the teacher increasingly supporting rather than directing task progression. These patterns reflect a reorganisation of classroom participation, in which students increasingly initiated and sustained mathematical activity while the teacher shifted toward monitoring and feedback. Such changes are consistent with DI, where responsibility for progressing tasks is distributed among students (Tomlinson, 2017).

5.1.4. Challenging Beliefs: Transitioning to a Student-Centred Learning Approach

At first, Ms. Maddie perceived DI as an impractical and time-consuming strategy, primarily due to concerns about classroom time constraints and the diverse readiness levels of her students. She questioned:

"How to present a mathematical concept to a student so they understand it? In what way? To simplify it to their level? How to approach a low-achieving student, how to approach someone who has already solved a certain task, to motivate them to think ahead?"

She believed that tailoring lessons to individual students' needs would disrupt lesson pacing and make too much work in her planning. Furthermore, she believed that direct instruction was the best way to teach because it made sure that all students received the same information in a clear way. However, as she engaged in video-based reflection, peer discussions, and lesson analyses through TPD, her perspective on effective teaching and learning began to change. Because of this change, she had to change the way she taught, placing greater emphasis on active student engagement, inquiry-based learning, and peer collaboration. She explained:

"I used to start lessons in a way that (...) I would present some kind of a problem from everyday life. [...] Now they [students] literally have to discover new knowledge in order to solve the problem they encountered."

Data obtained from observations further support this change. As Ms. Maddie embraced DI and inquiry-based learning, the way students interacted with each other in class changed. The COPUS data (Figure 2) show a substantial increase in collaborative problem-solving, from 10% in the initial phase to 55% in the final phase, along with an increase in student-led problem solving from 10% to 50%. These patterns reflect a shift in classroom participation, in which students increasingly initiated and sustained mathematical activity while the teacher focused on monitoring and feedback. Such changes are consistent with DI, in which students share responsibility for task progression (Tomlinson, 2017).

5.2. Changes in Teacher Practice

By the final observed lesson, Ms. Maddie had successfully integrated DI into her teaching, transforming her approach to lesson design and student engagement. This implementation of DI was evident in three key areas: tiered tasks, scaffolding for struggling students and enrichment tasks for advanced learners, and grouping to encourage peer collaboration.

5.2.1. Mathematical Tasks

Ms. Maddie developed tiered tasks that allowed students to engage with mathematical concepts at different levels of complexity. Before she started using DI, she noted that her tasks were often uniform, leading to disengagement among advanced students and frustration among those who needed additional support. Through participation in the TPD, she restructured her tasks from uniform to tasks adapted for struggling students, eventually incorporating open tasks with multiple entry points and tiered tasks with progressive levels of difficulty.

One of the most successful implementations of tiered tasks occurred during the STEM Centre Project, where students were divided into groups. The project required students to design their own STEM centre and analyse its structure, integrating mathematical concepts such as geometry, measurement, and cost analysis. Students were assigned one of the following roles:

- Assistants had to sketch geometric solids, identifying relevant dimensions, and calculating surface area and volume.
- Architects were responsible for reviewing the calculations of their peers, checking for errors, and making necessary corrections.
- Agency owner analysed construction feasibility and material costs, applying more advanced mathematical reasoning.

There was also a special team called the team of tutors. They were responsible for systematically monitoring and overseeing the progress of all students in their team, as well as providing assistance. This role was reserved for students who excelled academically and loved math. The structure of the task ensured all students engaged with the same core

task, encouraging collaboration (see Figure 2 and Table 5), problem-solving, and real-world application. Moreover, through this division of labour, students assumed task responsibilities, recognising that their contributions directly impacted the success of their team.

The collaboration in this project also took place online, on the Microsoft Teams platform under the supervision of the teacher, who created a separate class for each team and monitored their discussions (Figure 3).



Translation:

Student 1: The tutors have discussed your ideas and we would like to share a few thoughts with you. Your flat roof idea is very interesting and we would be very happy if you continued working on it. The only concern we have is that losing the roof would also mean losing the attic, resulting in a shortage of space. We suggest that you stick with your idea of a different roof, and somehow compensate for this shortcoming. You can raise another floor and match its height and the height of the flat roof to the height of the regular roof. I hope you understand what we wanted to say.

Ms Maddie: This seems like a good idea. Well done! I would like to encourage the students who came up with it to think about their idea once more, and if they are not sure what to do next, ask the tutors for help. Examine the task a few more times.

Student 2: Would you mind having an underground instead?

Ms Maddie: Student 2 must mean the basement. Interesting, I must admit!

Student 2: Yes, yes, but we will think it all through together.

Student 3: I have a proposal. As Student 1 already wrote, we can fit another floor and find a flat roof with the required roof height. The height of a regular roof is 2.3 meters, which allows a two-meter-high floor and a 0.3-meter-high flat roof. Is this what you had in mind?

Ms Maddie: All these ideas are really good. Before reaching a final agreement, please research the average height of such a flat roof, so that you are sure that 0.3 meters is not too low.

Figure 3. Example of students' communication about an assigned task.

Table 5. TOF Results on student collaboration, scaffolding and metacognitive skills.

TOF Dimension	Lessons 1–2 (Beginning)	Lessons 3–4 (Midway)	Lessons 5–6 (Final Phase)
Student collaboration	NI (individual work, limited interaction)	EI (more frequent peer discussions)	FI (core aspect of instruction)
Scaffolding for struggling students	NI (no scaffolding)	EI (occasional support)	FI (structured and embedded)
Metacognitive skills	NI (not detected)	EI (emerging thought-provoking questions and critical reflection)	FI (students actively engaged in self-reflection, explain their reasoning)

The collaborative nature of the project also led to stronger interpersonal connections among students, fostering a positive learning environment both inside and outside of the classroom. The teacher explained:

“Before the [DI] project, it didn’t matter what grade they got in math or how well they studied. Throughout the project, they realised that good results contributed to the overall success of the entire team. Since they felt personal and collective responsibility for their team’s success, the students constantly assisted one another”.

5.2.2. Scaffolding and Enrichment

Scaffolding was another critical component of Ms. Maddie’s approach to differentiation. Instead of directly intervening to support struggling students, she encouraged them to help one another, promoting collaborative learning and peer-assisted instruction. She elaborated:

“I attempted to encourage them to seek my assistance less frequently so they could learn to support each other’s learning. As a result, they became more independent in their learning. Even though I provided them with pre-made materials, they still needed to do their own research and come up with original answers.”

In addition to peer support, Ms. Maddie incorporated structured scaffolding mechanisms into her lessons. For example, she used Microsoft Forms with branching logic to create interactive tasks that offered guided prompts and differentiated pathways based on students’ responses (Figure 4). This design allowed struggling students to receive immediate feedback, additional hints, or redirection to simpler tasks, while students who completed initial tasks successfully, could proceed to more advanced problems.

As she explained, these Forms quizzes were used during lessons, in project-based tasks, homework, and remedial sessions. This made it possible for her to meet each student’s learning needs both synchronously and asynchronously (Figure 5). The teacher received real-time analytics on student performance, such as which students struggled with specific tasks, how many of them sought help, and what solution strategies they used, allowing her to adjust instruction accordingly. Moreover, she explained:

“[TPD] was a huge help to me. But what really helped me was learning to work with weaker students (...), to look for and create materials for students who are struggling.”

To encourage students to interact with the material in a variety of ways, Ms. Maddie offered DI resources such as visual aids, manipulatives, and interactive problem-solving

in the digital tool Genially. Ms. Maddie used extension tasks that called for higher-order reasoning, abstract problem-solving, and independent inquiry to make sure that high-achieving students were adequately challenged.

Pregled: Primjena Pitagorinog poučka na jednakokrani trokut

Osobe Pitanja

< [redacted] > Vrijeme do dovršetka: 17:04 Bodovi: 0/21

1. zadatak:

Kako bismo kratko ponovili naučeno gradivo riješiti ćemo jedan vrlo jednostavan zadatak. Izračunaj duljinu visine na osnovicu jednakokrannog trokuta ako je zadano $a = 16$ cm i $b = 10$ cm.

1. Trebaš li pomoć?

☐ da

☒ ne

Bodov / 1 bod

Potreban je pregled

Translation

Overview: Application of the Pythagorean theorem to an isosceles triangle

Task 1:

To briefly review the learned material, we will solve one very simple problem. Calculate the length of the height to the base of an isosceles triangle if it is given that $a = 16$ cm and $b = 10$ cm.

1. Do you need help?

- yes Points/ 1 point
- no Review required

Figure 4. Use of Microsoft Forms.

TELE2 30% 13:25

forms.office.com/Pages/Rt

(Bodovi: 1/2)

Pri mjerenju visine ljestvi kada su naslonjene na zid

☞ "Točno! Možemo primijeniti Pitagorin poučak na izračunavanje duljine ljestava ili visine koju dosežu ili koliko ih treba odmaknuti od zida,... Tvoj odgovor ne obuhvaća i jedan od zadanih trokuta. Pokušaj do idućeg sata razmisliti kako bi mogla primijeniti jedan od trokuta i Pitagorin poučak. Kao na primjer 3. zadataka. Imali smo izgradnju mosta, u kojem je bio korišten trokut. Kako bismo odredili visinu morali smo primijeniti Pitagorin poučak."

Translation:

Correct! We can apply the Pythagorean theorem to calculate the length of the ladder or the height it reaches, or how far it needs to be moved away from the wall... Your answer does not include one of the given triangles. Try to think until the next class about how you could apply one of the triangles and the Pythagorean theorem. For example, in task 3. We had a text about building a bridge in which a triangle was used. In order to determine the height, we had to apply the Pythagorean theorem.

Figure 5. Giving feedback using Microsoft Forms.

5.3. Impact on Student Engagement

By the final observed lessons, Ms. Maddie's implementation of DI had changed how students participated in lessons and interacted with each. Compared to her initial lesson, where differentiation was minimal and students relied heavily on teacher guidance, later

observations revealed a significant increase in student-initiated problem-solving activity and self-regulation (Table 5, Figure 2). As reported by teacher:

“Students became more engaged and motivated, and since they worked in a way that allowed everybody to contribute to the project, each one of them felt responsible for the team’s success [...] they pushed themselves to learn something in order to solve a specific problem.”

6. Discussion

This study examined how online video-based TPD influenced changes in teacher cognition and teacher practice, specifically in implementing DI. Engaging in structured video-based reflection within an online facilitator-led PLC was associated with the shifts in self-efficacy, self-evaluation, beliefs, and knowledge for teaching, which in turn influenced Ms. Maddie’s teaching practice. Our findings will be discussed in the text below.

6.1. How Did Video-Based TPD Influence Teacher Cognition?

Ms. Maddie used classroom videos to examine the nature of her teaching in a dynamic and structured way (Koellner et al., 2024). By watching her own teaching and taking part in discussions, she was able to use her own knowledge about her teaching choices and how her students reacted to them, which made the reflection process more concrete and useful (Borko et al., 2011). Initially, she struggled with self-doubt, particularly regarding the feasibility of DI, as she found it difficult to balance the varying needs of her students. However, video-based TPD improved Ms. Maddie’s confidence, which influenced her teaching practice and ability to meet diverse student needs. This aligns with research which indicates that self-efficacy in teaching mathematics is positively correlated with the use of effective pedagogical practices (Berg et al., 2025). Ms. Maddie’s shift toward student-centred teaching, as seen in her increased use of DI, mirrors these findings. Teachers with higher self-efficacy, like Ms. Maddie has become, are more likely to engage in student-centred instructional methods, provide worthwhile mathematical tasks, and create connections between mathematical concepts and students’ experiences.

Self-evaluation was another key area of change. Through video analysis and peer discussions, Ms. Maddie began to assess her teaching more systematically, leading to more deliberate instructional decisions. It became clear that she was getting better at evaluating her own teaching and using what she learned in future lessons. This suggests that structured self-evaluation helped her make long-term changes to her teaching (Koellner et al., 2024). This change aligns with research on teacher professional growth, where reflective awareness plays an important role for instructional effectiveness (Chapman, 2015). For Ms. Maddie, self-evaluation was particularly significant when she implemented DI. By using a more structured way of reflecting, she was able to connect what she wanted to achieve with what was actually happening in the classroom, which made her differentiation strategies work better.

Changes in Ms. Maddie’s knowledge for teaching mathematics were also apparent, particularly in her expanded repertoire of DI strategies. Initially, differentiation seemed overwhelming, but through repeated video-based reflections and discussions in PLC, she experimented with adaptive and tiered tasks, flexible grouping, and scaffolded tasks. Finally, her beliefs about teaching mathematics changed significantly. Participating in TPD challenged her assumptions about direct instruction, leading to a shift toward a more adaptive and student-led approach. Professional development that focuses on reflective practice has been shown to help math teachers change their beliefs about how to teach (Calleja, 2022), and prior research suggests that these cognitive transformations often precede meaningful and lasting changes in teaching practice (Lunn Brownlee et al., 2017).

In this sense, Ms. Maddie's changes in self-efficacy, self-evaluation, knowledge, and beliefs are an important step toward making math learning environments more engaging.

While this study provides evidence of such cognitive shifts, it remains necessary to consider whether they persisted beyond the intervention period. Research suggests that without continued reinforcement, teachers may revert to prior practices, particularly when facing time pressure or institutional resistance (Langelaan et al., 2024). Periodic video-based reflection sessions embedded in ongoing PLC could serve as a mechanism to maintain and deepen these cognitive changes over time.

6.2. How Did Video-Based TPD Influence Teaching Practice?

Classroom videos were a useful way in Ms. Maddie's professional development, just like how athletes watch videos of their performances to improve their skills. While much of teaching is habitual, structured video analysis made these habits more visible and open to critical examination, allowing her to consciously refine her instructional strategies (Xiao & Tobin, 2018). However, recognising areas for improvement was only the first step; sustained change required deliberate practice within a supportive professional learning environment. For Ms. Maddie, this involved continuously implementing DI in her mathematics classroom. The combination of deliberate classroom experimentation, peer discussions, and ongoing guided reflection supported her ability to make meaningful adjustments in her teaching over time (Graham et al., 2020; Hobbiss et al., 2021).

These cognitive changes were translated into concrete improvements in Ms. Maddie's instructional approach. She incorporated strategies such as real-world applications, open-ended investigations, and collaborative learning, methods that align with effective practices in mathematics education. The most significant improvement was her structured and intentional use of differentiation strategies, particularly through tiered tasks and scaffolding. Another notable change was the increase in student engagement. Instead of merely modifying mathematical content, Ms. Maddie's efforts focused on fostering greater student independence in learning, a key aspect of effective DI in mathematics (Bobis et al., 2021). Initially, she believed DI required creating separate materials for different students. However, through video-based reflection and peer discussions, she learned that the best way to differentiate instruction was to focus on the deep structure of tasks, such as conceptual flexibility and cognitive activation, rather than just surface features like layout or numerical complexity (Bardy et al., 2021). This transformation was particularly evident in her increased use of open-ended questioning and student-led problem-solving activities. These changes align with earlier research indicating that both instructional design and pedagogical discourse are both important for effective DI (Leuders & Prediger, 2016).

Beyond the impact of video-based TPD, it is important to examine the role of contextual factors in shaping instructional changes. Future research should investigate how factors like school leadership and administrative support shape teachers' instructional practices.

6.3. Digital Tools and Cognitive and Instructional Change

In addition to cognitive and instructional changes, the integration of digital tools played an important mediating role in enacting DI. In this study, technology was not part of the TPD but was adopted by the teacher as a practical way to implement ideas developed through reflection within the TPD. The use of tools such as Microsoft Teams, Microsoft Forms and Genially enabled the teacher to operationalise adaptive and personalised support for students, alongside real-time data collection and formative feedback. Moreover, video recordings, the video-conferencing platform, and the Moodle environment supported reflective teaching practices and informed pedagogical adjustments. These findings align with research showing that even in the absence of sophisticated AI systems, accessible

technologies can support personalised and inclusive pedagogy when guided by pedagogical intent (Küçükuncular & Ertugan, 2025). They also reflect Selwyn's (2024) concept of convivial technologies, that is, tools whose educational value emerges from teachers adapting simple resources to their professional purposes. Furthermore, recent work shows that thoughtfully designed online TPD can enhance teachers' self-efficacy and competences in supporting students' self-regulated learning (Linde et al., 2023). Situated within the broader process of digital transformation in education, the present case illustrates how low-tech digital environments can support pedagogical innovation when aligned with teacher agency and instructional goals, consistent with frameworks emphasising that technologies become educationally meaningful only when embedded in purposeful teaching practice (OECD, 2023; UNESCO, 2024).

6.4. Limitations of the Study

This study did not include student achievement data or pre-test/post-test comparisons. Instead, its primary focus was on improving teaching practice, particularly in response to the teacher's initial concerns about student demotivation and disengagement. Nevertheless, the teacher reported noticeable improvements in student behaviour and engagement throughout the intervention, suggesting a positive classroom shift. Additionally, a short post-intervention interview was conducted to gather students' perspectives on the new instructional approach; however, these data were not included in the analysis as they were not initially planned within the research design. Future studies should include systematic pre- and post-intervention measures of student achievement and student perspectives in order to better assess the broader educational impact of such video-based TPD.

It should also be noted that the very small sample size, involving only a single teacher, further limits the generalisability of the findings. An additional limitation concerns the teacher's initial professional characteristics. The participant was recommended for the TPD programme due to her high motivation and openness to adopting new teaching approaches, traits that likely facilitated her willingness to engage in video-based TPD and DI. Such intrinsic motivation may have increased the cognitive and instructional changes observed; consequently, the findings cannot be readily generalised to teachers who enter TPD with lower levels of motivation or readiness for pedagogical innovation. In line with case study methodology, the aim of this study was to examine how and under what conditions online video-based TPD can support meaningful changes in teacher cognition and practice. Accordingly, the results should be interpreted as demonstrating what is possible under favourable conditions rather than as outcomes expected across all mathematics teachers. Moreover, because the TPD design intentionally combined classroom video, structured feedback and collaborative peer reflection, the study does not disentangle the specific contribution of video from that of ongoing guidance and community support; the documented changes should be understood as emerging from this integrated design rather than from video use alone.

7. Conclusions

This case study examined how participation in online video-based TPD was associated with changes in mathematics teacher's cognition and teaching practice, particularly in relation to DI. The study showed how developments in self-efficacy, self-evaluation, knowledge of teaching, and instructional beliefs accompanied the gradual introduction of DI. The findings suggest that video-based TPD can help connect theoretical ideas with classroom experimentation (Gaudin & Chaliès, 2015), when teachers engage in sustained collaborative reflection. Although the school culture did not provide a particularly supportive environment for instructional change, Ms. Maddie found the encouragement and

professional support she needed through participation in the online PLC with fellow teachers and teacher educators. The teacher's rural workplace did not change the intervention's principles, but shaped its feasibility and relevance: the online format reduced geographical barriers and provided stable access to professional discussion that might otherwise be limited. For teachers working in rural schools with limited opportunities for subject-specific collaboration, online video-based TPD with PLC may provide an important mechanism for sustained professional discussion and reflective practice. Future research involving multiple contexts and direct measures of student learning is needed to examine the broader applicability of this approach.

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