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Exploring adaptive teaching with pre-service maths teachers

Christina Turner, Catherine Bell, Lee Parson

ABSTRACT

Teachers continuously notice, interpret and respond to what their pupils are doing and thinking as they navigate how best to adapt their teaching to meet pupils' current levels of understanding. To date, analysis of adaptive teaching has focused largely on the factors that limit novice teachers in adapting to meet pupils' needs. This study explores what pre- service teachers themselves perceive to be these barriers and sheds light on the initial

strategies that they rely on to meet their pupils' cognitive needs. This informs possible approaches to supporting pre-service teachers to develop their skills in adaptive practices.

1. INTRODUCTION

1.1 ADAPTIVE TEACHING

Successful teachers are experts in noticing pupil responses during lessons and using these to shape the next steps in learning (for an overview see Parsons *et al*., 2018). They use the rich information a classroom environment provides to switch between addressing the whole class and meeting the needs of individuals or groups of pupils. They consider how best to adapt explanations, choosing from various tools in a split second. These teachers reflect on their lessons, consider their knowledge about each pupil and adapt their subsequent lessons in response. This can be as straightforward as adding in consolidation questions when a teacher notices that a key skill has not yet been mastered, or as complex as considering different scaffolds, such as providing diagrams, to meet the needs of different pupils, thus allowing all pupils to work towards the same goal. Adaptive teaching, therefore, is a complex skill encompassing 'in-the-moment' teacher responses to classroom stimuli and the 'pre-emptive decisions' teachers make when planning, using both to increase the number of pupils participating in learning (Corno, 2008).

The Adaptive Teaching Feedback Loop initially proposed by Parsons *et al*. (2018) and enhanced by Gallagher *et al*. (2022) illustrates the relationship between teacher noticing of stimuli (for example, pupil gives an incorrect answer), teacher reflection and metacognition (for example, concluding that this pupil has a misconception) and teacher action (for example, unpicks misconception). This inevitably leads to another response, which again must be noticed and interpreted, leading to a Feedback Loop. In this model, they highlight teacher factors that mediate adaptive teaching such as knowledge, experience and beliefs, as well as barriers and affordances.

1.2 Pre-service teachers

As pre-service teachers (PSTs) are just beginning their journey as classroom practitioners, they are still learning how to teach and need more experience in the classroom to master their craft. There has been a wealth of research related to how this impacts adaptive teaching practices. Pedagogical content knowledge (PCK) coined by Shulman (1986) encompasses factors about pupils, classroom instruction and task design. This is a key driver in teachers matching the cognitive demand of tasks to pupil needs and providing individual learning support to enhance pupil progress (Baumert *et al.*, 2010). When teachers do not have strong PCK, they struggle to shape whole-class discussions moment- by-moment, limiting progress towards the learning goal, and they might have to rely on standard procedural methods as they do not know alternatives, making it difficult to adapt to pupil needs (Ball *et al.*, 2008).

Santagata and Lee (2019) contributed to this area of research focusing on teachers in their first year of teaching. As expected, they found that strong mathematical knowledge for teaching (MKT) was associated with high-quality mathematical instruction. However, the ability of novice teachers to engage in adaptive teaching by building on pupil understanding and responding to pupil difficulties was less clear. One barrier to this was the adoption of a set lesson style focusing on procedural accuracy, with minimal opportunities for pupil contributions and collaboration. Task choice also emerged as a potential barrier, as even when MKT was strong, the task did not always allow this to be used to develop pupil understanding.

Combined with limited PCK, PSTs lack experience in enacting adaptive teaching practices, and this, too, impacts their ability to meet pupil needs. Tailoring lesson plans for groups of pupils is challenging, as less experienced teachers are more likely to focus their thinking on instructional activities rather than on pupils' learning needs (Chizhik and Chizhik, 2018). PSTs also rely more on generic strategies than subject-specific ones, missing opportunities to deepen mathematical understanding (König *et al.*, 2020). Novice teachers also find it difficult to make changes within a planned lesson, and their perceptions of learning are shaped by teacher actions, rather than what pupils are doing (Sabers *et al.*, 1991; Hogan, 2004). Schoenfeld (2011) suggests that inexperienced teachers are preoccupied with classroom management, reducing their capacity to use formative assessment to shape the next steps in learning. Similarly, Rowland *et al.* (2005) acknowledge that being able to 'think on one's feet' in the classroom in response to pupil needs is more challenging for PSTs as they lack the experience to anticipate contingent events.

This study is timely as in England over the last decade, there has been a subtle shift in the language used in schools around meeting pupil needs. Historically, differentiation has been championed and in English schools this has often meant creating different tasks for different groups of pupils based on perceived ability (Boyd and Ash, 2018). More recently, the emphasis has shifted to being on adapting teaching to me*et all* pupil needs,
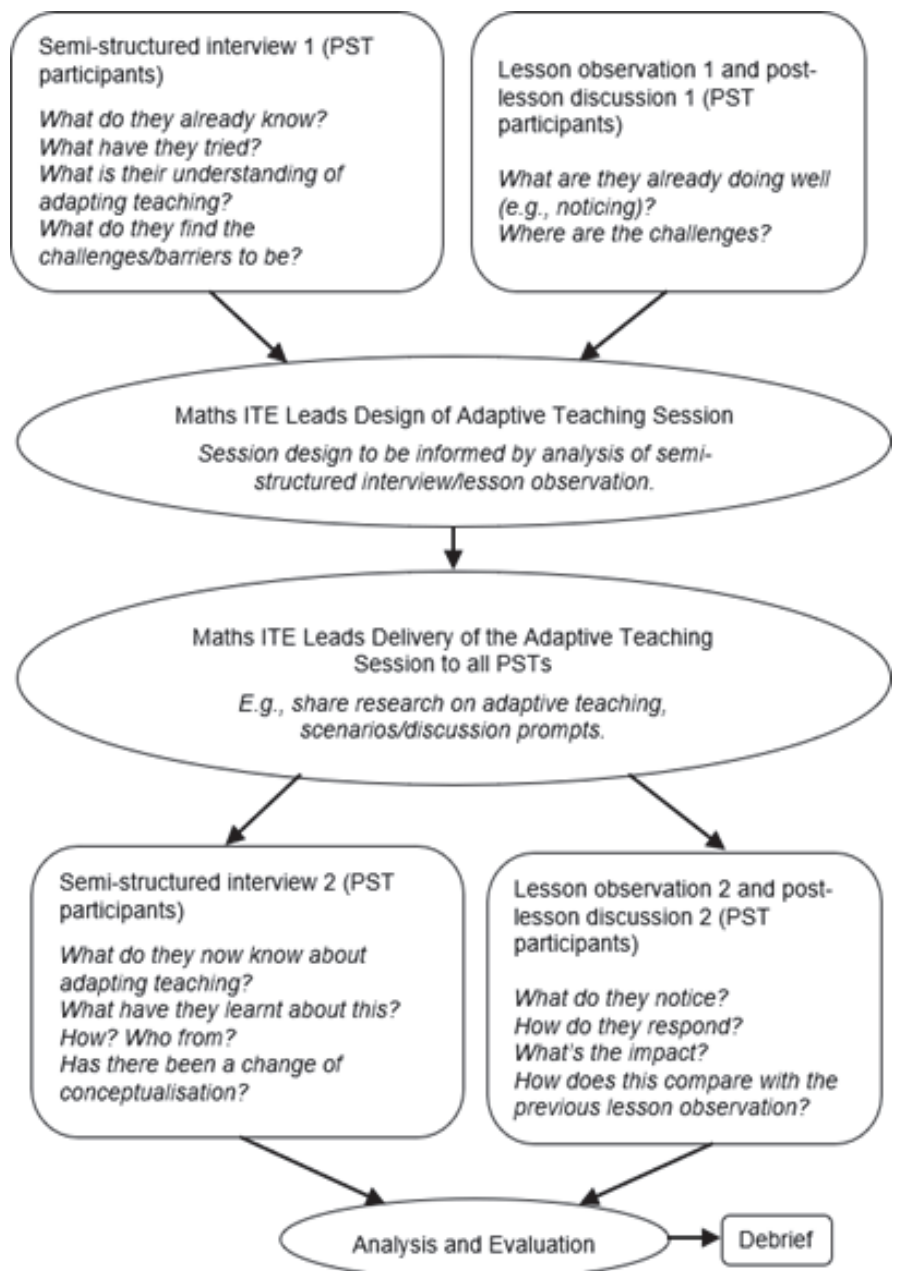

Figure 1 The Project Plan.

rather than differentiating in this way (Education Inspection Framework, 2019). Internationally, this is closely aligned with the perspective of differentiation as adapting within a diverse classroom, where the aim is to meet all pupils' needs, rather than those of individuals (Eikeland and Ohna, 2022). This has caused some confusion about how best to meet pupil needs at a time when a current issue facing mathematics education in England is equity and inclusion (Boylan et al., 2023). Initial Teacher Educators (ITEs) must be aware of specific adaptive teaching strategies that PSTs adopt both at the start and towards the end of their teacher education course. ITEs will then be better prepared to design courses that support PSTs to become more able to adapt their teaching at an earlier stage in their careers, thus enabling them to meet pupils' needs and narrowing attainment gaps.

1.3 RESEARCH QUESTIONS

1. Which adaptive teaching strategies do PSTs rely on?

2. Which adaptive teaching strategies do they develop over time (in the training year)?

3. What do PSTs perceive to be the challenges in adapting their teaching to meet the individual needs of pupils in maths lessons?

4. Do these perceived challenges change towards the end of the training year?

2. METHOD

2.1 CASE STUDY APPROACH

Researchers adopted a case study design alongside a cross-case analysis to identify patterns of PST thinking and classroom practice related to adaptive teaching (Cresswell, 2013). Participants are training to work in north of England secondary schools and undertaking a one-year Post Graduate Certificate of Education (PGCE) with QTS. This study focuses on adaptive teaching in mathematics, investigating PSTs' understanding of this, the adaptive teaching strategies they use and the challenges they face when attempting to meet the needs of all pupils.

An overview of the case study approach adopted is illustrated in Figure 1.

2.2 DATA CODING

The following thematic categories (Gallagher et al., 2022) were used: formative assessment techniques (for example, questioning), learning environment (for example, encouraging pupils), classroom management techniques (for example, refocusing), teaching strategies (for example, orchestrating classroom discussion), use of pupil information prior to the lesson to modify curriculum materials and school organisation (for example, using the school's prescribed methods of meeting pupil needs). When considering the challenges faced by PSTs in adapting their teaching, the following coding (again informed by Gallagher et al., 2022) was used: personal knowledge and experience of teaching, standards and testing, characteristics of the class, curriculum content and curriculum materials and resources. Researchers met after conducting the first semi-structured interviews and discussed emerging themes. They identified just one emerging theme which was 'uncertainty'. The data coding was then standardised.

2.3 LESSON OBSERVATIONS

To ensure consistency of observation researchers were asked to note down specific events that occurred during the lesson and how the PST responded to these. The post-lesson discussion then asked PSTs to reflect on adaptations made.

3. RESULTS AND DISCUSSION

3.1 Which adaptive teaching strategies do PSTs rely on? Which adaptive teaching strategies do they develop over time?

PSTs rely on a range of pre-planned formative assessment strategies through-out teaching their lesson to inform adaptive teaching strategies. Specifically,

they rely on departmental set starter tasks to identify gaps in pupil knowledge and understanding, with whole class assessment managed through the use of mini whiteboards enabling pupils to display responses. They then rely on marking pupil work when circulating the classroom to provide a snapshot of individual pupil's progress. Whole class questioning was also a key theme accompanied by a no-hands-up approach, where PSTs selected individual pupils to respond.

In response to assessments, PSTs adapted instruction by omitting some of the pre-prepared examples or modelled the same instruction with different numbers. PSTs appeared to be less well-prepared to interpret feedback from assessments and implement an action that helped pupils to make sense of the maths. One exception to this occurred when during a lesson a PST adapted their approach to teaching the rules of indices by moving from modelling these as a set of procedures, to deriving each rule from first principles. The PST reflected on this as an adaptive teaching strategy, noticing the impact of shifting the focus of the instructional activity onto ensuring the pupil understood the mathematical structure underpinning a procedure. This was particularly noteworthy as prior research indicates that PSTs are more likely to attend to procedural accuracy (Santagata and Lee, 2019). This PST started with procedural accuracy as the goal of the lesson, viewing conceptual understanding as an adaptive teaching strategy rather than being integral to mathematical sense-making. This emphasises the importance of teaching procedural fluency alongside conceptual understanding, as this is likely to minimise the need for 'in-the-moment' adaptations as pupils make sense of each step in their learning.

The most striking aspect of PST development impacting adaptive teaching was their understanding of mathematical progression in the examples modelled. For instance, in a lesson on solving inequalities, a PST reflected on their

choice of examples noting that these built on prior learning related to one-step and then two-step inequalities, to then having unknowns on both sides and finally to those with negative solutions. This was seen to shift the focus of adaptative teaching from troubleshooting to a more considered approach to planning the next step of learning for the whole class (in this case, exploring different methods of solving an inequality involving a bracket). This is in sharp contrast to the initial observation of this PST, in a lesson on factorising quadratic expressions, where no attention had been given to the added layer of difficulty when negative numbers are involved, or indeed the issue that can arise if a pupil is unable to recognise that the coefficient of   is 1. The PST attempted to adapt by reacting to pupils' mistakes, which meant that there were no opportunities to build understanding further in a small, stepped manner.

Another significant development was the active encouragement of classroom discussion. In the first lesson observation, one PST focused on behaviour management (Schoenfeld, 2011) and on moving through a set series of steps so that school-prescribed aspects of the lesson could be completed, such as the 'challenge zone' (Sabers *et al.*, 1991). Opportunities for whole-class discussion and purposeful pupil talk were limited, negatively impacting opportunities to adapt to meet pupils' needs (Santagata and Lee, 2019). However, in the second lesson observation where pupils were learning about scale, the PST encouraged talk throughout using specific prompts, for example, using an image of a bee, horse and tree (all drawn to different scales) accompanied by the question 'Which is bigger and why?' Retrospectively, the PST believed that 'maybe 30 seconds more of discussion could have helped get across that scales work both ways, you can scale up and down. I didn't want to take too much time up in the lesson.' This chimes with Mason's (2021) work on teacher noticing, with the PST knowing-that this was an important moment in the lesson (an opportunity to deepen pupil understanding of scale) and imagining themselves in the future, knowing to spend time on this learning point. Prompting these reflections, therefore, is an important aspect of PSTs being able to develop their approaches to adaptive teaching.

3.2 WHAT DO PSTs PERCEIVE TO BE THE CHALLENGES IN ADAPTING THEIR TEACHING TO MEET THE INDIVIDUAL NEEDS OF PUPILS IN MATHS LESSONS? DO THESE PERCEIVED CHALLENGES CHANGE TOWARDS THE END OF THEIR COURSE?

Initial challenges emphasised a lack of teaching experience, characteristics of classes, school organisational features and using prescribed lesson resources. Researchers had expected PSTs to refer to challenges associated with pressures on preparing pupils for tests or meeting attainment targets. However, this was not the case. This may be because PSTs are not yet fully accountable for pupils' test results or attainment targets. Towards the end of the year, PSTs' perceptions of what hinders meeting the needs of all pupils did not significantly change. Perhaps, being unable to overcome initial challenges in the brief time period allocated to the research influenced this outcome.

3.21 Personal knowledge and experience

PSTs noted that their experience impacts their ability to meet the needs of all pupils. PST attention is diverted in many directions, from managing behaviour to making explanations clear, and at the same time, they do this under the pressure of being observed by a more experienced colleague. Consequently, less attention is available for noticing what individual pupils are doing and saying, and then for making decisions related to this (Rowland *et al.*, 2005). This was summarised by one PST who stated, 'I'm thinking about a lot of things and know a lot of things, but when it comes to practically, you know, doing it (adaptive teaching), you have got one hour.' The challenge of thinking in-the-moment, whilst also thinking about subject content, modelling and managing behaviour, is a significant cognitive load and provides a reminder that PSTs require time between lessons to evaluate and reflect, unpacking these challenges, with mentors and ITE Leads providing frameworks in which to do this.

3.22 Characteristics of classes

Poor behaviour was also cited as a barrier which limited meeting learning needs. One PST described the time lost from a lesson when removing a pupil from the classroom. Another mentioned that a seating plan based on behaviour can pose a challenge to using adaptive teaching strategies, giving the example of pupil A who is talkative and a high attainer, who is seated with a quieter pupil B. The issue is that pupil B then does not 'do any work' whilst pupil A benefits from dominating the discussion. Another PST was uncertain about using a 'Think, Pair, Share' approach to identify and respond to misconceptions, as it was felt that some pupils would be reluctant to talk and others would misbehave. A different PST felt confident in meeting the needs of the highest attainers but questioned their ability to meet the needs of the low attainers. They described a lower-attaining class that they would soon be teaching as 'really quite challenging in terms of emotions and behaviour' and that 'anything different in the classroom can derail a lesson'.

PSTs also pointed to large numbers of pupils being in a class alongside wide-ranging attainment levels as a barrier to adapting teaching to meet learning needs. They also raised uncertainty about what to do if pupils finished their work at different times. This points to the need for a focus on task design and task choice in PST education, ensuring that PSTs understand how the task develops mathematical understanding, rather than it simply being a series of questions to get through (Santagata and Lee, 2019).

3.23 School organisation and prescribed curriculum materials/resources

Another challenge was how to scaffold learning appropriately. In some lessons, pupils' independent work was heavily scaffolded removing opportunities for the pupils to think about what they were doing. This limited opportunities for pupils and teachers to interact. The next step in a lesson did not always build on the previous step or scaffolding was too quickly removed, so pupils struggled to access the content.

There appear to be two contributory factors to this barrier. PSTs were unable to anticipate what the pupils would find difficult about the mathematics and the questions posed and so were unable to prepare the necessary adaptations. Secondly, this PST had been directed to follow a prescribed lesson structure and to use prescribed lesson resources which inadvertently caused a 'tick-box' approach to delivery, where they felt unable to flex. The PST felt that they might be criticised if they 'missed something' and so delivered everything as planned, even if they noticed that pupils were not ready for the challenge zone phase of the lesson. This is interesting, as research suggests that pre-prepared lessons can be useful for less experienced teachers (Ainsworth *et al.*, 2012) and that when inexperienced teachers have autonomy over methods of teaching, there is a negative impact on pupil test scores in mathematics and their self-efficacy (Jerrim *et al.*, 2023). Indeed, PSTs were observed using pre-prepared diagnostic questions well in their lessons to assess common misconceptions that they may have otherwise missed. One PST displayed a parallelogram with the lengths of the base, perpendicular height and slanted height labelled, and asked pupils to choose which, from four possible answers, was the correct area of the parallelogram. The three incorrect answers highlighted misconceptions, and the PST successfully addressed these. This suggests that where the intent of departmental planned pupil tasks is obvious, PSTs can make effective use of them in addressing pupils' learning needs. The barriers occur when the intent is less clear (for example, labelling of the pupil task as 'challenge zone' does not indicate the specific mathematical demand), and when the PST is unclear of how pupil tasks are sequenced to secure a coherent mathematical progression. Therefore, PSTs need guidance on how pupil tasks connect and so how off-the-shelf lessons are designed in full.

3.24 What other challenges were observed?

In lesson observations, interpretation of the feedback from assessment strategies was a barrier to addressing pupil learning needs. Specifically, an emerging theme was whether pupil–teacher understanding of needs was aligned. PSTs were seen to quickly intervene, attempting to solve a problem for a pupil, which did not address the problem they were experiencing. In one lesson a PST said, 'Two variables are in direct proportion if the two amounts increase at the same rate.' A pupil became confused when, in the first example, a table was given where the first variable was allocated values of 1, 2, 3, 4, 5 and 10. A pupil questioned why the variable increased from 5 to 10 and the PST immediately responded, 'Because it can,' thinking that this had addressed the issue. On observing this pupil, the problem that they were experiencing was rooted in the description of 'increasing at the same rate' which he had applied to the single variable, rather than to both variables. Hogan and Rabinowitz (2009) point out that novice teachers will speedily act, rather than first define the problem. Building on this, helping PSTs to check what a pupil has said, and then, to ask probing, as well as clarifying, questions, may support PSTs to process the feedback before then interpreting it and deciding on an action to implement.

3.25 Over time

Over time, PSTs were more able to reflect on the process of adaptive teaching in a granular manner. One PST reflected on their current ability to notice classroom stimuli and then to choose an effective adaptation as being a barrier, demonstrating knowledge of a conceptualisation of noticing close to that of Jacobs *et al*. (2010), where a teacher attends to pupil thinking, interprets this and responds to the pupil. It can be argued that a framework such as this, provides PSTs with the language that they need to evaluate their adaptive teaching practices holistically so that they can identify what works and what does not and what they might have done instead. Mason (2021) emphasises the importance of constructing a personal narrative such as this, in the process of making meaning of classroom events. Novice teachers find themselves noticing things that they had not previously, and realising that they have a wider range of tools available so that they can act differently next time.

3. LIMITATIONS

There were several limiting factors which must be considered. Firstly, three PSTs opted to participate in this research. ITE Leads agreed that the three participants appeared more confident than others in their cohorts and this may have impacted results. The contexts that the PSTs were working in varied, and this was not accounted for. Future research that compares PST perceptions of challenges to adapting teaching in schools with differing levels of teacher autonomy would provide helpful direction for PST education. Finally, the research was conducted over a relatively brief period. It would be useful to conduct further research that follows PSTs through into initial stages of their teaching career, giving a broader perspective on how novice teachers develop adaptive teaching strategies.

4. CONCLUSION

Adaptive teaching can be an abstract concept for PSTs who are grappling with other anxieties such as managing behaviour. The Adaptive Teaching Feedback Loop described by Gallagher *et al*. (2022) is a useful tool in providing a common language in which to discuss adaptive teaching. Breaking adaptive teaching into the steps of noticing stimuli, teacher reflection and metacognition and teacher action, allows PSTs a structure for their lesson evaluations and subsequent discussions. Adding to prior research findings, PSTs require support in moving beyond the noticing of surface-level features of learning, such as procedural errors, to noticing deep-level features of pupils' mathematical thinking. This study develops this further, highlighting PSTs' perceptions of barriers to this. Noteworthy is the perception that a fixed lesson structure and prescribed lesson content get in the way of adapting teaching to meet pupils' needs. Working with PSTs to understand the intent of lesson design and then building on this by using prompts to encourage them to design solutions to instructional problems, could develop their agency when serving school systems so that they can decide when and how to adapt. Developing this, they might begin byreflecting on case studies of classroom scenarios, identifying what a teacher might have done to pre-emptively adapt before the lesson, and what the teacher might do now once pupils' learning needs emerge. Whilst this might be a starting point for PSTs in familiarising themselves with the Adaptive Teaching Feedback Loop, they must ground this structured evaluation process within their own lessons so that they internalise the behaviours outlined in the Adaptive Teaching Feedback Loop. It is only by capturing the moment that a pupil's need emerges, and then re-imagining responses to this, that a PST will notice what this pupil understands about the mathematics and doesn't yet understand, thus allowing PSTs to develop a repertoire of subject-specific strategies to adapt to meet this need. ∎

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