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Evolution of Finch robot orchestrations in teaching primary school mathematics

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This study utilised the theoretical framework of instrumental orchestrations to analyse changes in types, frequencies, and sequences of orchestrations of two co-teachers in a 3rd grade Integrated Collaborative Teaching (ICT) classroom in New York City public school. The teachers implemented mathematics activities that used Finch robot and native block-based coding App to address topics in the standards-based curriculum while also attending monthly professional development (PD) sessions to support their implementation of these activities. Analysis of six videos collected over a period of one year indicated that as time progressed, the teachers felt more confident in using Finch to support mathematics instruction. They shifted from mostly teacher-centred orchestrations towards more student-centred ones. At the same time, they started using more types of orchestrations which also led on average to a larger orchestration frequency.

Keywords: Instrumental orchestration, primary mathematics, classroom teaching practice, robot coding integration, technology.

Introduction

The incorporation of robotics and coding into primary school mathematics has attracted considerable interest. Introducing young learners to robot coding as early as kindergarten is increasingly viewed as an effective strategy for developing computational thinking and digital fluency (Angeli & Valanides, 2019). Integrating robot coding into mathematics lessons can make the subject more engaging and relevant, thereby potentially improving students' attitudes towards mathematics (Zhang et al., 2021) and enhancing their content knowledge (Sáez-López et al., 2019; Souza et al., 2019).

We examined how a year-long professional development (PD) program influenced the types, frequencies, and sequences of orchestrations used by two co-teachers in a 3rd-grade Integrated Collaborative Teaching (ICT) classroom in a New York City public school. In ICT classrooms, general and special education teachers jointly instruct classes comprising students with and without disabilities. Initially addressing teachers' needs related to technology skills, PD subsequently refocused to discussions of cognitive demand in mathematics tasks within culturally relevant activities and facilitated the sharing and development of strategies to enhance instruction.

The Finch Robot, with built-in sensors and precise movement capabilities for measuring distances, determining orientation, and performing drawing tasks (<https://www.birdbraintechnologies.com/>), was used in the study. These features support teaching core mathematical concepts, such as counting, simple addition and subtraction, patterns, measurements, identifying basic 2D shapes, representation of numbers on a number line, fractions, etc., while providing immediate feedback through sound, light, and movement, enhancing student engagement and self-assessment (Kentros et al., 2019). Finch supported culturally relevant mathematics tasks co-designed by teachers and researchers by representing the story in each task, e.g., being a subway train that stops at different stations or a

shopping cart pushed through the store aisle. These tasks made mathematics meaningful to all students, including those with learning disabilities, by linking learning to their cultural and everyday experiences (Lyublinskaya et al., 2024). For example, using forward and backward movement blocks, students were able to link the movement of a robot representing a subway train to addition and subtraction on a number line. They also used sound or light blocks to indicate subway stops, connecting these stops to numbers on the number line.

Theoretical framework

This study applies the Instrumental Orchestration (IO) framework (Trouche, 2004), which examines how teachers intentionally organize and manage instructional environments to foster students' instrumental genesis. Instrumental genesis involves the process by which a digital artefact becomes an instrument through its use in learning activities, shaped by both the tool's design and the users' intentions and practices (Drijvers et al., 2019). Central to this framework are three key components: the didactical configuration, arranging artifacts and participants in the learning environment; the exploitation mode, detailing how these configurations are intended to support specific learning objectives; and the didactical performance, capturing the teacher's adaptive decisions during implementation. These components enable systematic guidance in technology-rich environments.

Initially developed for analysis of Computer Algebra Systems (CAS) integration into mathematics education, the framework applications have since expanded to include diverse digital tools and contexts (Drijvers et al., 2020). This study adds to this body of knowledge by applying this framework to examine robot coding orchestrations in the elementary mathematics classroom.

Instrumental orchestration involves teachers systematically guiding learning processes in technology-rich environments (Drijvers et al., 2020). Teachers' choices of orchestration types depend on their perspectives on teaching, mathematics learning, and practical constraints such as time and technology. Drijvers et al. (2020) identified eight whole-class orchestration types and five individual/group orchestrations. The modified version of this framework, as applied in this study, is detailed in the methods section.

Methods

This year-long study followed mixed methods research design and addressed the following research questions: 1) What are sequences and frequencies of the whole class and individual orchestrations with Finch in teaching mathematics in primary school? 2) In what ways do Finch orchestrations evolve over time?

The two teacher-participants were Maria and Yulia (pseudonyms). Maria, a general education teacher with nine years of experience, holds a bachelor's degree in childhood education. Yulia, a special education teacher with 11 years of experience, holds a master's degree in special education. Their class consisted of 14 students, evenly split by gender, with 43% being students with disabilities.

The teachers implemented 10 activities between October 2023 and May 2024, each lasting around 20-30 minutes, while also participating in grade-based monthly online PD sessions that focused on various aspects of implementation. Data included video recordings of six 35-minute lessons that integrated robot coding activities, e.g., moving Finch along a number line to develop addition and

subtraction strategies, drawing shapes with Finch to understand the difference between squares and rectangles, etc. Qualitative analysis involved using the codebook (Table 1) to identify Finch orchestration types and frequencies of whole-class and individual/group orchestrations with Finch. The study replicated video data analysis procedure suggested by Drijvers et al. (2009). Specifically, each "unit of analysis was an episode, which concerns the whole-class treatment of one task" or individual student/small group treatment of one task. "If this treatment consisted of different orchestration types, the episode was cut into sub-episodes" (Drijvers et al., 2009, p. 3). In addition to the orchestration types identified by Drijvers et al. (2019), the codebook also includes whole-class and individual Link-screen-embodiment orchestrations we identified during the analysis. We also examined the sequence of orchestrations in each lesson.

Table 1: Finch orchestrations codebook

| Whole-class orchestration (code) | Colour | Brief explanation | Individual/small groups orchestration (code) | Colour | Brief explanation |
|----------------------------------|--------|---|--|--------|--|
| Board-instruction (WBI) | | A teacher in a whole-class teaching in front of the board. No connections are made to the use of digital technology. | Technical-support (ITS) | | The teacher supports the student in technical problems, such as login difficulties, connection issues, or hardware issues. |
| Technical-demo (WTD) | | The demonstration of tool techniques by the teacher. | Technical-demo (ITD) | | Individual/small group demonstration of techniques for using the digital content by the teacher. |
| Explain-the-screen (WES) | | Whole-class explanation by the teacher, guided by what happens in the technological environment. The explanation involves mathematical content. | | | |
| Guide-and-explain (WGE) | | An explanation based on what is in the technological environment provided by the teacher with some, | Guide-and-explain (IGE) | | Individual exchange between teacher and (a pair of) student(s) in which the teacher provides guidance and instruction to the student, explains mathematical concepts or methods based on |

| | | | | | |
|-------------------------------|--|---|-------------------------------|--|---|
| | | often closed, questions for students. | | | what happens in the technological environment, or raises questions to make the student reflect on his actions and results. |
| Link-screen-board (WLSB) | | The teacher stresses the relationship between what happens in the technological environment and how this is represented in the conventional mathematics of paper, book and board. | Link-screen-paper (ILSP) | | The teacher stresses the relationship between what happens in the technological environment and conventional paper-and-pencil and textbook counterparts. |
| Link-screen-embodiment (WLSE) | | The teacher stresses the relationship between what happens in the technological environment and how this is represented through body movements | Link-screen-embodiment (ILSE) | | The teacher stresses the relationship between what happens in the technological environment and how this is represented through body movements |
| Discuss-the-screen (WDS) | | A whole-class open discussion about what happens in the technological environment. | Discuss-the-screen (IDS) | | The phenomena in the technological environment lead to a discussion between teacher and student(s). The student has considerable impact on the direction and the content of the talk, for example by expressing his difficulties. |
| Spot-and-show (WSS) | | Identification of interesting student work during the lesson, and its deliberate use in a whole-class classroom discussion | | | |
| Sherpa-at-work (WSW) | | Sherpa student uses the technology to present his or her work, with all students able to follow the actions of both the Sherpa | | | |

| | | | | | |
|--|--|---------------------------------|--|--|--|
| | | student and the teacher easily. | | | |
|--|--|---------------------------------|--|--|--|

Colour codes were assigned to each orchestration type and used in the process of annotated timelining (Lyublinskaya & Du, 2023) to look for changes in types, frequencies and sequences of orchestrations over time. The four shades of green represent student-centred (SC) orchestrations and other colours represent teacher-centred (TC) orchestrations.

Findings and discussion

We present here an analysis of changes in patterns of frequencies and sequences of orchestrations observed over time.

Patterns in frequencies of Finch orchestrations

The frequencies of orchestrations identified in the six videos of lessons are shown in Table 2.

Table 2: Frequencies of orchestrations identified in observed lessons

| Week | ITS | WBI | WTD | WLSB | WES | WGE | IGE | WDS | WLSE | WSS | WSW | ILSE | ILSP | IDS |
|-------|-----|-----|-----|------|-----|-----|-----|-----|------|-----|-----|------|------|-----|
| 1 | 4 | 2 | 3 | 1 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 2 | 4 | 4 | 4 | 2 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 14 | 2 | 3 | 1 | 2 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| 19 | 3 | 2 | 3 | 0 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sub. | 11 | 11 | 11 | 7 | 9 | 4 | 3 | 2 | 1 | 0 | 0 | 0 | 1 | 0 |
| 30 | 5 | 4 | 1 | 3 | 1 | 3 | 1 | 1 | 1 | 3 | 0 | 0 | 0 | 1 |
| 32 | 2 | 1 | 2 | 2 | 1 | 1 | 3 | 2 | 2 | 1 | 3 | 2 | 0 | 0 |
| Total | 18 | 16 | 14 | 12 | 11 | 8 | 7 | 5 | 4 | 4 | 3 | 2 | 1 | 1 |
| T/SC | TC | TC | TC | TC | TC | TC | TC | SC | TC | SC | SC | TC | TC | SC |

Initially, teacher-centred orchestrations dominated, with frequent whole-class presentations without Finch (WBI = 16), demonstrations of Finch's technical features (WTD = 14), and individual technical support (ITS = 18), reflecting teachers' focus on direct instruction and building technical skills. This aligns with the initial focus of PD on developing teachers' technical skills (coding with Finch). Whole-class discussions (WDS = 5) occurred throughout, but student-centred orchestrations emerged later. The gradual increase in student-centred orchestrations, such as demonstrations of problem solutions (WSS = 4, WSW = 3) and teacher-facilitated individual or group discussions of Finch codes in mathematics (IDS = 1), likely reflects both teachers' growing confidence with Finch and the shift

in PD focus from technical skills to pedagogy, emphasising student coding and connecting that to their mathematical understanding. This changes in PD focus influenced teachers' move towards student-centred approaches.

The findings also indicate a non-linear trend in orchestration frequencies suggesting the influence of factors like lesson topic, student needs, and time constraints on teachers' instructional choices. Nevertheless, the overall trajectory towards increased student-centeredness and diverse orchestrations reflects a positive influence of PD on evolution in confidence in using the Finch for mathematical learning, which is consistent with other studies (Drijvers et al., 2019).

Patterns in sequences of Finch orchestrations

The sequences of Finch orchestrations in each lesson were plotted on a vertical timeline (Figure 1). The evolution of Finch orchestration sequences across the lessons reveals a clear shift towards student-centeredness, as indicated by the ascending green line plot and the increase of green blocks, reflecting more effective integration of the Finch into mathematical practices.

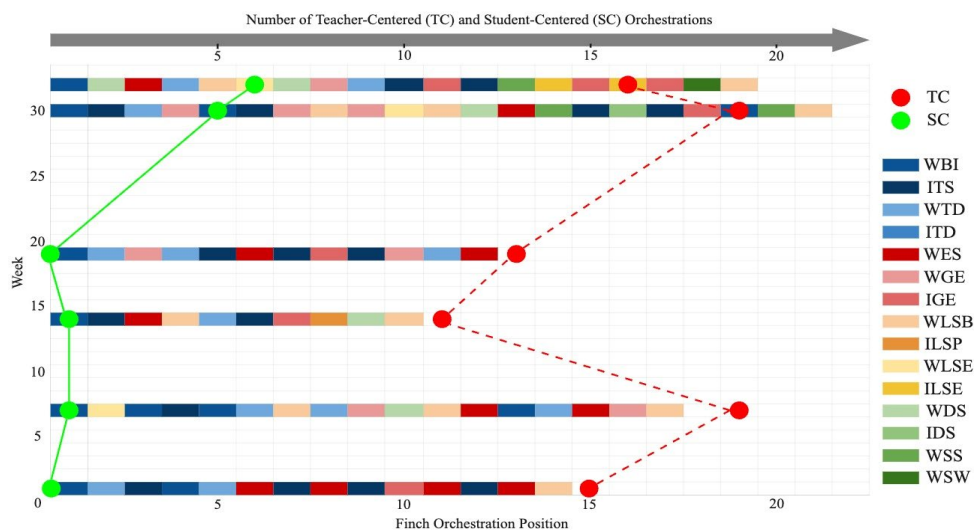


Figure 1: Timeline of Finch orchestration sequences

Analysis indicated that all lessons began with Whole-class board instruction (WBI) without using the Finch to outline the lesson flow and introduce problem scenarios. This was typically followed by technical support (ITS) and technical demonstration (WTD) to introduce Finch, often leading to individual guidance and explanation (IGE). Lessons usually concluded by linking Finch's actions (e.g., movement, lights) with traditional mathematical representations (WLSB), although Week 19 ended prematurely due to time constraints.

In early lessons (Weeks 1 and 7), Finch activities were mainly teacher-led, with a focus on technical demonstrations and explanations (shown in blue or red blocks). Mathematical content was gradually introduced, primarily through whole-class teaching. For instance, in Week 1, Yulia guided the class in counting robot lights to solve an addition problem. By Week 14, explanations and linking activities appeared earlier, reflecting a deliberate effort to connect Finch's functions to mathematics topics. For example, Maria linked robot movements to grid-based subtraction tasks. This phase also introduced

individual student interaction with Finch, enhancing hands-on learning. However, Week 19 highlighted challenges, such as rushed pacing and unfinished tasks, indicating the need to balance teacher guidance with student exploration.

In Week 30, green blocks, signifying student-centred orchestrations, became prominent. Student demonstrations and individual discussions fostered an interactive environment, encouraging students to take ownership of their learning. Examples include Yulia's whole-class presentation of a Finch-drawn shape coded by a student and Maria's individual discussions about shape properties based on student codes. By Week 32, the approach had evolved into a fully student-led model, with open discussions initiated immediately after problem introduction. Combining whole-class and individual activities with embodied demonstrations enriched the learning experience. For instance, Yulia, acting as Finch, used gestures to prompt a discussion on rectangle properties, and guided a student, acting as Finch, to draw a square by physically walking alongside them. Embodied teaching, central to instrumental orchestration, is a crucial role in learning. Drijvers et al. (2019) highlighted embodiment as key in their perspectives on instrumental orchestration, linking to instrumental genesis.

Conclusions

This study adds to the literature by examining the evolution of elementary school teachers' decisions in using robot coding in mathematics instruction. Findings reveal that as teachers engaged in targeted PD, their choices shifted from teacher-centred orchestrations to greater student involvement, reflecting the recognition of robot coding as a tool for supporting mathematical understanding. Embodied teaching provided students with tangible links to abstract concepts. Instructional practices are likely influenced by the ongoing intervention, which included monthly PD sessions that encouraged teachers to reflect on their teaching, build their confidence, and become more willing to let students take initiative and relinquish control over learning. In-class coaching provided support when teachers encountered challenges, reinforcing their growing confidence and suggesting that these changes were facilitated by targeted efforts rather than occurring independently.

Methodologically, this research advances prior studies by combining sequence and frequency analysis with annotated digital timelining, offering deeper insights into the dynamic integration of classroom technology. The study is limited to six lessons from one co-teaching team. Future research should include additional teams and teachers' perspectives to better understand the changes.

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