Primary Teachers' Adaptive Expertise for Teaching Interdisciplinary Mathematics and Science: Findings from a Video Questionnaire

Colleen Vale
Monash University
colleen.vale@monash.edu

Jan van Driel
University of Melbourne
j.vandriel@unimelb.edu.au

Gahyoung Kim
RMIT University
jinny.kim@rmit.edu.au

Joe Ferguson
Deakin University
joe.ferguson@deakin.edu.au

Wanty Widjaja
Deakin University
w.widjaja@deakin.edu.au

Lihua Xu
Deakin University
lihua.xu@deakin.edu.au

Lam Pham
Deakin University
lam.pham@deakin.edu.au

Amanda Berry
RMIT University
amanda.berry@rmit.edu.au

Adaptive expertise concerns the ability to respond effectively to novel and unexpected situations. This expertise is important for improving students' cognitive engagement, understanding and participation in meaningful learning. This paper presents findings on primary teachers' adaptive expertise in interdisciplinary mathematics and science using a video-stimulated questionnaire with multiple choice items and verbal explanations. Data were collected prior to the teachers' planning and teaching interdisciplinary lessons. Findings showed discrepancies between responses to the items and verbal explanations, indicating gaps between their espoused and enacted adaptive expertise.

Introduction

Adaptive expertise (AE) involves both innovation and efficiency (Bransford et al., 2005). Adaptive teachers apply deep levels of content and pedagogical knowledge in order to respond flexibly to unexpected, diverse and complex classroom situations (Anthony et al., 2015; Hatano & Oura, 2003; Timperley & Twyford, 2022; Yoon et al., 2019). Previous studies of adaptive expertise have used qualitative methods involving interviews, observations and videotaping of teachers and their teaching of science or mathematics lessons (e.g. Alonzo & Kim, 2016; Estapa & Amador, 2023). Others have used video analysis tasks to pose open-ended questions to analyse teachers' pedagogical content knowledge or their capacity to 'act in the moment' in research, teacher education or professional learning contexts (Borko, et al. 2015; Chan, 2021; Copur-Gencturk & Rodrigues, 2021).

In this paper we report findings from a video-stimulated questionnaire used within a design-based longitudinal study on the development of primary teachers' adaptive expertise when teaching interdisciplinary mathematics and science. We used a video-stimulated questionnaire to gather data about how teachers might respond to classroom situations to identify teachers' AE at the beginning of the longitudinal project. The research questions are:

- To what extent do primary teachers select and explain adaptive expertise practices in complex teaching scenarios in STEM lessons?
- How is their amount of teaching experience associated with their anticipated use of adaptive expertise?

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Theoretical Framework

Adaptive expertise as a construct has gained significant traction in education as it foregrounds teachers' responsiveness to the diversity of students in their classrooms and their needs as part of inclusive education (Anthony et al., 2015; Parsons, 2012; Soslau, 2012). In regard to science pedagogy, Crawford et al. (2005) align adaptive expertise as a disposition with "excellence in science teaching" (p. 3). Such teachers undertake causal and data-driven forward reasoning through self-regulation and cognitive flexibility to address student learning needs. Yoon et al. (2015, 2019) argue that "high quality teaching" (p. 903) in science manifests as adaptive expertise as the combination of flexibility, deep-level understanding and deliberate practice (see Table 1). Suh et al. (2023) propose that such adaptive expertise is necessary for teachers to effectively induct students into the epistemic practices of science, which supports the development of student disciplinary-specific agency. In regard to mathematics education, Baldinger & Munson (2020) suggest that adaptive expertise is aligned with "ambitious teaching practices" (p. 1), with such expertise emerging from a process of co-construction among teacher colleagues who share professional experiences to improve practice. The results of teacher adaptive expertise, Sherman (2020) argues, are increased opportunities for students to express their mathematical thinking in meaningful ways as elicited by responsive teachers.

This study uses Yoon et al.'s (2019) STEM-based framework for adaptive expertise (see Table 1) to examine teachers' use of adaptive expertise in interdisciplinary mathematics and science lessons. Each of the components (flexibility, deep level of understanding and deliberate practice) is defined in Table 1. Firstly, opportunist planning and flexible and critical application of content and pedagogical knowledge aligns with other research concerning acting-in-the-moment in mathematics lessons (e.g., Sherman, 2020). Secondly, to be adaptive experts, teachers need a deep level of understanding of the discipline and, in our context of interdisciplinary mathematics and science teaching and learning, knowledge of the connections between these two disciplines, to act efficiently and innovatively. With this knowledge, teachers can respond to the learning needs of all students and focus on developing student argumentation and understanding (Anthony et al., 2015; Bransford, 1999). Finally, deliberate practice involves making concerted efforts to reflect on their teaching using data on students' cognitive engagement and feedback from observers or co-teachers, to purposefully plan to improve their practice (Anthony et al., 2015: Timperley & Twyford, 2002).

Table 1

Adaptive Expertise Components (Yoon et al., 2019, p. 897-898)

Component
Flexibility: the ability to opportunistically plan, change enactments faster than non-experts, and flexibly and critically apply their knowledge to new situations while constantly learning.
Deep-level understanding: addresses the need to not only have acquired content and pedagogical knowledge, but to have a deep understanding of it in order to use such knowledge effectively.
Deliberate practice: addresses the need for teachers to receive feedback about and reflect upon their teaching either directly from their observations, from student outcomes, or from outside perspectives, with the intent to shift their practice based on feedback and reflection.

Methods

Following Copur-Gencturk & Rodrigues' (2021) recommendation to use video excerpts of authentic lessons, we selected video episodes of two primary teachers when they co-taught an interdisciplinary sequence of three lessons, "Keeping Your Finger on the Pulse" (Hughes et al., 2022) to a Year 5-6 class in the pilot study for the larger project. These teachers did not have a relation with the participants in the study. The broad aims of the lesson sequence included developing students' understanding of mathematics and science concepts, explaining their mathematical and scientific reasoning, and conducting investigations about heart rate. Specifically, the aims for students were to develop their understanding of the circulatory system, the use of the pulse to measure heart rate, exploring average heart rate, and the reasons for changes in heart rate along with developing knowledge and skills for proportional reasoning including rates, percentage and percentage increase.

Questionnaire Design

We designed and used a questionnaire composed of six video episodes to measure teachers' adaptive expertise including their anticipated actions regarding their deep level of understanding, flexibility and deliberate practice (Yoon et al. 2019). Vale et al. (2024) described the process and analysis used to select video episodes from the pilot study and design and validate the multiple-choice (MC) options and scoring for the video-stimulated questionnaire. Within the interdisciplinary context, the selected video excerpts focussed on the learning and teaching of mathematics (Items 1 and 3), science (Items 4 and 5) and connections between mathematics and science (Items 2 and 6). The agreed options were scored on a scale from 1-4, where 1 = low AE and 4 = high AE. In the validation and reliability process, we included open-ended questions so that teachers could explain their reasons for selecting the particular MC option. Three of the video-questionnaire items targeted teachers' deep level of understanding: one concerned mathematics (Item 1), another science (Item 5) and the third, both mathematics and science (Item 2). Two items concerned teachers' flexibility (Items 3 and 4) and one item, deliberate practice (Item 6). Each item included a description of the episode, the video excerpt (up to one minute in length) which participants clicked on to view, and the MC options for answering the question posed. The video stopped following a student comment, response or action and the participants were asked: "If you were the teacher, what would you do next? Choose one response from the list below." The teachers completed the questionnaire online and explained their choice orally rather than in writing.

Data Collection and Analysis

As part of the larger study, 15 participants from 5 metropolitan primary schools in Victoria attended a whole day professional learning session to prepare and plan for teaching one of two interdisciplinary lesson sequences. Prior to attending the session, the teachers were provided with draft lesson plans of the two lesson sequences. In the first session of the day, participants completed the video-questionnaire individually online.

Given the very small sample size, descriptive statistics were used to analyse the data collected. As discussed in Vale et al. (2024), the scores for the MC options were agreed upon prior to data collection. Following data collection, each verbal explanation was analysed by four researchers to reach agreement on the score for their explanation (EXP) from 1 (low AE) to 4 (high AE). Examples of teachers' explanations and their scores are provided in the findings. Means and medians were calculated for MC and EXP scores for each item and overall mean scores for each AE component and participant. Boxplots were used to illustrate findings.

Participants

Of the 15 teacher participants, five teachers across the five participating schools were identified as early career teachers as they had taught at Year 5 or 6 for 3 years or less. The other ten teachers had taught these year levels for more than 3 years, described as experienced teachers. Two of the experienced teachers had taught for more than 10 years. Fourteen teachers had experience of teaching Year 5 or 6 mathematics, but only five had experience of teaching Year 5 or 6 science. Two teachers had experience of teaching interdisciplinary STEM lessons.

Therefore, teaching interdisciplinary mathematics and science was not familiar to most of these teachers. All teachers had experience of co-planning either maths and/or science lessons, but only five teachers had experience of co-teaching mathematics, science or interdisciplinary lessons. Pseudonyms are used when providing examples of explanations of individual teachers.

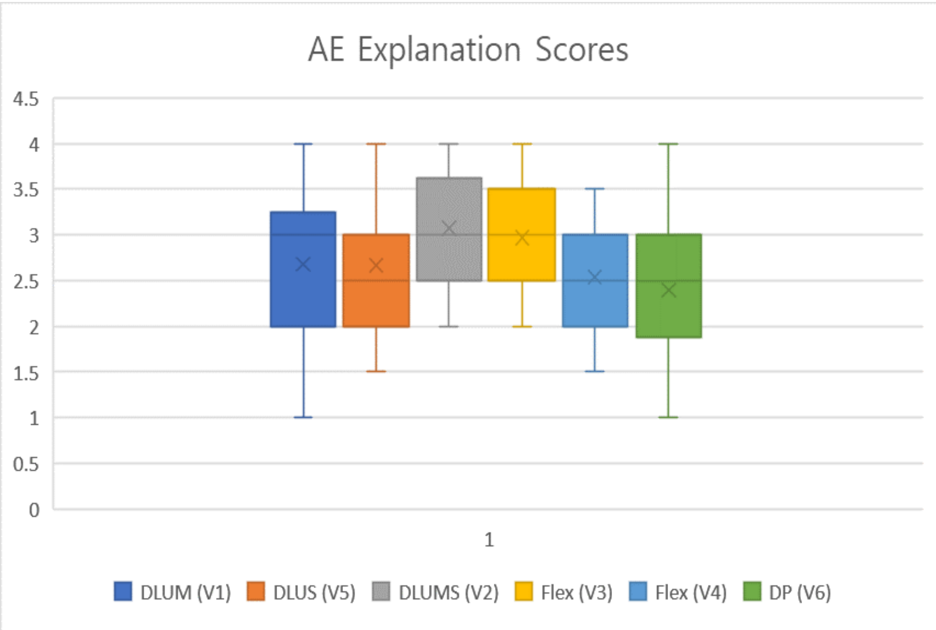
Findings

Mean scores were calculated for the MC scores and EXP scores for each of the six items and overall, along with the range, median and quartiles. The overall AE mean scores showed that the mean MC score ($m = 2.92$) was higher than the mean EXP score ($m = 2.60$). However, whilst the individual teacher's mean MC scores ranged from low (m=1.89) to high ($m = 3.67$), the range of the mean EXP scores was much narrower ($2.17 \leq m \leq 3.25$). Whilst four teachers seemed to be familiar with some AE teaching practices when making their MC selections ($m \geq 3.0$), a different five teachers explained their selection to show awareness and understanding of AE practices ($m \geq 3.0$) and how they would implement them. These teachers were from three of the five schools. Seven teachers recorded higher mean EXP scores than their mean MC scores, providing a clearer indication of their familiarity with an AE practice. A comparison between the five early career teachers and the ten experienced teachers revealed a larger range of mean EXP scores for experienced teachers ($2.2 \leq m \leq 3.25$) than for early career teachers ($2.4 \leq m \leq 3.0$).

In Figure 1, the range and quartiles for EXP scores for each item are illustrated. The highest EXP scores were recorded for the item about Deep level understanding of mathematics and science (Item 2) along with the first Flexibility item (Item 3), with about half the teachers scoring 3 or more. The broadest range of EXP scores and lowest mean scores were for Deep level understanding of maths (Item 1) and Deliberate Practice (Item 6). Findings for the three AE practices are presented below.

Figure 1

Boxplot for Explanation Scores for each Video Item



DLUM: Deep Level Understanding-Mathematics, DLUS: Deep Level Understanding-Science, DLUMS: Deep Level Understanding-Mathematics & Science, Flex: Flexibility, DP: Deliberate Practice, x: mean

Deep Level of Understanding - Mathematics, Science and Mathematics and Science (Items 1, 2 and 5)

For 7 out of 15 teachers their EXP score exceeded their MC score for the three Deep level of understanding items. The lowest mean MC score was for Item 1 about mathematics knowledge (*m*=2.57), whilst the highest mean MC score was for Item 2 about mathematics and science knowledge (m=3.13); the mean MC score for Item 5 about science knowledge was in between (*m*=2.67). The highest mean EXP score (*m*=3.07) was also for Item 2, whilst the mean EXP score for Item 5 about science (*m*=2.67) was similar to findings for Item 1 about mathematics (*m*=2.68). Early career teachers selected lower AE responses for Item 1 than experienced teachers, whereas all teachers recorded higher EXP scores than MC scores for Item 2 about science knowledge.

The first video excerpt (Item 1) explored teachers' deep-level understanding of mathematics. It took place in the first lesson when the class began exploring the human circulatory system and the meaning, measurement, and calculation of heart rate (bpm). The mathematics aim for the lesson concerned the conceptual understanding and meaning of rate and equivalent rates as applied to heart rate and measuring heart rate. The student in this video used the method of counting their heartbeat for 10 seconds and multiplying by six rather than what the teacher had planned - counting for 15 seconds and multiplying by 4. For this item, five teachers selected one of the two higher MC options: ask another student to repeat this in their own words (option A) or ask a student why this would work (option C) and their EXP showed the same spread ($3 \leq EXP \leq 4$). Altogether seven teachers' EXP scores were rated higher than 2.5 (see Figure 1).

Two experienced teachers and one early career teacher scored the highest rating for their explanation. Afelo (pseudonym), an experienced Year 5 & 6 teacher, demonstrated both content knowledge (measuring heart rate) and pedagogical knowledge (engaging students in mathematical thinking and justification) in their explanation: "…I would get another student to repeat the procedure, um, using their own words as it might provide like a new way for students to understand the same concept". They valued different explanations: "...if it's explained in a different way, um, it probably also would show other students in the class getting an understanding of the procedure that the student suggested…". They would also seek to elicit other methods of calculating heart rate: "… to see if anybody knows another way as well as the way that was described that might help as well, even if they were to do it for 30 seconds and then multiplied by two ...".

More than half the teachers selected one of the low scoring MC options (B—restating the procedure, or D—ask for another way to calculate bpm). Most of these teachers improved their score with their explanation. For example, an early career teacher explained that they would "... asked for another way to calculate beats per minute to show that there is more than one way, um, that they can get to this answer" (Rafel, MC score=2, EXP score=3). Other teachers were more focused on students using the planned method to calculate heart rate (bpm). For example, "So I would probably see if another student had a different way trying to work towards what had been planned, which was to count by 15 and multiply by four" (Arkey). That is, they would look for another student to suggest the planned ratio to use and if no one did, then they would explain the method to use.

Item 2 was selected from the video of the second lesson in the sequence. The goals for this lesson included drawing on students' experiences of pulse rate and heart function and collecting pulse rate data to make predictions about their pulse rate for a range of physical activities. In the video excerpt, the teacher observes a student's written pulse rate measurements whilst they are predicting pulse rate for the next physical activity.

One teacher chose the most adaptive MC option (C) and explained it well to demonstrate AE for content and pedagogical knowledge for both mathematics and science (EXP score=4). They compared the other two options before choosing C as they explained this action would be best to elicit the student's understanding:

> ... A, B and C kind of say the same thing, but they give different amounts of scaffolding. What did you find out to me is too open and too vague. 'What do you think about your prediction for heart rate for star jumps' is better because it gives them a little lead in as to what you're looking for. But it also allows the students to really apply their understanding and allows the teacher to gauge their understanding as well (Krong).

Another teacher chose low scoring MC option B (2) but their EXP score (3) was higher. Similar to Krong above, they compared the implications of different options. They considered option A was "too open" and that their response might focus on the physical activity rather than the scientific concepts and procedure for conducting trials. They suggested a more closed rewording "…what did you think about your prediction for the heart rates for star jumps?" (Afelo). They explained "...it would be a bad idea for the students to change their prediction on star jumps as um it's a bit of a learning curve and we want to teach students that it's OK to be off in your predictions because that's how we kind of get to learning" (Afelo). Aligned with the teacher above, they also thought that option C would give "a student that needs a little bit more support" (Afelo).

Five teachers recorded a lower EXP score than MC score. For example, one teacher chose option C (MC score=4), but their explanation (EXP score=3) focussed on getting the student to identify their error rather than to elicit their understanding: "…I want to elicit from the student, why they think their prediction isn't going to be accurate" (Zella). They indicated undertaking routine expertise in science teaching practices to "…talk about scientists making predictions and hypotheses that are often wrong…" They also spoke about the scientific "… understanding of the change or the adaptation that the body is making" (Zella).

Flexibility (Items 3 and 4)

Video excerpts for Items 3 and 4 explored teachers' anticipated flexibility. Interestingly, teachers responded differently to these two items. The highest mean MC score and EXP score for flexibility occurred for Item 3 from Lesson 1. The pulse rates of each student had been collected and displayed for the class with the range from 60 to 120 bpm. During a discussion on calculating the mean, one student claimed the average would be 166.1 bpm. This item concerned the teacher's capacity to act in the moment, to opportunistically change the plan for that part of the lesson.

The video excerpt used in Item 4 occurred at the beginning of Lesson 2 while the teacher was conducting a whole-class review of Lesson 1. A student asked about measuring pulse rate at the neck or wrist. This question provided a scenario where the teacher could plan opportunistically. However, most of the teachers' explanations for their MC option did not indicate flexibility as they did not indicate that they would take up the opportunity to plan in the moment and critically apply their knowledge. Of all six items, Item 4 recorded the second lowest mean scores for both MC and EXPs.

Seven teachers selected option B (MC score=2: Ask students "How can you find this out?) and nine teachers scored 2 or 2.5 for their EXP score. Four teachers received the same score for MC and EXP. Two teachers selected option B because it was the most open-ended response. One teacher argued "So, I might ask a student how he could find this out. Then hopefully they will look at repeating the experiment using the pulse rate in the neck" (Leina). Another teacher (EXP score=3.5), showed that their flexibility was more adaptive:

> Ask students how they could investigate this question themselves. Have students discuss different ways to measure this. Students ultimately compare the measurement of wrist to neck. Direct students to make a prediction prior to conducting their tests (Trent).

Deliberate Practice (Item 6)

One video excerpt explored teachers' AE with regard to DP (Item 6). It occurred in the third lesson when students were investigating activities to increase heart rate by 50%. The video excerpt is a conversation between the co-teachers during the lesson as they reflected on the students' approaches and deciding on next steps for the lesson.

The explanations showed that the teachers reflected on the observations discussed by the co-teachers in the video excerpt and decided on an action to take, however, Item 6 obtained the lowest mean MC score (m=2.21) and lowest mean EXP score (m=2.39) of all the items. The lowest MC score and EXP scores for Item 6 were for responses that did not indicate deliberate practice or did not involve engaging with the co-teacher in carrying out their chosen action. One experienced teacher without co-teaching experience, chose the most adaptive MC option (D): "to chat with the groups of students" (Dona), to collect data about students' process and findings. However, their explanation did not match this option. Instead, they described a routine practice: "I would probably stop and reiterate to the class that they need to… measure their resting heart rate…" (Dona, MC score=4, EXP score=1). Conversely, another experienced teacher, with experience of co-teaching, chose one of the least adaptive MC options: Let's stop the class and find out from the students how they are measuring heart rate (B, MC score=2) but provided one of the more adaptive explanations (EXP score=3). They focussed on students' social engagement and their engagement in mathematical and scientific thinking: "I think it is important for children to listen to their peers and discuss ways that they are measuring their heart rate…" (Rachel). Both responses show that the teachers' anticipated individual action would follow discussion with the co-teacher, but neither referred to what their co-teacher might say or do whilst they enact these routines.

Discussion and Conclusion

The inclusion of the explanation question with each video item provided a clarification of teachers' intended action with respect to AE. For some items, participants scored higher for the MC option and for other items higher for their explanation. Overall, for all six items the range of MC scores was broader than for their EXP scores, indicating that some teachers' explanations did not match their selected higher scoring AE MC option, whilst others explained something more adaptive than the MC option selected. This finding may indicate that some teachers identify the more AE option, but their explanation suggests that they were less familiar with how to enact it. Conversely, other teachers were better at explaining what they would do than selecting an option. This finding also suggests that some MC options may be improved with rewording.

As reported by Yoon et al. (2015), while some of the experienced teachers scored higher than early career teachers in this study, we should not assume that more experience leads to more AE in all complex situations. Also, similar to Yoon et al. (2015), we found differences in teachers' level of AE for the different AE components. Differences in AE for the three deep level of understanding items and the two Flexibility items showed that their likelihood of using AE depended on the disciplinary context, mathematics or science, or the degree of unexpectedness and how to act in the moment. There was only one video item for deliberate practice, and it occurred when the co-teachers consulted with each other. The five teachers with co-teaching experience recorded high levels of explanations for deliberate practice.

The video excerpts used in this questionnaire included students' learning actions and not the response or action taken by the teacher. This enabled the participating teachers to select and explain intended actions rather than critique another teacher's actions. This provided an indicator of their level of AE rather than their assessment of another teacher. In the next step of our study, teachers will review videos of their teaching of two STEM lesson sequences. We will encourage the teachers to review their videos with regard to adaptive expertise. Findings from this questionnaire study will be compared to their developing adaptive expertise gathered through observation and videos of lessons and teacher interviews and reflections on their lesson videos of their interdisciplinary teaching.

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