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Achieving Teacher Professional Growth Through Professional Experimentation and Changes in Pedagogical Practices

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Abstract: To facilitate the professional learning of teachers and bring about changes in pedagogical practices, it is necessary to understand the process by which teachers grow professionally. Professional growth can be achieved when teachers work together to engage in professional experimentation and see results in terms of salient outcomes for their students. This paper reports on a study of teachers' pedagogical practices as they introduced adaptations to focus on personalising students' learning in mathematics. Two cases are presented to demonstrate how teachers in two schools used student mathematics test data to determine students' strengths and needs, in order to personalise learning experiences. The findings highlight how shared responsibility and purposeful use of student data can lead to positive professional growth for teachers and improved learning outcomes for students.

Introduction

Developing an understanding of teachers' behaviour and practice and their responsiveness to change continues to be a focus in the literature (e.g., Fullan, 2020). While there is general consensus about the importance of teacher professional learning, there is less consensus about how this process occurs (Justi & van Driel, 2006). Research suggests professional learning in general is more likely to be successful if it takes place as close to the teacher's working environment as possible, provides opportunities for reflection and feedback, involves a conscious commitment by the teacher, and makes use of external expertise such as the services of a consultant and/or critical friend to build capacity (Geiger et al., 2015; Fullan, 2020; Lovitt & Clarke, 1988). Borko et al. (1997) found that professional learning experiences that provided opportunities for teachers to explore new instructional strategies and ideas in the context of their own classroom practice were among the most effective for promoting and supporting teacher change. The Australian Association of Mathematics Teachers (AAMT) agrees and advocates that professional learning for teachers of mathematics has to be relevant, personalised to meet the needs of the educator, collaborative, evidence-based and sustained (AAMT, 2013). The term 'teacher professional growth' was used by Clarke and Peter (1993, p. 167) to highlight that teacher change resulting from professional learning is a continuing process, and Clarke and Hollingsworth's (2002) Integrated Model of Professional Growth, which builds on the original work of Guskey (1986), provides a means of interpreting how teacher professional growth occurs.

Accounts of researchers working alongside teachers in classrooms to develop pedagogical practices are well documented in the literature (e.g., Thomas et al., 2019; Goos et al., 2000), with researchers able to provide an external source of information or stimulus (Clarke & Hollingsworth, 2002). Furthermore, researchers can support teachers to implement new practices as they engage in professional experimentation (Clarke & Hollingsworth, 2002). In the study discussed in this paper, teachers participated in a research project that aimed to improve regional low SES students' learning and wellbeing in six case study schools in Victoria and Tasmania. These schools were selected as being representative of other low-SES sites in regional centres. Teachers from the case study schools, in collaboration with the research team, selected a focus of professional growth from five pillars: personalised learning, flexible use of space, team teaching, use of digital technology and student wellbeing. Teachers at the two case study sites discussed in this paper identified personalised learning incorporating a team-teaching approach as a key focus for better supporting student learning and wellbeing needs.

Learning is considered to be personalised when learners are motivated to learn because they view the learning task or experience as engaging and meaningful, and as directly addressing their learning needs (Bray & McClaskey, 2012). When learning is personalised, students enact and review personal learning processes and have increased input in the design and focus of topics, which improves motivation for learning (Prain et al., 2018; Schwartz et al., 2011). There is evidence that the active problem-solving and enhanced student agency inherent in personalised learning approaches can be relevant and motivating for students (Belenky & Nokes-Malach, 2012; Schwartz et al., 2011). This has particular implications for mathematics learning, where low levels of engagement with the subject has been an ongoing concern in recent decades (Marginson et al., 2013).

As a means of personalising individual instruction, the two schools focused on using student data. The purposeful use of student data has been found to improve school practices and subsequently student learning (Masters, 2010; Muir et al., 2018), and the teachers in the case studies were exposed to other schools in the project that were capitalising on the use of student test data to plan individual programs. Teachers were motivated to adopt a personalised learning approach to teaching mathematics, informed by the use of student data, to make learning about mathematics more relevant and motivating for students. For many teachers in general, this would require a shift in pedagogical practices that may be difficult to implement and sustain. This paper describes the approaches undertaken in two case study schools, the changes required in teachers' pedagogy to enact the approach, and the professional growth experienced by the teachers as a result of this enactment. Specifically, the study addresses the following research questions:

1. What professional growth did teachers experience as a result of a focus on personalised learning?
2. What factors influenced the professional growth of these teachers?

The two selected cases illustrate different approaches taken by teachers to personalise the learning of mathematics for students. While both schools used students' mathematical data to inform pedagogical decision making, one (secondary) school based their instruction around the use of Maths Pathways (an online educational website) and flexible learning spaces, while the other (primary) school utilised fluid groupings and collaborative planning and teaching. Both cases required a shift in teachers' pedagogical approaches to planning and teaching mathematics in their individual classrooms. This study explores the processes of professional growth that enabled the teachers to embrace personalised learning, and thus contributes to existing research through using the context of personalised learning in mathematics to demonstrate how professional growth can occur.

Review of the Literature

Professional Learning and Professional Growth

Education scholars contend that one-off professional learning experiences have limited capacity to bring about effective and sustained changes in teachers' practice (e.g., Boyle et al., 2004; Fullan, 2020). Instead, professional learning is strongly shaped by the context in which teachers' practice, which is usually the classroom (Timperley, 2008). To make significant changes to their practice, teachers need multiple opportunities to learn new information and understand its implications for practice (Timperley, 2008), trial new approaches, and evaluate the impact of these approaches. As additional enablers, Timperley (2008) recommends that collegial interaction and external expertise are required to challenge existing assumptions and develop new knowledge and skills associated with positive outcomes for students. A professional growth approach (Jackson, 1974) describes teachers engaging in professional learning as practitioners of the art of teaching, rather than remediating personal inadequacies. This approach is more likely to result in participants seeing a perceived need for professional learning that is related to their work with learners (AAMT, 2013). The school context also influences teachers' professional growth (Clarke & Hollingsworth, 2002).

Professional learning that develops teachers' knowledge and skills is more likely to result in changed practices if teachers adopt these approaches into their repertoire (Clarke & Hollingsworth, 2002) and are supported to do so. Whether these changes are maintained is often determined by the demonstration of learning success by students. If changes in teaching approaches result in salient outcomes (Clarke & Hollingsworth, 2002), or in other words, outcomes that can be perceived as favourable by teachers, then it is likely that the changed approaches will be maintained.

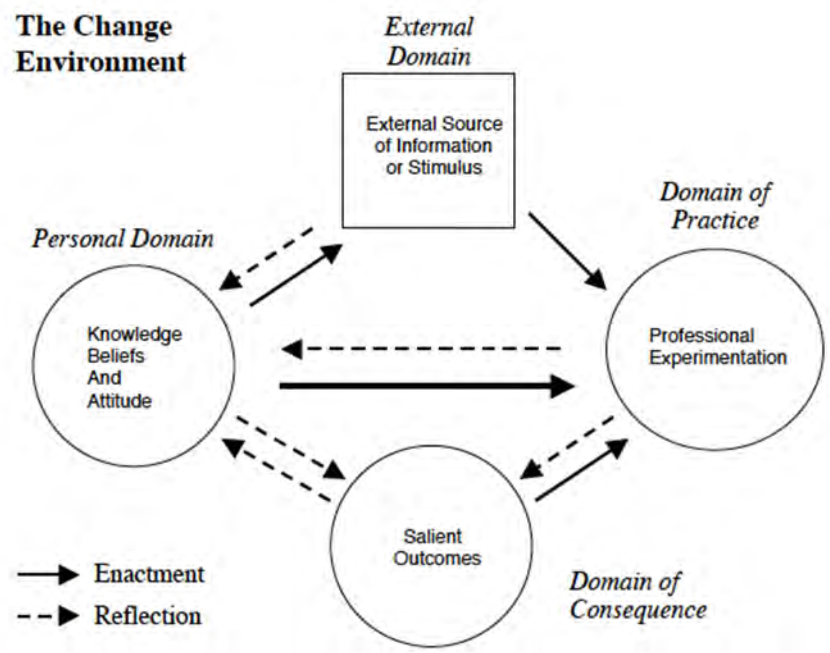

Figure 1: Interconnected model of Teacher Professional Growth (Clarke & Hollingsworth, 2002).

The Interconnected Model of Teacher Professional Growth (Clarke & Hollingsworth, 2002) identifies the mediating processes of reflection and enactment as the mechanisms by which change in one domain leads to change in another. As shown (Fig. 1), four domains are identified, with the type of change reflecting the specific domain. The external domain is distinguished from the other domains by its location outside a teacher's world. The domain of practice, the personal domain and the domain of consequence constitute the teacher's professional world. Change may occur in any domain. For example, using a new teaching approach is relevant to the domain of practice, and a changed perception of salient outcomes related to classroom practice would reside in the domain of consequence. Clarke and Hollingsworth (2002) used data from three Australian studies to provide the empirical foundation of their model. Along with finding that the school environment had a substantial impact on professional growth, having a community of colleagues with whom consequences of experimentation were shared facilitated the documented changes in teachers' practices. These findings are consistent with other research that endorses collaboration, particularly in the form of professional learning communities, where practices are deprivatised (Vescio et al., 2008), enabling teachers to engage in meaningful reflection alongside colleagues working in similar contexts (Buysse et al., 2003). These similar contexts can include considerations such as working in contemporary spatial configurations that afford a variety of social and pedagogical approaches (Fisher, 2016).

The model has been applied in a range of contexts to identify growth in teachers' learning, including science teachers' content and pedagogical content knowledge about the roles of models in science education (Justi & Van Driel, 2006), teachers' pedagogical content knowledge related to multiplicative thinking (Downton et al., 2019), and teachers' professional learning in mental computation (Hartnett, 2011). Common to all studies was the consideration of the framework in terms of designing professional learning experiences, and collection of data related to changes in each domain.

Personalised learning and use of student data

While it is beyond the scope of this paper to discuss personalised learning in detail, for the purpose of this study, personalised learning is:

> *Instruction that is paced to learning needs, tailored to learning preferences, and tailored to the specific interests of different learners. In an environment that is fully personalised, the learning objectives and content as well as the method and pace may all vary (so personalisation encompasses differentiation and individualisation) (Bray & McClauskey, 2012, p. 2).*

While personalisation may encompass differentiation and individualisation, it essentially involves instruction that is 1) paced to learning needs, 2) tailored to learning preferences, and 3) to the specific interests of different learners. By contrast, differentiation involves learning goals that are the same for all students, but the method or approach of instruction varies according to individual students' learning preferences and needs (Suprayogi et al., 2017). While individualisation also has similar learning goals for all students, it is unlike personalisation and differentiation in that the instruction differs mainly in pace, adapted to the learning needs of different learners, allowing students to progress through material at different speeds according to their learning needs (Bray & McClaskey, 2012).

Teacher strategies to support personalised learning assume a progression of learner capabilities, in that teaching practices fall into a continuum from teacher-regulated control to co-regulation/negotiation between teachers and students, through to increased learner independence (Prain et al., 2018). This is particularly applicable to any school context where students have less autonomy over what, how and when to learn. It is also reasonable to suggest that student-centred personalisation would evolve gradually, beginning with teacher-regulated strategies that include teachers taking the major responsibility for student motivation and differentiation of learning experiences (Tomlinson, 1999). Personalisation of learning can occur, but primarily it is the teachers who design options for students in curricular content, learning processes and assessment methods, and provide frameworks for tasks and model strategies. Teachers monitor students' progress, while students are expected to fulfil teacher-determined learning gains (Prain et al., 2018). Providing mathematical experiences that are personalised for individuals necessitates an awareness of where students are currently at in terms of their mathematics understanding. A key finding from a study aimed at developing an evidence base for best practice in mathematics education identified that data can be used to monitor student outcomes and progress in mathematics (Smith et al., 2018). *Analysis and discussion of data* was one of the eight domains identified in the Teaching and Learning School Improvement Framework (Masters, 2010), whereby outstanding schools were characterised by having established and implemented a systematic plan for the collection, analysis and use of student achievement data. Furthermore, data were used throughout the school to identify gaps in student learning, monitor improvement over time and monitor growth across the years of schooling (Masters, 2010). The Grattan Institute also recommended the use of data to inform teaching, on the basis that it facilitates teachers to have a shared sense of responsibility for student learning, assists with developing a common language across the school, and can provide the basis for in-house professional learning (Goss et al., 2015). Providing students with access to their data, and subsequent articulation of learning goals for mathematics, is an example of how a student's individual data can be used to personalise learning experiences in mathematics.

Methodology

The cases reported in this paper were part of an Australian Research Council funded linkage grant involving six schools from two Australian states that aimed to improve regional low SES students' learning and wellbeing.

The multiple case study approach described by Yin (2009) is used to provide a fine-grained examination of a teacher practice adaptation across two different school contexts. A within-case analysis is presented for each case study to identify the distinctive characteristics of each site, followed by a cross-case comparison. Similarities and differences between each case were examined by the research team, based on a systematic comparison between the literature and the data (Eisenhardt, 1989). Teacher practice was considered as a participatory activity that could not be investigated separately from the classroom context (Clarke & Hollingsworth, 2002).

Data Collection and Analysis

While the specifics of data collection, participants, and procedure are provided separately in relation to each case, the primary sources of data for both were lesson observation field notes and interviews. Field notes and interview transcripts were both analysed using inductive and deductive codes, related to evidence of professional experimentation in personalising learning in mathematics, and use of student data. Teacher interviews were primarily analysed using the domains from the Interconnected Model of Professional Growth (Clarke & Hollingsworth, 2002). Initially open codes were used and then grouped into the four domains. As an example, "All students achieved growth … and even Ethan improved by 25" was initially coded as improved test results, and grouped under the domain, 'Salient outcomes'.

The cases are presented using Clarke and Hollingsworth's theoretical framework. The first case documents the professional growth that occurred when teachers capitalised on mathematics test results to personalise students' mathematics learning with data gathered through observations and teacher and student interviews. The second case provides an account of the teachers' growth that occurred when they attempted to personalise the learning of mathematics based around the Maths Pathways program, with data gathered through lesson observations and teacher interviews. Full ethical approval was obtained for the study and pseudonyms have been used throughout in the reporting of results.

Results

Case 1: Mallee Primary School

Mallee Primary School is a rural school with a total student population of 413. The participants for the study were four Year 5 and 6 teachers and their classes, which totalled approximately 120 students.

The researcher's role at Mallee Primary School was partly observer, participant-observer, and external source of information or stimulus (Clarke & Hollingsworth, 2002). Beginning in 2017, the researcher, who was a mathematics teacher educator, met each term with the Year 5/6 teachers and school leaders to identify the mathematical focus for that term. The researcher and teachers worked collaboratively to develop or adapt a pre-test on the topic that was administered to all students. The teachers marked the tests and organised the students into four ability groups based on the results. They conducted interviews with the students to share individual test results and asked students to write personal goals for mathematics learning. With the support of the researcher, the teachers collaboratively, then individually, planned whole group experiences for the student cohort.

In addition to *regular* mathematics classes, two to three sessions per week were planned whereby the students gathered in the Performing Arts Centre (PAC) space. PAC maths (as it came to be called) involved a 15-20-minute session planned and led by one of the teachers. Typically, the sessions involved familiarising students with a relevant mathematical topic or concept for that cycle. In this case, the topic was different mental computation strategies. Students were introduced to strategies and provided with problems to calculate mentally before they participated in whole group sharing of selected students' strategies. Students used miniature whiteboards to record their thinking when required. Following the whole group session, students were split into ability groups and moved to their allocated teacher's classroom. Each teacher was responsible for providing targeted instruction for their group. The experiences for each group were similar but differed in terms of the magnitude of the numbers involved in the calculations and pace of instruction. The teaching of mathematics continued in this way for four to six weeks, before students completed a post-test. Results were then discussed amongst teachers and students and a new focus was identified.

The data reported in this paper relates to the fourth cycle, which was undertaken in Term 3, 2018. Data sources included lesson observations and focus group interviews conducted with students and teachers. Interviews were semi-structured, of approximately 15 minutes in duration, audio-recorded and transcribed. Three focus group interviews were conducted with the teachers and analysed to look for evidence of changes in practice using codes informed by the four domains of Clarke and Hollingsworth's (2002) model. The results are organised around the four domains of the model.

External Source of Information or Stimulus

The primary external sources of information or stimulus for the teachers were information sessions conducted by the research project team, site visits to other schools in the project, and modelling and expertise shared by the researcher who worked with the school. Four staff from the school visited each of the six Victorian schools in 2017-2018. The visits allowed the teachers to observe different ways in which personalised learning was enacted, particularly in open-plan settings, and across a range of subjects. The concept of PAC maths evolved from the first visit as the teachers were impressed with how the Victorian teachers planned collaboratively and shared responsibility for whole cohorts of students rather than individual classes. They were also interested in trialling the teaching of a whole cohort of students in a school with no open-plan classrooms.

The researcher supported the teachers with the adoption of new practices that were mathematically pedagogically sound and acted as an external stimulus. Typically, her role involved modelling of lesson starters in the PAC space with the students, providing resources for differentiating mathematical teaching and learning across a range of topics, and observing teachers' instructional group lessons. In addition, she conducted interviews with students and provided teachers with feedback on their attitudes towards PAC maths. One of the teachers, Julie, in a focus group interview, commented on how the influence of the researcher's contestation of habituated ideas impacted on the use of appropriate pedagogical practices for teaching mental computation:

I've always been saying, "Show your thinking, your steps of thinking" but if they know it's seven straight away, it doesn't really matter what's happening in their head, which was interesting for me to realise. They don't have to always show their thinking.

Domain of Practice: Professional Experimentation

Professional experimentation involved the adoption of PAC maths teaching approaches to complement regular classroom mathematics lessons. Students were grouped according to their performance on pre-tests, and each teacher was allocated a group to work with over the course of four to six weeks. There was provision for students to move in and out of these groups throughout this period, depending upon their progress in the group. This was a significant departure from traditional teaching practice where each teacher is responsible for an allocated class group. While the team of Year 5/6 teachers regularly engaged in collaborative planning, the PAC maths approach involved more targeted planning based on student data. Following the marking of students' pre-tests, the teachers discussed teaching approaches and strategies that would be appropriate for each grouping, using the Australian Curriculum: Mathematics (AC:M) as a guide for appropriate learning experiences. Each teacher was responsible for selecting or developing experiences for their group. In addition, they were scheduled to lead whole cohort PAC maths introductory sessions. Throughout each cycle, teachers met once a week to reflect on the experiences, update colleagues on planning decisions and discuss the focus of the whole cohort introductory sessions.

Grouping arrangements meant students would not necessarily be taught by their class teachers. This was a form of professional experimentation, as many teachers and students were required to establish new relationships. Student comments indicated they perceived working in a flexible space as beneficial to their learning: "It's a lot more exciting and it's really easier to work in an open space." (Ian, Grade 6 student).

Students' accounts of typical mathematics lessons experienced in previous years demonstrated the changes in teaching approaches that occurred through teachers' professional experimentation: "I think maths has changed a lot since kinder … because last year we just got given the worksheet and it had to be done by some date, and then we had to do it with no help" (Mark, Grade 6 student).

In terms of teacher reflections on professional experimentation, most of their feedback focused on their experiences working with their instructional groups as the following illustrative feedback shows: "The strategies that we've named up and the language that's been associated with them has started to come through" (Cathy, Grade 5/6 teacher).

In summary, PAC maths allowed for collegial experimentation. The teachers adapted their practice from a traditional, class-based approach to a whole cohort and fluid groupings approach that involved adopting a shared responsibility for teaching mathematics. Changes in practice as a result of this experimentation were perceived as positive by teachers and students.

Domain of Consequence: Salient Outcomes

Student positivity about the PAC maths approach was evident in observations of their engagement in whole class PAC maths sessions and subsequent instructional groupings. In their focus group interviews, teachers commented on the lack of behaviour management issues and the students' willingness to adopt the approach: "We've had very little behaviour management … the kids have really coped with it. There have been no complaints" (Julie, Grade 5/6 teacher).

Another salient outcome was that teachers found it easier to teach the subject matter to students with similar ability levels:

> *When you've just got your class, the range [of abilities] is so huge. All across the whole 5/6 cohort, there's a big lot of D kids. Because you've got Ds and you've got your As and a few Es*[1]*, it's really hard to plan at everyone's level. (Julie, Grade 5/6 teacher)*

Consistency in teaching approaches and the use of common language were other salient outcomes identified by the teachers and students. For example, Troy, one of the teachers, noted, "I think that all teachers using the same language is good". Ultimately, the approach was adopted by teachers to improve students' mathematical outcomes, and for each iteration of PAC maths, teachers saw an overall improvement in students' results. Troy drew attention to student learning outcomes "…some of the shifts were significant for a lot of kids. Devon was a really good one, he actually jumped plus ten. And Jill jumped plus 24, so she went from 15 to 39. Wow. So that was a really massive gain as well. Yeah. And Nigel actually went from 16 and a half to 39. Other salient outcomes noted by both teachers and students included increased enthusiasm for mathematics and greater challenge and success in the subject.

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[1] Grade descriptors used to describe achievement against the standards:
A indicates that a student has demonstrated excellent achievement of what is expected. B indicates that a student has demonstrated high achievement of what is expected. C indicates that a student has demonstrated satisfactory achievement of what is expected. D indicates that a student has demonstrated partial achievement of what is expected. E indicates that a student has demonstrated limited achievement of what is expected.

Personal Domain: Knowledge, Beliefs and Attitudes

Shifts in teachers' practices indicated growth in their professional knowledge. Teachers' comments indicated they believed that similar ability groupings made instructional teaching easier, and that students also preferred that approach.

By allocating different teachers to different instructional groups each cycle, students were exposed to different teaching styles. For example, teacher Cathy stated: "That's been really powerful for the kids to see that we all teach [from] top group to the bottom group". The PAC maths approach to teaching mathematics provoked changes in behaviours and attitudes amongst teachers who were able to reconsider ideas about what student learning in mathematics looked like and the advantages of fluidly grouping students according to ability.

Summary of Case Study 1

Overall the results from this case demonstrate that professional growth occurred as a result of external input and collegial experimentation that allowed teachers to recognise salient outcomes in students' achievement. Shifts in teachers' practices occurred as they observed the benefits of the approach and as they engaged in regular reflection and discussions to collaboratively plan the cycles of instruction. Student outcomes data showed that they were achieving growth in their mathematical knowledge, which provided motivation for teachers to continue with the approach.

Case Study 2: Grevillea College

Grevillea College is a secondary school with approximately 650 students from Years 7-10, located in a low SES part of a large regional town in Victoria, Australia. The school consists of four open-plan learning communities, which each hold around 150 students, divided into two neighbourhoods.

This case study reports on three mathematics teachers, George, Miley and Sam, who were working in one neighbourhood with 75 Year 7 and 8 students. Ten observational visits were made to Grevillea during 2017, three in each of the first and third terms, and four in the second. Each observational visit was for a 70-minute class, during which time informal conversations were also conducted with teachers as they worked. Ongoing meetings between the researcher and teaching staff members were used to discuss and reflect on the observations, to identify key themes and issues related to personalising learning within the neighbourhood context.

The mathematics teaching approach at Grevillea was based on the Maths Pathway online program, a personalised data-driven teaching approach that supported students along individual pathways, guided by a computer program that supported regular testing and generation of targeted exercises aimed at a student's point of need. It is possible, using this program, that each student in the class could be working on a different topic module. The data provided from Maths Pathways enabled teachers to monitor each student's progress, including diagnostic evaluations of topic understanding and conceptual misunderstandings.

External Source of Information or Stimulus

The initial stimulus for the development of a personalised model of mathematics learning was the availability of instantaneous data and targeted learning activity modules from Maths Pathways. These student data allowed teachers to measure the impact of ongoing changes to teaching context and practice. All classes were timetabled into one large flexible space. The teachers' experimentation suggested that there was no immediately obvious or agreed approach for effective use of Maths Pathways.

Essentially, the development of a personalised model of mathematics using Maths Pathways enabled a shift from didactic teaching to individualised mathematics programs for a diverse cohort of students. Data-driven teaching complemented existing on-demand assessment, tracking and targeted attention to individual student achievement used at Grevillea. This personalised approach challenged the traditional whole-class mathematics teaching usually found at Grevillea and raised questions about the role of the mathematics teacher, since Maths Pathways conducted all diagnostic and summative testing, preparation of work modules, and provided feedback on areas needing remediation. The Maths Pathways data showed that among the 75 Year 7/8 students, there was a broad spectrum of capacity, ranging from students operating at Year 2 level to those at Year 8 level. As noted by the teachers in early observations, this justified the use of a program capable of generating personalised work curricula for the cohort.

Through their collaborations, the three teachers identified that their role was to support individual student progression. There was no whole class direct instruction observed from any teacher during Terms 1-3. This was a significant teacher adaptation to practice as they responded to the possibilities of collegial practice, Maths Pathways and the flexible spatial context. A key influence on the process appeared to be the interaction among teachers as they planned and constructed practice changes within the flexible learning space.

As data were collected for this case study using observation, it is important for the researcher role to be noted as a further external source of information. In this case study, the researcher's role was to provide information and feedback to the teaching team. In classroom observations, the researcher aimed to be unobtrusive. Students and teachers being observed were aware of the presence of this observer who did not lead any instruction or overtly influence the teaching or learning activities other than engaging in occasional conversation about the mathematics activities.

Domain of Practice: Professional Experimentation

In the observations conducted during Term 1, three Year 7 and 8 mathematics classes were timetabled into this shared neighbourhood four times a week. It was observed that the teachers taught their own classes, largely in their own corners of the neighbourhood. However, the three teachers appeared to be aware that the learning neighbourhood space afforded flexible teaching and learning practices. George commented that although the teachers were aware of each other, they tended to concentrate on their own students, but there were ongoing collegial planning discussions about how they could use both the Maths Pathway data and the shared space to improve the teaching of mathematics (Observations 1-3).

It was apparent that Term 1 was being used to build familiarity among teachers and students of how Maths Pathways could be used to support the personalisation of learning. During the observations, the teachers became aware of the visibility of their own and each other's practice and started to discuss the possibilities of a more collegial approach to planning and teaching together to take advantage of the data driven teaching program.

As an insight into the teachers' reasoning, George commented that students "have to participate in their own way; they have independent control over their own learning activities". This independence was supported by the availability of achievement data directly to students from Maths Pathways. George also developed ideas about how the classroom space would support teaching practices: “We have to have space between kids and groups; and space for teacher navigation of the room to see and help individuals; but we have to keep them all apart”.

During Term 2, the teachers started to experiment with how they used the space for mathematics teaching (Observations 4-7). There was an emerging “fluidity” (George comment, Observation 6), with more interaction between the three classes. In contrast with the observations from Term 1, this involved more teacher movement between classes, and the use of small student groupings, based on similar abilities. The metaphor of fluidity became useful for the teachers to see how the teaching space was or could be experienced by students. Based on teacher comments during Observations 4-7, it was clear that the teachers acknowledged each other’s expertise and had a shared belief in the capacity of students to be active and autonomous learners. Miley said, “The main thing for this group is to learn maths and we need to find a structure to do that.” Finding a structure meant considering different modes of teaching and configuration of the learning environment. The fluid grouping of students was a key element of adaptation of classroom and program structure. From this, it was apparent that the role of the teacher was to be responsive to the Maths Pathways data, to engage with individuals and small groups at a point-of-need.

The observations during Term 2 identified that once each week a teacher would take a group of ten students aside for about thirty minutes for targeted teacher-led instruction. These groups were drawn from all three classes, with selection based on Maths Pathway data showing similar ability. The groups would either focus on remedial or extension work, with teachers rotating responsibility for the groupings, which were fluid in nature, meaning that students could move between groups according to progress. This meant a partial weakening of the notional classroom boundaries established in Term 1 (Sam comment, Observation 5).

Terms 2 and 3 presented opportunities for the teachers to experiment with different teaching and learning processes, including how to identify and use the affordances of the Maths Pathways data and the shared classroom space. The teachers’ preparedness to experiment with teaching approaches indicated that they were willing to collaborate to devise solutions to the question of how to teach using a data driven program. Importantly, teaching using Maths Pathways allowed a combination of using technology to mediate the personalised learning programs for each student, while affording a rethinking of the teacher role to individualised support and targeted teaching of small groups.

Domain of Consequence: Salient Outcomes

Towards the end of Term 3, the teachers seemed to have established a model that integrated pedagogy with the flexible space. The observations showed that all teachers shared the classroom space, with students able to sit in social groups throughout the community space. This reflected a different way of teaching mathematics, based on the use of data to inform personalised learning, collegial teaching practices, and using the spatial affordances.

Maths Pathways was the basis for different teaching routines to be established which focused on supporting personalised learning, drawing on individual teaching expertise and capacity to plan for targeted small group teaching. Teacher visibility and movement in the space supported this approach to personalisation. The flexible space afforded different student groupings and seating arrangements, along with the possibilities for collaborative teaching practices. As stated by Sam, “the reality is we need to have arrangements for both control of behaviour and student learning.” The changes to the level of student engagement with the teaching and learning processes was a key element in the teacher consideration of the success of each different pedagogical or learning environment variation.

Personal Domain: Knowledge, Use of Data, Collaboration

At the end of Term 2 (Observation 7), the teachers were asked to reflect on their use of space during recent teaching. George and Sam indicated they were thinking outside of their own classroom space which suggests that the teachers were making judgements about how different spaces could be used to support teaching and learning processes. The Maths Pathways data was used by teachers to track individual student progress during the period of the study. Over this period, a steady increase in student learning progress was noted by the teachers. However, they were reluctant to report this data as part of this research, as they recognised that many variables could explain the changes to student progress. They perceived a general positive sense of student engagement but identified that the spatial and pedagogical experimentation was a work-in-progress.

At the start of Term 3, the three teachers had a meeting and agreed on key practice principles and spatial arrangements: individual student learning; collegial planning and practice; and targeted grouping of students. The idea of productivity became key, meaning student participation in the data-driven program, and their classroom engagement.

During the observations, the students usually worked productively, with teachers monitoring and moving constantly through the space. Using the Maths Pathways data, teachers were also able to monitor student learning progress on a lesson by lesson basis. Further, the teachers started to develop open-ended problem-based lessons, to be delivered once a week, that provided a whole class, mixed-ability, approach to applying mathematical knowledge to problems. The model of practice had moved to personalised learning based on a participation model that reflected learner ability and learning preferences. There were three elements that provided the basis for this personalised model of teaching mathematics. The first was teacher knowledge of how to engage students through both pedagogy and use of flexible space. The second was to apply Maths Pathways data to respond to learning issues. The final was to work collegially which was evident in the teaching of the different student groups. The way this model was then actioned was based on perceptions of the possibilities of different spatial arrangements within the flexible neighbourhood space.

Summary of Case Study 2

This case study demonstrates how three teachers created a personalised model of teaching mathematics over three terms. In this time, the teachers used affordances of both the flexible space and the data-driven Maths Pathways program to support their individualising of instruction. Further, to address student engagement and participation, they used their knowledge and experience of how to respond to the range of student learning preferences and ability by developing a collegial approach to configure their practices conducive to the spatial environment.

Discussion

In this study, we examined how teachers' professional growth occurred as a result of changes in teachers' mathematical practices, bought about by a focus on personalised learning. Clarke and Hollingsworth's (2002) model of professional growth was employed to demonstrate how engagement in a research project (a stimulus in the external domain) contributed to changes in teachers' understandings (personal domain) towards personalising mathematics teaching and learning (professional domain). The following discussion synthesises the results from the two case studies to highlight the changes in teachers' practices that occurred as a result of their involvement in the study, and their subsequent professional growth.

Changes in Teachers' Practices

In both cases, teachers used student test data to inform teaching, with their mathematics practices shifting from individual teaching approaches to collaborative endeavours, involving the use of individualisation and fluid groupings. Personalisation was evident through differentiation and individualisation. This personalisation can be characterised as varying the nature of the learning experience of mathematics learning. In line with suggestions of the AAMT (2013) and Timperley (2008), the two cases provided multiple opportunities for the teachers to trial and reflect on relevant, collaborative, evidence-based and personalised approaches to the teaching of mathematics, enabling teacher professional growth.

Both case studies capitalised on the use of student data to differentiate the learning of mathematics for students. The practice of sharing data with students and encouraging them to set personal goals and take ownership of their learning marked a shift in practice in both cases. Similarly, the use of data to form similar ability groupings was common to both cases. In the first case, teachers shared students' test data with students and pursued a fluid grouping approach to supporting students' growth in understanding and achievement. In the second case, a computer program was employed to encourage independent learning in a flexible learning space. Teachers provided individual support for student goal setting and incorporated fluid groupings for targeted small group teaching. In both cases, student data was used as a student resource to support student ownership of learning processes. This represented a change in practice from previous years in which data were not shared with students or used to individualise learning across grade cohorts. The teachers shifted from a focus on the systemic collection and analysis of data used to monitor improvement over time and growth across years (Masters, 2010) to data collection used to inform teaching and facilitate a shared sense of responsibility for student learning (Goss et al., 2015). The two case studies showed how teachers attempted to employ personalised approaches to make performance data meaningful to students to help them understand where they could improve. Both scenarios revealed that students were interested and motivated to improve their own mathematics performance.

The collegial and collaborative approaches discussed by teachers in both cases and the subsequent enactment of these approaches provided evidence of a collaborative work culture and deprivatised practices (Vescio et al., 2008). Again, this demonstrated a change from previous practices, whereby teachers may collaboratively plan for mathematics teaching but not collaboratively engage in the teaching of mathematics (Geiger et al., 2015). Part of the success of this collaborative approach to teaching was the use of fluid ability groupings, enabling teachers to focus on learners at a particular developmental stage. The use of fluid groupings was a factor identified as best practice in mathematics education and was a characteristic of schools that achieved sustained growth in numeracy outcomes (Smith et al., 2018).

While ability groupings have limitations, the fluid ability grouping approach employed in both cases meant that students were not permanently consigned to an ability group and could move between groups. Both case studies made use of fluid ability groupings and appeared to offer conditions in which learning could be more individualised to help differentiate the learning for a range of ability levels.

Both cases provide evidence of how the learning environment influenced teaching practices. Building on the research of Fisher (2016) who found that contemporary spatial configurations can foster changes in pedagogical approaches, including social and personal learning, the large physical spaces in these two case studies also allowed for: collaborative approaches to teaching; students from different classes to work together; fluid groups to be formed and taught using different spatial configurations; and a sense of being open or visible to outside researchers or other educators. Importantly, working together in a shared space meant that the teachers' expertise was available to all students, echoing the findings of Rytivaara et al.'s (2019) study of teachers working in shared spaces.

Changes in Teachers' Professional Growth

The study demonstrated how changes in teachers' practices, resulting from external stimuli such as participation in a research project, availability of detailed student data, or flexible learning environments, could lead to teachers reconsidering their practice through collaboration and experimentation. Through both schools' involvement in the research project, which allowed researchers to work alongside them, teachers were exposed to *an external source of information or stimulus* that motivated them to adopt new practices. *Professional experimentation* occurred in both cases through the shift from a class-based approach to a whole cohort approach that involved a shared responsibility for teaching mathematics and a greater focus on individual learning.

Both cases demonstrate shifts in practices, but as the research indicates, these shifts may not have been sustained if there was no evidence of changes to student learning outcomes (Clarke & Hollingsworth, 2002). In both cases, *salient outcomes* were evident in student and teacher engagement and satisfaction with the new approach.

For both cases, shifts in teacher practice occurred as they observed the benefits of the approaches and through their opportunity to engage in regular and collaborative reflection, planning and teaching (Fullan, 2020). Both cases demonstrate a professional learning community model, whereby students' needs and capabilities were discussed with colleagues working in similar contexts (Buysse et al., 2003). Teachers in both cases were able to reconsider ideas about what learning in mathematics looked like and how grouping for instruction, for example, could help differentiate the learning for a range of students. Overall, the teachers at each school showed a willingness to be open to acquiring new knowledge, and to experiment with new practices, experiencing positive benefits as a result.

Conclusions and Implications

In the ongoing efforts to make mathematics learning relevant to students, this research explored ways in which teacher professional growth can be achieved through a focus on changing pedagogical approaches, which is this context, involved personalising the learning of mathematics. Strategies employed by the participating teachers were designed to enable students to access mathematical content that met their present needs as well as providing opportunities for using assessment in ways that supported their own valued goals. The two case studies afford insights into how shared responsibility and purposeful use of student data can lead to positive teacher professional growth and improved learning outcomes for students. The professional growth was enabled by the flexible learning environments which provided opportunities for teachers to work collegially, and to experiment with a range of teaching practices and learning experiences.

Clark and Hollingsworth's (2002) model of professional growth proved useful for interpreting changes in teachers' practice. Exposure to different enactments of personalised learning, and involvement in the research project, offered productive ways for teachers to experiment with implementing personalised approaches in their classrooms. These results have implications for school leaders and teachers who are interested in bringing about changes in mathematics teaching and learning practices that place an emphasis on individual student progress. Teacher professional growth can be facilitated through classroom-based professional learning, and ongoing access to expert knowledge and support.

It is important not to overstate the success of these initiatives. While we suggest that improvement in student achievement in both case studies may have been influenced by the strategies outlined in this paper, there are likely many other contributing factors. We also acknowledge that the case studies involved two schools and two researchers in contexts that were supported by school leaders, with participants willing to invest a significant amount of time to the project. Nevertheless, the cases illustrate that classroom-based professional learning that is supported by a knowledgeable other, and collegial in nature, can have a positive impact on teacher professional growth. Future studies could examine how professional growth has occurred in other subject areas and how it is sustained over time. In addition, the influence that such an approach has on student learning and motivation would also be worthy of further research.

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