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Exploring instrumental orchestration practices for formative assessment through digital technology

Min Chen¹, Rogier Bos, Michiel Doorman and Paul Drijvers

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This study investigates how teachers orchestrate student learning by using technology as well as formative assessment practices in classroom settings, using instrumental orchestration and formative assessment with technology frameworks. Our research question is: how can teachers conduct formative assessment as part of their orchestration practices when using digital technology? This study analyses twelve videos from technology-rich mathematics classrooms in China. The results show frequencies and relations of orchestration and formative assessment practices observed in the videos, and that orchestration practices are predominantly teacher-led, involving supporting direct instruction and providing individualised feedback.

Keywords: Instrumental orchestration, formative assessment, digital technology.

Introduction

Digital technologies have greatly increased the possibilities and potential for mathematical teaching and learning as well as for formative assessment (Weigand et al., 2024). In the context of formative assessment, integrating technology not only provides teachers with immediate feedback on student progress, enabling real-time monitoring of understanding, but also aligns with pedagogical goals to make the formative assessment process more dynamic, responsive, and supportive for student learning trajectories (Dalby & Swan, 2019). However, Drijvers and his colleagues (2013) emphasise that despite the potential of digital technologies to enhance teaching and learning, their adoption by educators does not necessarily lead to improved outcomes. This suggests that simply having access to digital tools is not sufficient—what matters is how teachers use them in response to students' needs. The challenge for teachers in using technology lies not in the technology itself, but in understanding how it can be adapted to enhance student learning, highlighting the need for educators to carefully orchestrate and guide the students' learning processes.

Building on this view, while digital technologies offer new possibilities for formative assessment, their use in classrooms still relies on how teachers manage the integration of these technologies in classroom settings. To better understand this process, *Instrumental Orchestration Theory* offers a framework for analysing how teaching practices shape students' interaction with digital tools. This theory conceptualises a teacher's role in guiding students toward mastering tools and facilitating their learning process (Trouche, 2004). It emphasises how teachers can intentionally and systematically integrate digital technology into their teaching to support students' instrumental genesis, the dual process in which learners adapt tools to their needs while being influenced by the tools in their cognitive and practical activities. Teachers play an important role in orchestrating this process by designing learning environments that support the interaction between learners and tools, ensuring that instrumental genesis unfolds meaningfully (Drijvers et al., 2010). Panero and Aldon (2016) further argue that a teacher's orchestration skills, developed through the appropriation of technology use for formative assessment, are cultivated alongside the students' instrumental genesis. The relationship

between instrumental orchestration and formative assessment with technology could be synergistic, integrating digital technology to create a better way to evaluate and support student learning.

Research has explored digital technology's general capabilities, but few studies have examined the integration of digital technology into live formative assessment, highlighting a gap between ideal and practical implementations. For example, Børte and colleagues (2023) report that teachers struggle to adapt digital technology within their existing formative assessment practices, which not only results in a misalignment between digital technology and formative assessment but also creates difficulties in aligning digital technology with pedagogical methods. This misalignment leads to a missed opportunity to fully explore the potential of digital technology for student-centred learning. To address these challenges, this study investigates the relationship between digital technology, instrumental orchestration, and formative assessment in mathematics education, focusing on how formative assessment is integrated into orchestration practices when using digital technologies.

Theoretical Background

This study adopts the definition of formative assessment from Black and Wiliam, who describe it as an assessment that “elicits, interprets, and uses evidence about student achievement...to make decisions about the next steps in instruction” (2009, p. 9). This definition places emphasis on the continuous, responsive nature of assessment and highlights the teacher's role in adapting instruction based on student needs. In exploring how such processes can be supported through digital technology, this study draws on two theoretical perspectives:

Instrumental Orchestration Theory was developed to shed a light on how the integration of technology into whole-class instruction can be orchestrated in various ways. According to Drijvers and his colleagues (2010), teachers demonstrate technological tools during *Technical-demo*, explain on-screen activities to the whole class during *Explain-the-screen*, or foster discussions about on-screen content during *Discuss-the-screen*. Other orchestration types include highlighting relevant student work for whole class discussion as *Spot-and-show*, connecting digital activities to their representation in traditional mathematical formats as *Link-screen-board*, and asking *Sherpa* students to use technology to perform tasks guided by the teacher as *Sherpa-at-work* (Trouche, 2004). Furthermore, teachers' walking around to provide individual feedback that is referred to as *Work-and-walk-by* (Drijvers, 2011), and teachers' providing screen-based explanations and posing closed questions that is referred to as *Guide-and-explain*, or teachers' reliance solely on traditional board instruction without digital technology is termed *Board-instruction* (Drijvers et al., 2013).

Formative Assessment with Technology, drawing on the work of Dalby and Swan (2019), explores how digital tools can be integrated into formative assessment to support classroom teaching and learning. The framework outlines a circular process consisting of four interrelated stages: *Ask*, *Answer*, *Analyse*, and *Adapt*. The flow diagram (see Figure 1) shows how the four stages connect in practice and helps clarify how technology can be part of classroom formative assessment routines.

Taken together, these two frameworks offer complementary lenses: one emphasises how teachers manage digital tools during instruction, and the other focuses on how technology can support more dynamic and responsive assessment. This study connects these perspectives to examine how

formative assessment is shaped within technology-rich classrooms, and how orchestration practices contribute to that process.

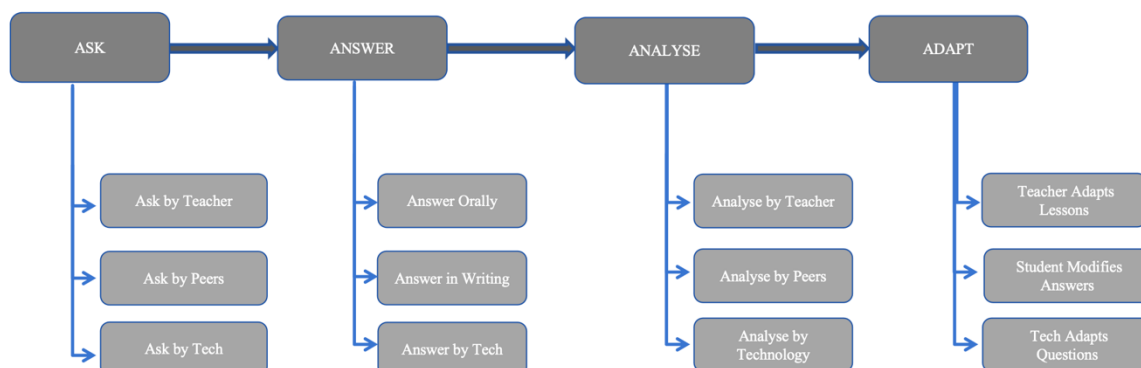


Figure 1: Formative assessment with technology, adapted from Dalby and Swan (2019)

Method

This study investigates through video analyses how secondary school mathematics teachers from Jiangsu Province, China, integrate digital technologies into their teaching practices, including interactive digital whiteboards, tablets, mathematical visualisation tools, software like Desmos and GeoGebra, and immersive technologies such as Augmented Reality. We choose twelve videos of award-winning lessons from the 2022 “*Jiangsu Province ICT-integrated High-Teaching Quality Course Competition*” for observation and analysis. These videos represent exemplary lessons, rather than typical classroom instruction, designed to demonstrate considered best practices in integrating technology within mathematics education. Thus, we expect that the videos could illustrate successful examples of technology-rich classroom practices. The research question of this study is: *How can teachers conduct formative assessment as part of their orchestration practices when using digital technology in mathematics classrooms?*

When analysing the data, we focus on understanding how the orchestration interventions employed by teachers provide them with opportunities to monitor the progress of their students and to assess their work. Initially, the identification of orchestration types was conducted using the instrumental orchestration framework (Drijvers, 2011; Drijvers et al., 2010; Drijvers et al., 2013). Subsequently, the analyses applied Dalby and Swan’s (2019) framework to explore the teachers’ formative assessment practices. Finally, we identified one significant event showing the potential of specific orchestration for formative assessment practice. The coding process was conducted via Atlas.TI, which is a qualitative data analysis software. The unit of analysis was defined as an *episode*, which includes the whole-class treatment of a single task within the video. These episodes were further divided into sub-episodes, if multiple orchestration types were observed in a sequence. Formative assessment instances were identified only when technology was explicitly used to evaluate student understanding, such as gathering evidence on student learning (e.g., digital polling for immediate feedback), analysing this evidence (e.g., reviewing digital submissions for accuracy), or adapting instruction based on technological results (e.g., adjusting tasks based on displayed responses).

Inter-coder reliability was established by having a second coder review three videos with predefined quotations. After an initial coding of one video, the coders reviewed discrepancies in their coding decisions. Through discussion, the coders resolved disagreements, such as whether an adaptation stage of the formative assessment process occurred during the lesson. After reaching a consensus on the coding, the second coder analysed the remaining two videos, resulting in a Krippendorff's alpha score of 0.695. This indicates moderate agreement, which is acceptable given the interpretive complexity of the videotaped classroom interactions.

Results

Table 1 provides information on the frequencies and the relationship between orchestration practices and formative assessment processes. The *Guide-and-explain* and *Work-and-walk-by* types are most prevalent, highlighting the teachers' preference for direct teaching with immediate feedback. The *Sherpa-at-work* and *Spot-and-show* types also frequently occur, though to a lesser extent. Other types are less commonly observed in the classroom settings, with some types such as *Technical-demo* and *Board-instruction* appearing only occasionally across the data (see Table 1, second column).

In the first stage of formative assessment, *Ask*, the orchestration types of *Guide-and-explain* and *Work-and-walk-by* prominently utilise teacher-led and technology-mediated questions. A notable number in Table 1 is the high engagement through technology, particularly in *Work-and-walk-by*, which shows the most frequent use of digital technology for questioning. We observed in the videos how during the *Answer* stage in orchestrations like *Sherpa-at-work* and *Work-and-walk-by* students are often invited to answer through digital technology. We noticed how the following orchestrations in the *Analyse* stage increased the depth of the analysis. *Guide-and-explain* is heavily utilised, with 51 instances of teacher-led analysis (see Table 1), demonstrating the teacher's central role in evaluating student responses. Similarly, *Spot-and-show* stands out with 17 instances of peer analysis, where student work becomes a focal point for whole-class discussion, enabling peer feedback. The *Adapt* stage, essential for completing the formative assessment loop, reveals fewer instances across orchestration types, indicating that teachers often implement the first three stages without consistently completing the adaptation phase. Notably, *Spot-and-show* emerges as a significant orchestration type in this stage, with 4 instances of prompting student rethinking and 8 instances of lesson plan adjustments based on whole-class discussion insights. However, a key observation in Table 1 is the zero instances of changes in technological resources, suggesting that digital technology may play a limited role in the adaptation process of formative assessment.

Based on the frequencies shown in Table 1, a small number of orchestration types, including *Guide-and-explain*, *Work-and-walk-by*, *Sherpa-at-work*, and *Spot-and-show*, appear more regularly and are often linked to key stages of the formative assessment process. These include teacher-led questioning (*ask*) and students' oral responses (*answer*), and in some cases, signs of teachers analysing student input and adjusting their actions (*analyse and adapt*). Other orchestration types, like *Technical-demo* and *Explain-the-screen*, are used less often and show little evidence of movement beyond the initial stages. The coding results reflect a general pattern of teacher-directed interaction with limited engagement in the full sequence of formative assessment processes.

Table 1: Frequencies of coded instrumental orchestration practices and formative assessment processes

FA practices ----- IO practices	Frequency	Ask			Answer			Analyse			Adapt		
		by peer	by teacher	by technology	in writing	orally	via technology	by peer	by teacher	by technology	changes in resources	changes to lesson plans	rethinking of students
Board-instruction	5	0	0	0	0	1	0	0	1	0	0	0	0
Discuss-the-screen	10	0	10	9	1	9	0	3	2	0	0	0	0
Explain-the-screen	10	0	0	0	0	0	0	0	5	1	0	2	0
Guide-and-explain	52	0	37	30	0	43	1	8	51	15	0	8	1
Link-screen-board	13	0	5	3	1	3	0	0	5	3	0	0	1
Sherpa-at-work	35	0	17	14	2	9	32	2	31	6	0	3	1
Spot-and-show	30	0	2	1	1	1	1	17	30	5	0	8	4
Technical-demo	8	0	0	0	0	0	0	0	0	0	0	0	0
Work-and-walk-by	52	0	45	50	24	2	27	1	20	1	0	1	0
Total	215	0	116	107	29	68	61	31	145	31	0	22	7

Illustrative Event

The following event was chosen because it vividly demonstrates how a specific instrumental orchestration practice uses digital technologies to enhance formative assessment, exemplifying the study's findings in a technology-rich classroom setting.

In Figure 2, the teacher employed the *Spot-and-show* orchestration type to select and display examples of student work that showcased a range of solution approaches, including typical mistakes and alternative strategies. By sharing these examples with the entire class, the teacher created an opportunity for students to critically compare different strategies, identify mistakes, and discuss the underlying reasoning behind them. The teacher supported this process by asking follow-up questions and helping students explain their reasoning clearly. When errors were identified, the teacher

prompted the original students who made these answers to revise their work and articulate their thought process. This iterative process of analysis, feedback, and revision fostered a collaborative learning environment in which peer discussion played an important role. As a result, students became more engaged and took a more active role in making sense of the mathematics.

Overall, the *Spot-and-show* orchestration type supported the complete formative assessment process by enabling the teacher to monitor student progress, promote peer feedback and discussion (*Analyse*), and guide students to reflect on their understanding (*Adapt*). This continuous cycle of feedback and reflection facilitated real-time identification and resolution of misconceptions, ultimately enhancing both individual and collective learning outcomes.

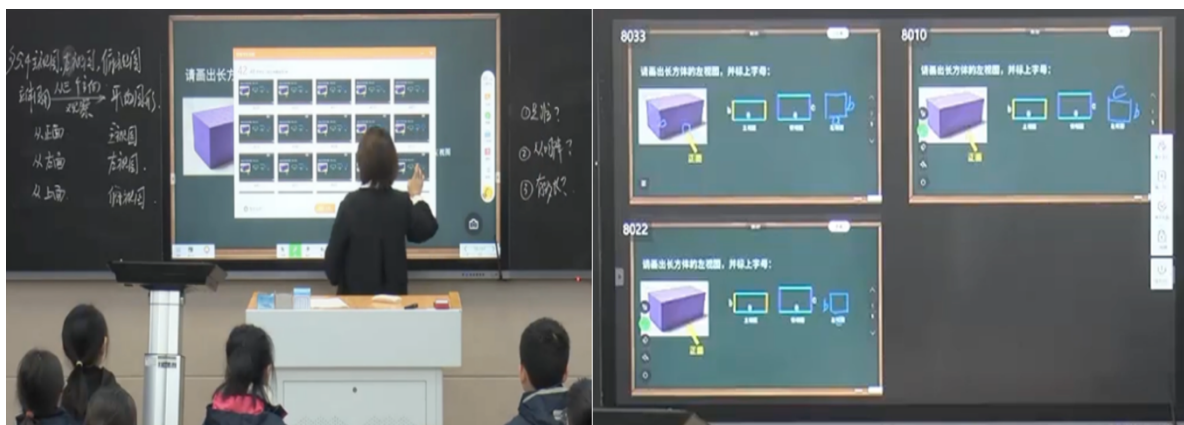


Figure 2: The screenshots of *Spot-and-show* orchestration type

Conclusion and Discussion

With this study, we investigated how teachers conduct formative assessment as part of their orchestration practices when using digital technology. The study has revealed how teachers integrated various orchestration practices at different stages of the formative assessment process.

Table 1 shows that in the *Ask* phase of formative assessment, *Work-and-walk-by* occurs most frequently. This orchestration uses technology-mediated questions to engage students. In the *Answer* phase, *Sherpa-at-work* actively involves individual *sherpa* students in solving tasks using digital technology, allowing them to showcase their problem-solving process to the entire class. In the subsequent *Analyse* stage of formative assessment, *Guide-and-explain* is used extensively in our sample videos for detailed examination of student work, demonstrating the teachers' central role in evaluating student responses and providing whole class feedback. This highlights that teachers typically lead the analysis process of formative assessment, consistent with prior findings by Panero and Aldon (2016). Although the *Adapt* phase is critical to completing the formative assessment loop, we observed that it is often not fully executed. The exception is *Spot-and-show*, where facilitating continuous observation, providing immediate feedback, fostering peer discussion, and encouraging reflection constitute a complete formative assessment process, as illustrated in the previous example. Finally, this study also shows that digital technology in our sample videos primarily facilitates interactions between the teacher and students, rather than direct student interaction with the digital technology itself. This outcome may, however, have been influenced by the choice of videos, which

focused more on whole-class practices, and the didactical configuration in the classroom. In addition, some orchestration types inherently provide more opportunities for students to engage directly with digital technologies.

This study also reveals that digital technology enables teachers to conduct prompt assessments, provide timely feedback, monitor student progress, and summarise student responses, which supports formative assessment, as noted by Dalby and Swan (2019). However, as shown in Table 1, the formative assessment process remains largely teacher initiated. This suggests a need to better balance teacher-led and student-driven contributions to formative assessment, highlighting the critical role of teachers in shaping formative assessment processes through their orchestration strategies, underscoring that the true value of digital technologies lies not only in their technical affordances but also in how they are integrated by teachers to enhance student engagement and support formative assessment (Cusi et al., 2017). However, how these orchestration strategies unfold in real-time classroom settings remains underexplored. Future research should investigate strategic orchestration of students' instrumental genesis by teachers, the collaborative design of digital technology between teachers and students, and the development of adaptive technologies for personalised feedback in automatic formative assessment (Børte et al., 2023; Panero & Aldon, 2016; Weigand et al., 2024).

The use of award-winning lessons as study samples introduces certain limitations of this study. Firstly, these lessons, designed to showcase best practices, may not represent typical classroom settings, which limits the generalisability of our findings to everyday teaching. Secondly, teachers and students might perform differently under competition conditions, potentially affecting the authenticity of interactions and technology use. Finally, this study found that the *Adapt* stage of formative assessment occurred less often, highlighting the need to explore its underpinning causes to better support the complete formative assessment process. Several practical factors may contribute to this pattern. Teachers often face tight schedules and feel pressure to stay aligned with predefined lesson plans, especially in high-stakes or demonstration contexts, making it difficult to make real-time instructional adjustments. Additionally, although formative assessment is generally recognised as important in mathematics education, *Adapt* is sometimes viewed more as a post-lesson reflection than as a process occurring during instruction. Furthermore, many teachers may lack access to professional development that supports teachers in using digital tools to inform instructional decisions, rather than solely for presenting content or collecting responses. Future research could first examine how the *Adapt* phase of formative assessment is enacted in regular, naturalistic, and more diverse classroom settings. This would help determine whether the patterns identified in this study extend beyond the current context and inform further inquiry into the factors that shape adaptation practices within formative assessment.

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