Capitalising on student mathematical data: An impetus for changing mathematics teaching approaches

Tracey Muir
University of Tasmania
<Tracey.Muir@utas.edu.au>

National testing and reform agendas, with their focus on school improvement, has led to increased collection and scrutiny of student data. The analysis of these data usually occurs at a school level, often by school leaders. What is less common is the opportunity for students to scrutinise their individual data and take ownership over the results and subsequent learning experiences. This paper reports on a study whereby students and teachers collaboratively interpreted mental computation test results and identify future teaching and learning directions. The findings showed positive outcomes for students led to changes in teacher growth and approaches to their teaching of mathematics.

A key finding from a study aimed at developing an evidence base for best practice in mathematics education (Smith et al., 2018) identified that data can be used to monitor student outcomes and progress in mathematics. Purposeful use of data was a characteristic of the successful schools in the study, with the report recommending that sharing best practice models for using data would benefit all schools. Direct measures of student outcomes, and the collection and analysis of data, have also been identified as essential contributors to school improvement (ACER, 2019). 'Analysis and discussion of data' is one of the eight domains identified in the Teaching and Learning School Improvement Framework (Masters, 2010) whereby outstanding schools are characterised by having established and implemented a systematic plan for the collection, analysis and use of student achievement data. Furthermore, data are 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 through the provision of a checklist of effective uses of data such as a shared sense of responsibility for students' learning; developing a common language across the school; and in-house professional learning (Goss et al., 2015).

This paper reports on a study which was part of an ARC research project which aimed to improve students' learning and wellbeing through a focus on personalised learning and team teaching in six different Australian schools. Each school identified a curriculum focus, which in this case was mathematics, and for the purpose of this paper, the topic of mental computation. Clarke and Hollingsworth's (2002) model was used to inform the professional learning and subsequent professional growth experienced by the teachers in the study, with student data collected pertaining to students' performance in mental computation. These data were subject to subsequent analysis, and formed the basis for future teaching and learning experiences. The following research questions were addressed for this paper:

1. *In what ways can student data on mental computation performance inform subsequent mathematical teaching experiences?*
2. *In what ways does a shared responsibility for teaching mental computation contribute to teacher growth?*

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Theoretical Background

Schoenfeld (2014) identified five key dimensions which characterise quality learning in mathematics: curricular coherence of the subject, cognitive demand of tasks, student access to mathematical content, opportunities for student agency, authority, and identity, and effective use of assessment. Cox et al. (2015) documented a case study whereby students experienced personalised learning in mathematics that met Schoenfeld's dimensions. Curriculum coherence, for example, was provided through a focus on student learning intentions, and individualised mathematics programs, and students worked in groups at the same level. Of particular relevance to this paper is the consideration of effective assessment, whereby consideration is given to the monitoring of student understanding and timely planning that addresses students' needs and offers ways to progress in performance (Black & Wiliam, 2009). The schools in Cox et al.'s (2015) study used student data collected through NAPLAN and diagnostic tests to design individualised programs for their secondary classes. The researchers found that test results, despite being trenchantly criticised elsewhere for their reductive effects on curricular content and methods, actually allowed teachers to tailor curricular experiences and progressions to meet the developmental needs of individuals in mathematics.

Teacher change and professional growth

According to Guskey (1986), teacher change is likely to occur only after changes in student learning outcomes are evident. Guskey and others (e.g., Fullan, 2015) highlight the limitations of one-off professional learning opportunities and advocate the situating of professional development within realistic contexts. For teachers to make significant changes to their practice, multiple opportunities are required to learn new information, trial new approaches and evaluate the impact of these approaches (Timperley, 2008). In addition, collegial interaction and expertise are required to challenge existing assumptions and develop new knowledge and skills associated with positive outcomes for students (Timperley, 2008). Change is more likely to occur if teachers are seen as learners and schools as learning communities (Clarke & Hollingsworth, 2002), and more likely to be sustained if there is evidence of student learning success. With this in mind, Clarke and Hollingsworth (2002) developed an Interconnected Model of Teacher Professional Growth which identifies the mediating processes of reflection and enactment as the mechanisms by which change in one domain leads to change in another. As shown in Figure 1, four domains are identified, with the type of change reflecting the specific 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. Through the use of the model, Clarke and Hollingsworth (2002) found that having a community of colleagues with whom consequences of experimentation were shared facilitated documented changes in teachers' practice. These findings are consistent with other research that endorses collaboration, where practices are deprivatised (Vescio, Ross, & Adams, 2008), enabling teachers to engage in meaningful reflection alongside colleagues working in similar contexts (Buysse, Sparkman, & Wesley, 2003). Clarke and Hollingsworth's (2002) model has been applied in a range of contexts to identify growth in teachers' learning (e.g., Downton, et al., 2019), and was used to interpret the changes in teachers' practice reported in this paper.

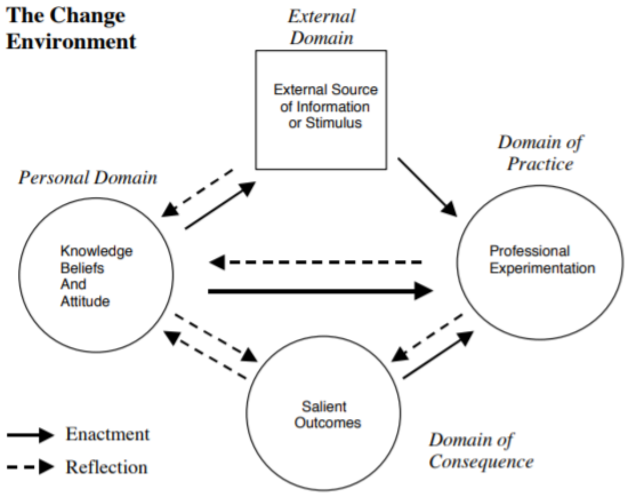

Figure 1. Interconnected model of Teacher Professional Growth (Clarke & Hollingsworth, 2002, p. 951).

Mental computation

Mental computation and the explicit teaching of strategies was selected as a focus by the teachers in this study as they consistently found that students in their Year 5 and Year 6 classes were relying on written methods, rather than mental methods, to solve basic number fact problems. Mental computation is emphasised in the Australian Curriculum: Mathematics (ACARA, 2018). By Years 5 and 6, students are expected to solve problems involving multiplication of large numbers by one- or two-digit numbers using efficient mental strategies (ACMNA100), use efficient mental strategies to solve problems (ACMNA291), including those involving all four operations with whole numbers (ACMNA123). While specific mental computation strategies are not identified, McIntosh and Dole (2004) identified a number of strategies including bridging 10, commutativity, and doubles.

Methodology

The study reported in this paper was part of a wider collaborative project which aimed to improve regional low SES students' learning and wellbeing. Involving six different schools from two Australian states, each school developed their own projects which included individualised approaches to supporting learning and wellbeing, in response to the interests and needs prominent in each site. The project reported here involved teachers capitalising on mathematics test results to personalise students' mathematics learning.

The project used a longitudinal multi-phased mixed methods design study (Creswell, 2003) to examine the effects of the proposed strategies as they were enacted in each school site. Each project site entailed an interpretative cycle whereby observations and teacher insights and practices, gleaned from interviews and meetings, progressively fed into the findings and forward planning.

Context and participants

The site which is the subject of this paper was Epping Primary School (pseudonym). Epping Primary School is a semi-rural school with a total student population of approximately 500. The participants for the study were four Year 5 and Year 6 teachers and their classes which totalled approximately 120 students. Following ethical approval, full consent was given by the teachers and the participating students' parents.

Data collection and procedure

The researcher's role was partly observer, participant-observer, and an external source of information or stimulus (Clarke & Hollingsworth, 2002). Beginning in 2017, the researcher met each term with the Year 5/6 teachers and school leaders to identify the mathematical focus or topic. The researcher and teachers worked collaboratively to either develop or adapt a pre-test on the topic (e.g., mental computation) which was administered to all students. The teachers marked the tests and then organised students into four similar ability groups based on the results. They also conducted interviews with the students to share individual test results and have students write their personal goals for mathematics learning. With the support of the researcher, the teachers adopted a shared responsibility through collaboratively planning for and then teaching, the selected mathematical topic to the whole cohort of 120 students.

In addition to 'regular' mathematics classes, 2-3 sessions were planned weekly whereby all the students gathered in the Performing Arts Centre (PAC) space. PAC maths (as it came to be called) involved a 15-20 minute session which was planned for and led by one of the teachers. For mental computation, the sessions would involve familiarising students with different mental computation strategies, providing them with problems to calculate mentally and then whole group sharing of selected students' strategies. Students used individual whiteboards to record their thinking when required. Following the whole group session, students were then split into four groups and moved to their allocated teacher's classroom. Each teacher was responsible for adapting instruction on a previously agreed strategy for their particular group. The emphasis was on increasing students' range of strategies and teachers typically made use of games and activities to develop the strategies. The experiences for each group were similar, but tended to differ in terms of the magnitude of the numbers involved. The teaching of mathematics continued in this way for 4-6 weeks, and then students were given a post-test. Results were again discussed between the teachers and the students, and a new focus was identified. The data reported on in this paper relates to a fourth cycle undertaken on mental computation in Term 3, 2018.

Data analysis

The data discussed in this paper include pre- and post-test results, student data interviews and a teacher focus group interview. The pre- and post-tests were co-designed with the teachers and the researcher and contained 73 items. Essentially the items were the same for both tests with some variation in the numbers given. There were 50 items that required instant recall, but most items required application of strategies as illustrated in Figure 2. The strategy items were marked according to a rubric designed by the teachers and used a rating scale of 0 (no or incorrect response), 1 (partially correct response) and 2 (complete correct response). The response shown in Figure 2 scored a 2. It was possible to score a total of 116 in both the pre-test and post-tests. Interviews were semi-structured, audio-recorded, of approximately 15 minutes in duration and fully transcribed. Student data interview scripts were open coded, with mathematical language and goals being examples of two codes applied. The teacher's focus group interview was analysed to look for evidence in changes in practice using codes related to the four domains of Clarke and Hollingsworth’s (2002) model. The next section presents the results of the study.

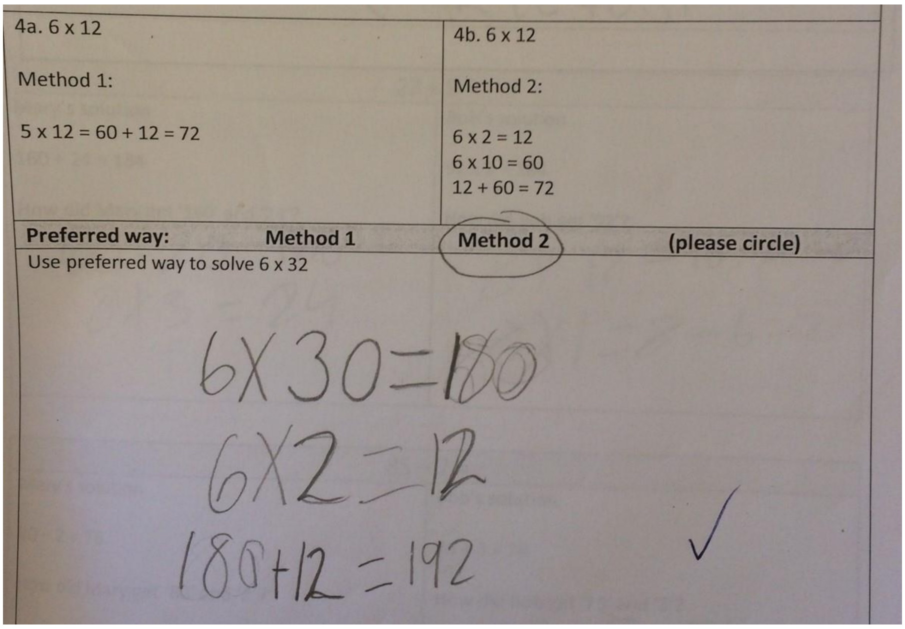

Figure 2. Example of test item and student’s response

Results

Prior to participating in the project, each of the Year 5/6 teachers were responsible for individually planning, developing and teaching mathematics to their own classes. As a result of the project, the teachers assumed a sense of shared responsibility for students’ learning, and changed their approach to collaboratively plan for the whole cohort of Year 5/6 students, based on the results of a pre-test. Individual data interviews were held with students, 15-minute introductory sessions were conducted with the whole cohort, and students were organised into fluid groupings for targeted instruction, based on the results of the test. Students’ and teachers’ experiences of this approach are detailed in the next sections.

Capitalising on student pre-test data

In order to capture how students experienced PAC maths, two students, John and Tina (pseudonyms), have been selected to illustrate how the approach worked in practice. John scored 56 in the pre-test and was particularly confident with instant recall. He indicated in his interview that:

> I reckon I did pretty good. I like times tables, so I’m pretty good with times tables. I think I did pretty good … I liked part two where you had to choose your method, then you had to tell in your answer why it was preferred.

He was less confident with the items that required him to interpret the work sample responses and left most of Part 5 blank which required the use of specific mental computation strategies to solve the problems (“it was a bit hard for me”). John initially identified that his goal would be to “work on harder questions”. His teacher helped him to refine the goal in the following way:

> We've got to have a look at your goal and see if it's very specific or not. So, work on harder questions. We might not know exactly what that looks like, so is there another way that we can be a bit more specific about that? Questions that involve what?
>
> John: Involve maybe harder times tables, like 23 times 200 or something.

In the interviews each student was also encouraged to set a mathematical behaviour goal. After some discussion, John identified that this goal would be to have a go at questions he was not sure about, rather than leaving them blank.

Tina scored 92 in her pre-test and made an attempt to answer every question. While she could identify two different ways to solve problems when asked, her responses showed a preference for the formal algorithm because "it is quicker and easier for me". She was able to articulate areas in which she was confident with and others which she found challenging:

> I did well in the timed questions, then I sort of went downhill through the rest of the test but I still did my best. It was hard for me to say how I did it because most of it was in my head. Division was more challenging because most of the division questions I get always have sevens and eights in them and I can't really divide with seven and eights.

Salient outcomes: Students' perspectives

Along with the whole cohort of Year 5/6 students, John and Tina participated in 2-3 whole group 15-minute sessions in the PAC, followed by 45 minutes of targeted group instruction. According to John's teacher, he was placed in the 'second top' group, where specific mental computation strategies such as doubling and bridging 10 were taught. In his post-interview, John indicated that he thought he had achieved his goal and learned about strategies such as bridging 10 and doubling and halving. He scored 92 in his post-test (an improvement of 31%) and indicated that he liked the PAC maths approach:

> You get to work in groups where you can interact with other people, plus they help you out if you don't know a sum, like, they can teach you how to do it.

Tina was placed in the 'top' group, for her targeted mathematics instruction and scored 105 in her post-test. In her post-test interview she acknowledged that the teaching approach had helped her towards achieving her goal:

> [We learned about] split and divide and split and multiply and friendly and fix … where you make one of the numbers up to ten, instead of having a unit in it and you add that back on later … so 49 plus 20, and you make it into 50. 50 plus 20 is 70, then you minus the one that you added on, so that's 49.

Tina also expressed a liking for the PAC maths approach:

> There's other people in the room … and I like watching what answers they get, once I've got my answer and I'm holding it up. I like seeing how other people have thought, that's my favourite thing about PAC maths … and I like the groups because in [regular] class I have people that are lower than me, so we have to teach them stuff I already know.

Salient outcomes: Teachers' perspectives

The focus group interview provided teachers with the opportunity to discuss the benefits and challenges of the PAC maths approach. They found the pre-test was useful in terms of identifying that while many students did well on the multiplication items, many students found division challenging and did not see the connection between the two operations. The collaborative planning and whole group teaching sessions enabled "all teachers to be using the same language which is good" and the targeted instruction groups provided for differentiation with a smaller range than typically experienced in a regular class grouping:

> Maths is hard to teach in our [regular] class … the range is just so huge … all across the 5/6 cohort there's a big lot of D kids and because you've got Ds and you've got your As and a few Es, it's really hard to plan at everyone's level. [Jane]

> I think that's the key to helping them go forward because you don't have to worry about those ones - you've just got that core of the kids. You know very explicitly what they can and can't do and how you can just push them to move that little bit further because it's just targeted at them. [Tim]

Other than logistical issues early on with factoring in planning time and booking the PAC space, the teachers all agreed that PAC maths was not only beneficial for the students, but also for their own teaching practice:

> I think it's been good in the sessions that we do have together that they [students] realise that sometimes we can be so isolated in our rooms, "Oh, we're all learning this." That's quite a powerful thing … it's pushed us out of our areas as well. It's been really powerful for the kids to see that we all teach – I mean, I've gone from taking the top group to the bottom group and that has been really powerful for the kids to see … it's just been good … everyone's been happy. [Jane]

Discussion

There is evidence that Schoenfeld's (2014) five dimensions of quality learning were enacted through the PAC maths approach. Collaborative planning provided for curriculum coherence across the Year 5/6 cohort. The whole cohort grouping at the beginning of each session ensured that all students received the same core content, experienced different teaching styles, developed a common vocabulary, and were exposed to a wide range of different students' thinking strategies. Like the students in Cox et al.'s (2015) study, these students worked in similar ability groupings, with the establishment of personal learning goals fostering the development of individualised learning.

Clarke and Hollingsworth's model (2002) provided a useful lens for understanding teachers' growth and commitment to sustain the practice. Through the researcher and their involvement with other schools in the project, the teachers were exposed to an external source of information or stimulus. Site visits to other participating schools allowed teachers to observe different enactments of personalised learning and they were particularly impressed with the shared practice of capitalising on the use of student data. The teachers then engaged in professional experimentation through their use of pre- and posttests, whole cohort PAC sessions, which deprivatised their practice (Vescio, et al., 2008) and grouping for instruction. They were motivated to continue with cycles involving different topics when students' results improved from pre- to posttests (salient outcomes) and they experienced satisfaction from their teaching approaches.

In terms of improving students' mental computation skills and knowledge, the interviews showed that students were able to identify learned strategies that were helpful and efficient and helped them to achieve their personalised mathematical goals. The test results allowed teachers to identify gaps in students' learning (Masters, 2010), while the interviews allowed teachers to tailor curriculum experiences to meet the individual needs of students (Cox et al., 2015).

Conclusions and Implications

While the collection of student data is becoming increasingly prevalent in our schools, more could be done to capitalise on this valuable source of information. Analysis and discussion of data has been identified as an essential component of school improvement (ACER, 2019), yet examples of effective ways of how this might be done is limited in the literature. The approach detailed in this paper provides such an example, which could be adapted by schools in similar contexts. It is likely that within any school, that is typically organised in year cohorts, students are exposed to different mathematical experiences depending upon their teacher's interpretation of the curriculum. PAC maths made provisions for teachers to develop a shared responsibility for the Year 5/6 cohort and students and teachers benefited from being exposed to different teaching, deprivatisation of practice (Vescio, et al., 2018) and interaction with different students. The project provided teachers with the opportunity to engage in professional experimentation (Clarke & Hollingsworth, 2002), and salient student outcomes provided an impetus for professional growth to occur. It is hoped that the project detailed in this paper has provided teachers and school leaders with an insight into how rethinking current teaching approaches can lead to improved mathematical outcomes and experiences for students.

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