Visualiser, whiteboard or PowerPoint; the impact of modelling mathematics using different modalities on the accuracy of student work

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I observed anecdotal evidence that the modality chosen by teachers presenting examples seemed to impact student participation and accuracy in example-problem pair work, where students are expected to copy an example and then complete a similar 'my turn' problem. This research was designed to systematically review student books and identify any trends in their work when I modelled examples using a PowerPoint, whiteboard and visualiser. The data suggest participation is consistent across the three modalities, but accuracy varies. The visualizer seems to ensure the most accuracy across multiple metrics. I explored the context of the trends using a reflective journal.

Keywords: modality; visualiser; whiteboard; PowerPoint

Introduction

In September 2022, my department announced a focus on the presentation of student books. This prompted me to trial modelling examples in an exercise book, using the visualiser camera to display on the smartboard what I was doing. I noticed that all students were participating, including some pupil premium (PP) and special educational needs and disabilities (SEND) students who previously refused to participate in written work or made regular mistakes. On circulation I could also see that all their books were remarkably consistent for both examples and practice.

I discussed these observations with teachers and leaders in three secondary schools across multiple disciplines and was intrigued to hear others making similar anecdotal observations. All had been encouraged to try the visualiser by word of mouth and felt that it was a markedly different experience for them and the students. However even those leading continuing professional development courses couldn't direct me towards any formal research or literature to validate or explain the differences in teacher or student experience when working on the visualiser as opposed to the whiteboard or PowerPoint (PPT). I therefore wanted to conduct research that would establish if the choice of modality impacts student work, with a literature review and action research journal to identify any wider theories about how and why any trends may occur.

Literature review

"Writing mathematics (on paper, blackboards or even the air) is indispensable for doing and thinking mathematics" (Greiffenhagen, 2014, p. 504). This assertion, evidenced by the fact that anyone working on a mathematical problem will quickly find something to write with and something to write on, underpins the importance of considering our approach to presenting written mathematics. Giardino (2018) stresses that material and environmental factors around mathematics activity should be studied, arguing that the surfaces and tools used with different modalities act as 'material anchors', the physical features of which affect our production of writing and diagrams, with the resultant choices of spacing and symbols influencing our thinking and understanding.

Giardino (2018) acknowledges that there has not been much research of this kind. What research there has been tends to focus on the actions and opinions of teachers. For example, there are multiple researchers who comment on the prevalence of 'chalk and talk' in mathematics teaching and the ongoing teacher preference for doing maths 'live', be that on blackboards (Greiffenhagen, 2014) or via tablets (Billman, Harding and Engelbrecht, 2018). Both these studies argue that PPT leads lecturers to move through the maths too quickly, is too inflexible for incorporating class discussion and removes previous steps from view too soon (Greiffenhagen, 2014; Billman, Harding and Engelbrecht, 2018). Having identified that PPT is unpopular with lecturers for these reasons, Billman, Harding and Engelbrecht (2018) go on to consider digital pen technology vs blackboards. They acknowledge the cultural significance of blackboards as a symbol of mathematics and contrast that with how tablets improve visibility for large audiences and allow the integration of multimedia and saving and sharing notes electronically (Billman, Harding and Engelbrecht, 2018). However, they do not explore whether the act of writing on the different modalities impacts what and how the teachers or students write.

This links to a pertinent aside made by Mavers (2009) as they discuss the use of whiteboards and visualisers in a primary setting:

> It might be argued that a shift in materiality from the surface of the dry-wipe whiteboard and the marker pen to the page and the biro is inconsequential, in that the content of what is demonstrated remains constant. However, there are also differences. (Mavers, 2009. pp 15)

This is the kind of material consideration Giardino (2018) suggests is often overlooked. Some differences identified are the magnification of text and text-making movements on the visualiser, the detachment of the teacher's body from the presenting area removing distractions, adjustments to pacing and narration to include thinking time and specific references to placement as well as content (Mavers, 2009). Thus, we can see that the physical adjustments made lead to behavioural changes from the teachers and, it would presumably follow, the students too. This is also indicated by Liljedahl (2018), who reported that using whiteboards and paper on vertical and horizontal surfaces changed students' behaviour during group work. Students started working on whiteboards within 20-23 seconds, whilst on paper they started writing after 2.1-2.4 minutes and group discussion significantly increased for both modalities when shared work surfaces were vertical (Liljedahl. 2018, p. 315). Although Liljedahl's work isn't focused on modalities used for presenting information to a class, it follows logically that teachers may make similar behavioural changes when changing modality.

Baldry (2022) suggests that there is perhaps a cultural blind spot in Western mathematics teaching regarding explicit consideration of how we write mathematics. Japanese teachers are specifically trained in 'bansho', the detailed prior planning of board work (Baldry, 2022). This includes assigning regions of the board with explicit purposes, considering which examples to place side by side for comparison, methodically using colour to highlight specifics, routinely recording class discussion, and avoiding erasing work to capture and preserve the full mathematical 'journey' of the lesson (Baldry, 2022). This kind of planning is absent in UK mathematics teacher training, and therefore instinctive behavioural changes elicited by changes of modality, like those observed by Mavers (2009) and Liljedahl (2018), might have greater impact on both teacher and student work. What these instinctive changes are and how modalities could be more consciously chosen for different purposes within the classroom could have significant impact on teaching and learning.

Methodology

I decided to do an action research project, studying my own practice with my students. I already use a combination of modalities in my classroom, and I wanted to see how student books, which I often review, reflected my usual practice rather than specially designed examples.

I wanted to ensure changes to modality was the primary influence on student behaviour. To reduce variation in behaviour management and instructions I developed a consistent, scripted direction to write the example in their books and complete the 'my turn' activity that followed, praising two students and giving one a reminder to join in. I also chose to work with one class of

13–14-year-old students across multiple lessons and topics. I selected a group that was set 3 of 4, as this class includes a range of prior attainment and seven students with PP and/or SEND profiles.

I collected student books across 2 weeks of lessons. Topics covered included expanding double brackets, factorising and solving quadratics and arithmetic with fractions. We had one single lesson using PPT with 2 examples; one double lesson using the whiteboard with 4 examples; one double lesson using the visualiser with 3 examples; one double lesson using each of the three modalities and 3 examples. I collected data for all 12 examples and 'my turn's and have presented the averages from these.

Accuracy framework

In the style of Liljedahl (2018), I created a set of metrics for reviewing student work. As I was focussed on written work rather than group discussion, I trialled the modalities with another class, then used a deductive process to develop and test my metrics. Liljedahl (2018) used rankings of 1-4, but I took a binary approach of 'accurate or not'.

	Metric	Criteria
1	Title	written 'example 1' with correct number and 'my turn'
2	Question	written in full, including any instruction words
3	Diagram	use of any arrows/sketches/underlining
4	Mathematical notation	use of any mathematical notation demonstrated
5	Spacing	position on the page, alignment of any related notation
6	Notes/steps:	any numbered subgoals, steps or comments I have written.
7	Colours:	use of coloured pens to match my colour coding
8	Correct answer	correct answer copied (example) or calculated (my turn)
9	Idiosyncratic notes	Student's own additions to layout, calculations or notes

Table 1: Metrics for accuracy

Data and trends

Metrics	Visualiser Example	Visualiser My turn	Whiteboard Example	Whiteboard My turn	PPT Example	PPT My turn
Number participating	23	24	24	23	22	21
Title	80%	78%	91%	81%	80%	52%
Question	94%	95%	97%	100%	76%	52%
Diagrams	84%	78%	72%	73%	67%	25%
Mathematical notation	69%	58%	43%	29%	66%	27%
Spacing	77%	64%	48%	43%	60%	46%
Notes/steps	95%	NA	62%	NA	71%	NA
Colours	36%	14%	2%	0%	2%	0%
Correct answer	94%	93%	88%	89%	85%	84%
Idiosyncratic notes	14%	7%	28%	18%	20%	14%

Table 2: Average percentage of accurate student work across 12 example problem pairs. Green highlights the modality with the highest joint average across both example and 'my turn'. Red highlights the lowest joint average

From the data in Table 2, we see minimal difference in student participation between modalities. Inconsistencies were generally due to broader patterns in the full data set. For example, attendance varied across the 4 lessons. 2-4 students consistently didn't participate in the final example of the lesson. Some seemed not to want to start a fresh page, others may have lost concentration. Topics that were familiar from previous learning also showed slight reductions in participation, whilst new content consistently had 100% participation. I didn't expect such consistency between modalities from my anecdotal observations. I wonder if my script clarified that students should write in their books. Perhaps my instructions were less rigorous before, but in the case of the visualiser the non-verbal cue of changing to an exercise book mitigated the issue.

In terms of accuracy, the PPT example-problem pairs consistently show lower accuracy, supporting the observations of Greiffenhagen (2014) and Billman et al. (2018). Accuracy is especially low in the 'set up' and 'close' phases, with students making more errors and omissions when copying titles, questions, diagrams, and answers. Perhaps students don't attend to all the information on the slide, particularly any that is unanimated and displayed throughout narration.

In contrast, we see that when working from the whiteboard students accurately set up their titles and questions, but their layout, notation and subgoals are less accurate. This is concerning, as the mathematical processes are what we hope they are attending to during these tasks. However, they do make the most idiosyncratic notes, which will form the basis of a special case below.

Finally, we see the visualiser is consistently where student work is most accurate across multiple metrics. This supports Mavers (2009) comment that although the content is very similar, the modality produces behavioural change. The only metric where the visualiser performs poorly is idiosyncratic notes. This raises the question: are students thinking harder during whiteboard examples and simply copying during visualiser examples? The high accuracy of visualiser 'my turn' work seems to refute this. However what students and teachers attend to merits further consideration. I will do so by presenting some special cases found during this research. These special cases were taken from the double lesson with all 3 modalities because it covered one topic, fractions arithmetic, and had the most consistency in the application of metrics, allowing meaningful comparisons of student work. In what follows, Student A is a student with good prior attainment. Student B is a student with SEND. I chose their work because they highlight the key features of each special case raised.

Idiosyncratic notes

My definition of 'idiosyncratic notes' included written notes and changes to layout. This means that SA2, SA3 and SB12 were each deemed to have idiosyncratic notes. The case of student A adding algebraic illustrations of numerator, denominator and reciprocal demonstrates engaged mathematical thinking. I found it typical that students making notes like this did so across multiple modalities, as Student A does with the whiteboard and visualiser. The case of Student B adding boxes and changing alignments demonstrates idiosyncratic layout, during which they seem to be thinking more about placement than the mathematics itself. However, SB3 shows Student B no longer made such layout changes when working from the visualiser. This suggests they were no longer making active layout decisions, perhaps because the page on screen matched their own, meaning they didn't need to transpose anything. This could be significant for students with SEND, as it reduces cognitive load and allows them to attend to the mathematics.

These observations question whether the idiosyncratic notes from the whiteboard focused more on layout or mathematics. If the former, perhaps students are distracted by decisions about how to transpose information from the whiteboard into their books. If the latter, perhaps there are benefits to the reduced accuracy of whiteboard work. A future study could explore the contents of students' idiosyncratic notes and the quantity and quality of their verbal questions from each modality.

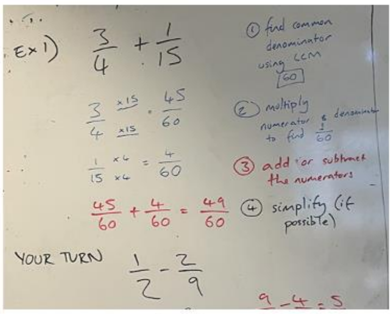

Figure 1.1: My whiteboard example 1 (T1)

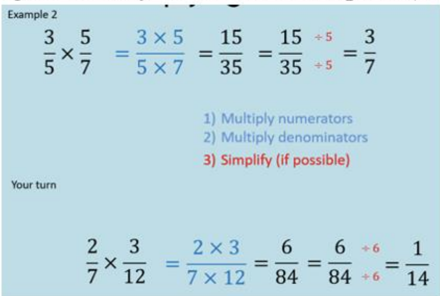

Figure 1.1: My PPT example 2 (T2)

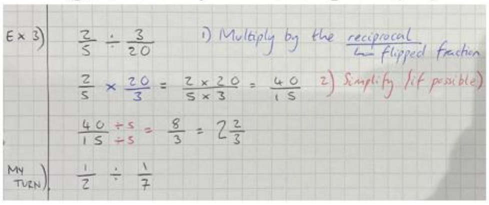

Figure 1.1: My visualiser example 3 (T3)

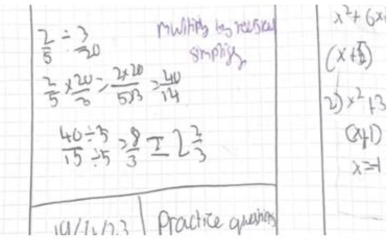

Figure 3.2: Student B example 3 (SB3)

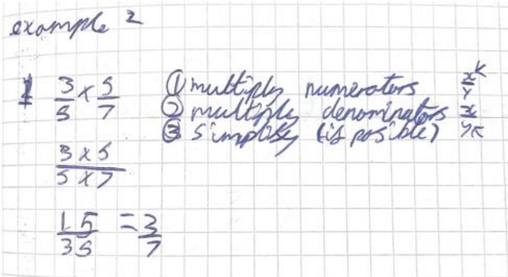

Figure 2.1: Student A example 2 (SA2)

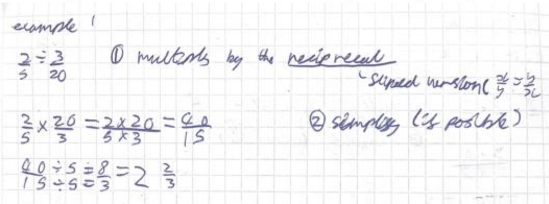

Figure 2.2: Student A example 3 (SA3)

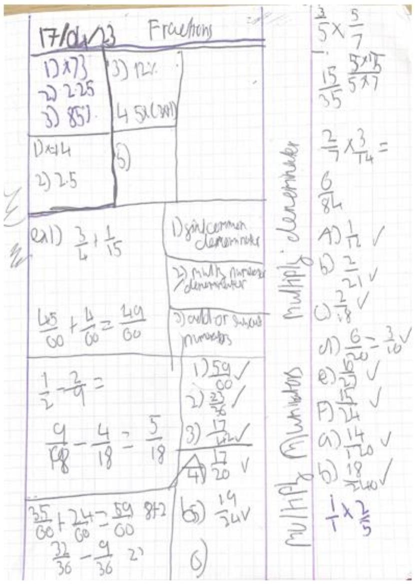

Figure 3.1: Student B example 1&2 (SB12)

Titles

Titles offer insight to teacher mindset. On the whiteboard and PPT I write ‘your turn’ as a title, whereas on the visualiser I write ‘my turn’. I observed the same phenomenon in other teachers’ lessons during my reflective process. Students must then decide whether to write ‘your turn’ or ‘my turn’. For T1 27% wrote ‘your’ and 41% wrote ‘my’, whilst on T2 19% wrote ‘your’ and 43% wrote ‘my’. This suggests some additional mental processing for students to adapt the title, as well as a subtle but important change in teacher mindset from a position of ‘instructor’ to that of both ‘instructor’ and ‘model student’. I believe this subconscious change is due to the ‘material anchors’ described by Giardino (2018), as having a student book and tools in front of me shifts my focus to what they are doing, not what I want them to do.

Use of colour

A striking trend is the visualiser being the only modality where multiple students change colour with the teacher. As T1, T2 and T3 demonstrate, the colour choices I made had been carefully considered to link vocabulary to mathematical activity and to demonstrate subgoals. Despite using the same colours and making specific reference to changing colours while presenting all three, students only did so on the visualiser. Perhaps students are used to seeing colour changes on PPT and whiteboard that they either cannot or need not emulate. Or perhaps the material act of me picking up a biro like their own gives a non-verbal cue which they associate with their own actions.

Conclusion

The purpose of this research was to establish whether teacher choice of modality for presenting examples impacts student work. The data collected across multiple lessons and topics demonstrates clearly that it does. The special cases indicate that changes in modality impact both teacher and students' behaviour and attention. This is supported by the limited literature exploring the central conceit that the 'material anchors' of the modalities we choose impacts how we behave and what we think about.

I believe these observations present a profound opportunity to further explore the behavioural impact of working with different modalities. This falls into two specific areas for research. The first is what students attend to when receiving information from different modalities, and which purposes each modality is therefore best suited to within a lesson. For example perhaps vertical surfaces could be used to support class exploration and discussion, with the visualiser used to support written work. The second is to explore changes to teacher behaviour, layout and instruction when using each modality. This could link to existing best practice around modelling, such as simultaneous presentation of visual and auditory information and directing student attention effectively.

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