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Teaching Science Out-of-field: Beliefs and Practices

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Abstract: Out-of-field teaching in science is a phenomenon in many secondary schools across the world. While the reasons for out-of-field teaching are complex, its incidence is heightened in low socio-economic communities and in regional and remote school locations. Research on out-of-field science teaching in secondary schools has tended to focus on teacher competence, particularly in relation to pedagogical content knowledge. However, while teachers' beliefs and teaching practices within their specialist subject are shown to be related, it is unclear how teachers' beliefs and practices alter when teaching across subject boundaries. Using a boundary-crossing lens, where teachers engage in passing back and forth between different contexts, this study explored the relationship between teachers' beliefs about their in-field and out-of-field discipline (science) and the connections to their teaching practice. Interview data, including a video-stimulated interview of a lesson in a teacher's specialist field and then a subsequent out-of-field lesson, were analysed using the framework of a belief that investigated the relationships between in-field and out-of-field beliefs and practices. Findings indicate that those who teach science out-of-field revert to traditional ways of teaching, despite being more open and adventurous in their in-field discipline areas. However, there were significant instances of boundary crossing with their pedagogy to support their teaching – both in-field and out-of-field. These findings support the development of structured mechanisms and strategies to assist teachers to cross boundaries to establish new and unique interdisciplinary practices.

Keywords: *Boundary crossing, constructivist beliefs, out-of-field science teaching, process beliefs.*

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Introduction

International research highlights that many teachers are required to teach out-of-field (OOF) that is, to teach a subject discipline for which they have no specific training (Ní Ríordáin & Hannigan, 2009; Törner & Törner, 2012). Evidence exists to highlight this as an issue in the USA (Adamson & Darling-Hammond, 2012), Israel (Donitsa-Schmidt et al., 2022), Europe and other OECD countries (Price et al., 2019) and Australia (Weldon, 2016). OOF teachers face the challenge of limited content knowledge and reduced pedagogical content knowledge in their OOF subject (e.g., Kola & Sunday, 2015; Nixon et al., 2017). Although targeted professional development may assist "the knowledge and teaching skills in the relevant disciplines" (Productivity Commission, 2017, p. 90), it may not address other elements which are influential in teachers' success in teaching OOF. There is a need to understand how, for example, a teacher's beliefs affect their effective teaching of OOF disciplines (e.g., Wong & Luft, 2015).

In Australia, secondary school teachers are often required to teach across at least two subject specialisations, and many beginning teachers are provided with teaching loads outside their subject specialisations (Hobbs & Quinn, 2020; Weldon, 2016). This is compounded when schools are in remote and/or low socio-economic areas (Weldon, 2016). Out-of-field (OOF) teaching has been implicated in lower levels of student engagement and student participation, often resulting in reduced achievement (du Plessis, 2015; Mullis et al., 2016). Currently, there are limited retraining opportunities for teachers wanting to upgrade their knowledge, skills and pedagogy in new disciplines. The outcome is that often OOF teachers are required to learn 'on the job' (Hobbs, 2013). This necessitates the adaptation of teaching skills to new disciplines, the learning of new content, and the ability to plan new curriculum in areas for which teachers are untrained. For the inexperienced teacher, this is challenging and adds significantly to their workload. There are some indications from research (Handal et al., 2013; Vale & Drake, 2019) that this can lead to teacher attrition and high levels of staff turnover in disadvantaged schools. While teachers' beliefs and teaching practices within their specialist subject have

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been shown to be related (Mansour, 2013), it is unclear how beginning teachers' beliefs and practices alter when teaching across subject boundaries.

This paper presents results from the first year of a 3 -year longitudinal study that explored the practice of early-career secondary teachers from three different regional schools (outside of big cities). A boundary-crossing lens (Akkerman & Bakker, 2011) was used to examine teachers' beliefs and pedagogy as they engaged in the process of passing back and forth through different subject-teaching contexts. Studying how beginning teachers negotiated new understandings in their professional knowledge, practice, and engagement in science as an OOF area, this paper considers the nature of the teachers' beliefs about science and their in-field (IF) subject, as well as how they transfer teaching practices between IF and science subjects?

These questions are addressed through research exploring how this OOF science teaching role is perceived by different teachers. Teachers were interviewed three times in the first year – individually, with a mentor and a reflective interview which included the teacher reflection of classroom teaching video material.

The paper draws on a socio-cultural/constructivist framework, taking account of contextually-located processes of making sense of experiences rather than decontextualised accounts of learning. In investigating how beginning teachers understand teaching science as an OOF subject, considering their learning experiences as 'boundaries' to negotiate and cross provides a useful metaphor to illuminate practice. While barriers or boundaries may be a strong feature of many teachers' experiences of OOF teaching, earlier research by Hobbs (2013) shows that some teachers gain positive experiences and grow professionally when teaching OOF. This research interprets boundary crossing as influential in aiding teacher development.

OOF Teaching in Science

Much current research on OOF teaching and teacher knowledge in secondary school science teaching grapples with questions of what constitutes competence in pedagogical content knowledge (PCK) in science and how this is this best achieved by teachers (Kola & Sunday, 2015; Loughran et al., 2008). PCK here is interpreted to be "a form of content knowledge that embodies the aspects of content most germane to its teachability" (Schulman, 1987, p. 9). It is considered a distinct combination of content and pedagogy, essential to the teaching of a given subject or discipline. Sometimes the terms 'subject' and 'discipline' are used interchangeably, but in this paper, 'subject' refers to a body of knowledge (content) whereas 'discipline' is a social phenomenon about developing specialised knowledge and also ways of thinking, developing and applying that knowledge (Williams & Roth, 2019). In particular, it is the disciplinary 'ways of thinking' that are being targeted in this paper and articulated through teacher beliefs. Beginning teachers have less developed PCK, in both their in-field and OOF disciplines, and for teaching OOF (Donitsa-Schmidt et al., 2022; Hobbs & Quinn, 2020; Nixon et al., 2017). Beliefs about the discipline, its learning, and teaching are aligned with pedagogical content knowledge (Tsai, 2002; Wong & Luft, 2015), and reflecting on teaching, influences teachers' beliefs and practices (Dixon et al., 2004). Previous research indicates that the practice of OOF teaching also depends on a teacher's adaptability and school support mechanisms, in particular the learning culture enabled through school structures and leadership (Donitsa-Schmidt et al., 2022; Long et al., 2012)

Secondary science teachers are required to have developed science content knowledge, and professional practice, including understanding of how science is taught, as well as an awareness of how to engage students in effective learning. There is an assumption, supported by some research (e.g., du Plessis, 2015) that out-of-field teachers have less knowledge of the discipline, content, and pedagogical content knowledge. Certainly, some studies have found that teachers not qualified or trained in science do demonstrate weaker knowledge of science and confidence in their science knowledge (e.g., Lyons et al., 2006). School leaders, faced with problems of matching expertise to teaching needs, find themselves assigning less qualified teachers to teach science subjects. This is especially true when there is an overall shortage of qualified teachers in that discipline, or the school location precludes access to a science teacher. (Vale et al., 2020; Weldon, 2016).

Using a boundary-crossing lens, this study reports on the beliefs and practices of teachers who are teaching science out-of-field and the relationships between beliefs and practice across subject boundaries. It considers the questions,

1. What is the nature of the teachers' beliefs about Science and their IF subject?
2. How do the teachers describe their transfer of teaching practices between IF and science subjects?

Theoretical Frameworks

In this section we discuss boundary crossing theory and the frameworks of science beliefs

used to conduct this study.

Boundary Crossing Theory

With respect to teaching, boundary crossing occurs through 'the efforts by individuals or groups at boundaries to establish or restore continuity in action or interaction across practices' (Bakker & Akkerman, 2014, p. 225). Teaching OOF is characterised as crossing a boundary between IF and OOF subjects (Hobbs, 2013). The boundary becomes visible as the teacher recognises that differences exist between the knowledge, identity, and practices of a familiar field and the new field. Akkerman and Bakker (2011) identify the mechanisms for learning at the boundary, to enable a focus on the learning possibilities associated with crossing boundaries. Learning has occurred when there is some continuity of practice, identity or knowledge as the teacher moves between the two fields.

Crossing boundaries when teaching provides opportunities for teacher learning as the connections and relationships between disciplines and disciplinary ways of thinking are not only recognised, but also involve both one-way transfers and two-way interactions across the boundary. This means that IF beliefs, knowledge and practices can be adapted and modified, not simply transferred, to build beliefs, knowledge, and practices concerning OOF teaching and that OOF teaching experiences and learning can be reflected back on and challenge beliefs, knowledge and practices for in-field teaching. Learning at the boundaries involves processes such as identification, coordination, reflection and transformation (Akkerman & Bakker, 2011). 'Identification' involves the recognition of intersecting practices, considering the value of the practices and where the nature of the practices might be redefined. With 'Coordination', boundary crossing involves the transfer of beliefs, practices and knowledge such that "routinized exchanges between practices are established, to make transitions smoother" (Akkerman & Bakker, 2011, p. 146). In coordination, there is a move towards the efficiency of practices. Reflection relates to considering the similarity and differences between beliefs, practices and knowledge in two different subject areas. It requires teachers to consider mutual meaning making and connections between the practices, and challenges teachers to consider changing their practices. Transformation requires teachers to integrate their understanding and consider new practices. Transformation leads to significant and "profound changes in practices, potentially even the creation of a new, in-between practice" (Akkerman & Bakker, 2011, p. 146).

Beliefs Structures for Teaching

The relationships between teachers' beliefs about a discipline and its teaching, and their classroom practice are dialogic, wherein ideas/beliefs/practices are communicated, exchanged and agreed upon (Beswick, 2012) and depend on context (Ajzen & Fishbein, 1980). Teachers may hold different sets of beliefs where one set of beliefs is enacted and the other is not (Ajzen & Fishbein, 1980; Tsai, 2002). Beswick (2007) found that teaching practice can alter without a change in beliefs. Yet others have reported on the influence of professional learning programs, mentoring and support on the relationship between beliefs and practices (Donitsa-Schmidt et al., 2022; du Plessis, 2019).

In a comprehensive report in 2009, the Organisation for Economic Co-operation and Development (OECD*,* 2009) collected data related to the analysis of teaching practices and beliefs from across the world. The study found that teaching practices and beliefs were dependent on a complex structuring of the following factors:

- Professional competence: content knowledge and PCK
- Beliefs about the nature of teaching: direct transmission or constructivist beliefs
- Classroom practice: structuring, student orientation and enhanced activities
- Teacher's professional activities: co-operation among staff
- Classroom environment: time on task and disciplinary climate
- School level environment: school climate and teacher-student relationships
- Overall job-related attitudes: self-efficacy and job satisfaction.

In particular, much of the research on teacher beliefs and their effects on a teacher's classroom practice indicates that these are inextricably linked with the teaching context and 'institutional discourses and cultures' (Biesta et al., 2015). du Plessis (2019) found that a teacher's experience and knowledge, as well as classroom, school, and other factors all have influence on their beliefs and practices.

While previous studies have shown that teachers' beliefs fit into a number of possible structures (Kaymakamoğlu, 2017; OECD, 2009), specialist beliefs frameworks for specific discipline areas are scarce. Kaymakamoglu proposed that teachers' beliefs, their perceived practice and their actual classroom practice could be determined by considering a number of dimensions against a traditional model of behaviourism or constructivism.

Beliefs About Science Teaching

Anderson (2015), when reporting on the nature of beliefs of primary teachers who were teaching science, found that "beliefs about purposes of science education, the nature of science, and science teaching and learning strongly influence teacher practice and knowledge" (p. 395). Teachers' broader general understandings of education as well as their knowledge of the science curriculum were also influential on the type of science learning opportunities and experiences offered to the students (Anderson, 2015). Teachers' beliefs had an impact on the nature of subject matter knowledge and on their development of pedagogical content knowledge. Hancock and Gallard (2017) and Wong and Luft (2015) stated that science teaching beliefs and practices align with experience or transmission, and are student-centred or teacher-centred.

In 2002, Tsai proposed that teachers' beliefs about science education could fit into three general categories (see Table 1):

- "The 'traditional' category perceives teaching science as transferring knowledge from teacher to students, learning science as acquiring or 'reproducing' knowledge from credible sources, and scientific knowledge as correct answers or established truths" (p.773)
- "The 'process' category perceives teaching science and learning science as an activity focusing the processes of science or problem-solving procedures, and scientific knowledge is viewed as facts being discovered through 'the' scientific method or by following codified procedures." (p.773)
- "The 'constructivist' category views teaching science as helping students construct knowledge, learning science as constructing personal understanding and science as a way of knowing." (p.773)

Tsai's research found that most science teachers had 'traditional' beliefs and that the science teachers involved held views that were closely aligned. Tsai called these closely aligned beliefs 'nested epistemologies' and the research found that the 'nested epistemologies' tended to be found in teachers with more teaching experience and practice.

Table 1. Frameworks of Beliefs About the Nature of Science, its Teaching and Learning (Tsai, 2002, pp. 774-776)

	Beliefs about the nature of science	**Beliefs about learning science**	**Beliefs about teaching science**
Traditional	Science provides correct answers, or science represents the truth	Acquiring and reproducing knowledge from credible sources	Transferring knowledge from teacher to students
Process	Science is discovered through 'the' scientific method or by following codified procedures	Focussing on the process of science or problem-solving procedures	Focussing on the process of science or problem-solving procedures
Constructivist	Science is a way of knowing, and it is invented through agreed conventions and paradigms	Constructing personal understanding	Helping students to construct knowledge

Frameworks are useful tools to consider but teachers do not necessarily fit neatly into each of these categories or their beliefs related to one perspective and consistent across the three domains. These dimensions relate to their classroom practice, as acknowledged by others who have explored the relationships between beliefs and practice (Anderson, 2015; OECD, 2009). However, consistencies in these beliefs and across dimensions are not always evident (Mansour, 2013), especially for beginning teachers. Teachers without experience of teaching in a discipline, either as a beginning teacher or an out-of-field teacher, may exhibit conflicting beliefs across these dimensions and between beliefs and practice.

Science teaching is aligned with socio-constructivist beliefs about learning and uses student-centred approaches, embracing inquiry (Constantinou et al., 2018). Whilst these categories in Table 1 provide a useful tool for analysing teachers' beliefs, the categories may better reflect a continuum where teachers shift from traditional to constructivist, according to teaching needs.

As the teachers in this study are specialists in a range of disciplines, we have not used

specific beliefs frameworks for each discipline when analysing their IF beliefs. In fact, specialist beliefs frameworks for other disciplinary areas are a scarcity. Rather we

have noted and used the three types of teaching practices in the framework: traditional,

process and constructivist to analyse in-field practices.

Continuities of Beliefs, Knowledge and Practices Across Subject Boundaries

Akkerman and Bakker (2011) proposed that for OOF teachers, the transformation of their practice to a 'new, in-between practice' is the goal. For IF teachers, crossing boundaries occurs frequently as they negotiate the complexity of the classroom dynamics. However, it is much more challenging to move from teaching in an in-field area to teaching in an OOF area.

Boundary crossing supports and promotes inter-disciplinary understandings, which is particularly relevant in the current context with attention on OOF teaching in science and mathematics around the world (Hobbs, 2013). Boundary crossing theory recognises context, such as knowing students and community with respect to different disciplines and learning environments. Studies that use boundary crossing theory seek to understand the nature of the domains, boundaries, boundary crossers (brokers), boundary objects and the actions when crossing of boundaries to understand the learning process and outcomes.

Bakker and Akkerman (2014) indicate that the transfer of a teacher's beliefs, knowledge or practice may be in one direction only. In an earlier publication, Vale et al. (2020) proposed that there is some continuity of practice between IF and OOF teaching where a teacher's beliefs, knowledge and practice move across boundaries to transform to an 'in-between' state.

The model (Figure 1) developed by Vale et al. (2020), illustrates that there can be movement back and forth across the disciplines. With respect to teaching, it recognises the connections and relationships between disciplines and disciplinary ways of thinking and involves not only one-way transfers but two-way interactions or "dialogue" between different meanings across the boundary that is, dialogic learning (Akkerman & Bakker, 2011). Dialogic learning in this model implies that learning takes place through an interchange of ideas where 'something new may emerge' and where 'one practice may be defined in light of another' (Akkerman & Bakker, 2011, p142). This means that in-field beliefs, knowledge and practices can be adapted and modified, not simply transferred, to build out-of-field beliefs, knowledge and practices and that out-of-field experiences and learning can be reflected back on and challenge in-field beliefs, knowledge and practices. The context or settings within which the domains reside are also critical for understanding the dialogical learning that takes place (Williams & Berry, 2016).

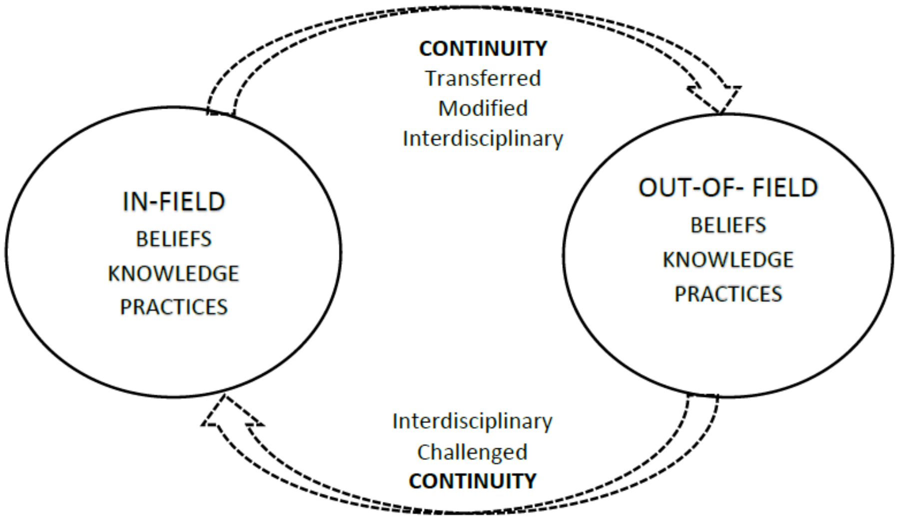

Figure 1. Continuity model - Continuities of beliefs, knowledge and practices across subject boundaries. (Vale et al., 2020)

The two domains in Figure 1 are the IF subject and OOF subject, containing three interacting elements: knowledge, beliefs and practice. To teach OOF, teachers need to cross the boundaries, developing their knowledge of the content and curriculum, while attempting to develop their practice of teaching the subject. Schulman (1987) included knowledge of other subjects when defining pedagogical content knowledge, so this illustrates a possible continuity across domains. This model, and previous research (Vale et al., 2020, 2021), illustrates that in-field teaching beliefs, knowledge and practices may be taken to OOF through processes of transfer, modification or direct continuance. While Bakker and Akkerman (2014, p. 224) proposed that the transfer of beliefs, knowledge, and practices is usually 'unidirectional', this model suggests a dialogic learning process which moves back and forth across the IF/OOF boundaries and supports the idea of opportunities for learning through the processes such as identification, coordination, reflection, and transformation (Akkerman & Bakker, 2011). Identification occurs when boundary crossers identify what is the same and what is different, without addressing differences. When boundary crossers translate or transfer objects or practices across fields, the learning process that occurs is called coordination. Learning through reflection includes a focus on, and explication of, differences to learn something new. Finally, transformation is learning that leads to profound changes in practice in both domains.

Methodology

The original project (2015-2017) investigated beginning teachers' beliefs and practices as they cross subject boundaries to teach school subjects for which they did not have specific disciplinary training. In particular, the project investigated the changing landscape of perceptions and practices of secondary school teachers who had been teaching science and mathematics for fewer than three years at the start of the project. The research focused on teachers from six regional schools across three states in Australia: Victoria, New South Wales, and Queensland. The project mapped the development of beginning and OOF teachers' beliefs, knowledge, and practice. The authors are the researchers involved in two schools and attended each of their case schools to conduct interviews. The project received ethical approval from the lead university and expedited ethics approval from two other Australian universities.

Participants

While the complete study related to six secondary schools in regional Australia (three states: Victoria, New South Wales, Queensland), with 22 teachers who were teaching a range of subjects OOF, this paper considers the information from the four teachers who were teaching science out of field in their first year of the project.

Table 2. Participants' Qualifications, IF Subject Teaching and OOF Subject Teaching

Name	School	Experience (Year 2015)	Qualifications (Discipline specialism)	IF Subject(s) 2015 Year level in brackets.	OOF Subject(s) 2015. Year level in brackets.
Seth	C	5	Unknown	Indonesian (7)	English (7); Mathematics (7); **Science (7);** Humanities (7)
Samantha	C	4	B.Arts (Literature, Cinema, Cultural Studies, History) M. Teach. (English/Maths)	English (11-12); Media (10-12); English (7)	Mathematics (7); **Science (7);** History (7)
Stefan	D	3*	B.Sci (Zoology)/Dip Ed(TFA, 2013-2014)(Science, Humanities)	Science, Chemistry & Physics (10); Science (8)	Mathematics (8 & 9); **Physics** (11)
Giselle	A	1**	B. Arts/B.Teach (Sec)/Grad Cert Theology	History; Humanities	Personal Development and Health; Mathematics; **Science**; English; Home Eco;

Notes: * This teacher worked as a teacher associate (para-professional) for two years while completing his teacher qualifications and is in his first year as a registered teacher at the time of the study.

** This teacher worked as a casual relief teacher and was employed over a long time at the school, taking on OOF for both short and long periods of time.

Data collection

Data used for this paper were gathered in the first year of the project through individual semi-structured interviews of approximately 40 minutes duration and a video-stimulated stimulated interview of teaching practice (approximately 30 minutes duration). Interview tools were informed by the Boundary Between Fields Model (Hobbs, 2013), which outlines three groups of factors likely to influence teachers' approach to crossing boundaries (support, context and personal factors). Interview questions were framed around seeking information in relation to a school/teacher's support, the context in which they worked, personal factors and teaching and learning experiences.

The semi-structured individual interviews were audio-recorded and included a range of questions to elicit their beliefs and teaching practices about teaching science and their in-field subject along with information about their teaching experience and support and professional learning opportunities provided by their school. Examples of questions explicitly designed to elicit their beliefs and teaching practices include:

- What do you think makes a good lesson for the various subjects you teach? Give me an example from the different subjects that you teach.
- Thinking and working scientifically is an aspect of science. What do these terms mean to you?
- How do you incorporate thinking and working scientifically in your teaching of science? Give an example.
- What are you passionate about in your teaching and how is this demonstrated for the different subjects you teach?

The video-stimulated interview focused on critical moments occurring in the lessons. The teacher video-recorded one of their lessons (30-50 minutes) in their in-field area and one science lesson that they taught OOF. Following the teaching of each lesson the teacher watched the video and identified critical moments for student learning or teacher learning that occurred during the lesson. Critical moments "represent those points in a lesson where something a student or teacher says creates a moment of choice or opportunity for the teacher" (Myhill & Warren, 2005, p. 1). For each lesson and video-recording the teacher completed a Critical Moment Timesheet. The interview prompts used in the audio-recorded video-stimulated interview focused on explaining and reflecting on the critical moments selected by the teacher. This included reflecting on the planning of the lesson; the teaching pedagogy enacted; their developing understanding of their students; their developing understanding of the subject; and how they saw themselves as a teacher of the particular subject. Examples of some questions used are:

- Thinking about those critical moments in each subject, what is the same and what is different about the critical moments that you selected for these two subjects? Why are they the same/different?
- Thinking about these two lessons and whether they were or weren't examples of good teaching and learning, what do you feel about the differences in the way you approach teaching these two subjects?

Data analysis

The raw data, presented as interview transcripts, were uploaded into NVIVO, where they were scanned for key words. Two members of our research team independently coded the data that has been analysed below within NVivo as a method of measuring inter-coder reliability. In this way, we ensured that we were reliably interpreting the codes in the same way (Richards, 2009) and could rely on our researcher colleagues to use it in the same way. Then a subsequent independent review of the data tabulated in the Findings section (Tables 3-6) were reviewed by this paper's authors. These key words were then grouped into themes and the data were coded using the themes. Emergent themes included 'teacher beliefs' and science pedagogy. For the four teachers involved in this article, all transcripts were then re-scanned to highlight the statements relating to teacher beliefs and their science pedagogy.

These individually coded transcripts were then overlayed with the Tsai (2002) framework of beliefs with respect to beliefs about science, school science, learning science and teaching science. Teacher interview data were searched for examples of comments that aligned with 'traditional, process or constructivist' beliefs. Data about their teaching practices gathered from the video-stimulated interview were coded as reflecting traditional, process or constructivist approaches to teaching science. Each teacher's transcripts were analysed for their beliefs about the nature of OOF science and/or IF subject (N), its learning (L) and teaching (T). All statements relating to the nature of the subject, students' learning and the teaching practice were extracted. They were then coded depending on whether they exhibited traditional (TR), process (PR) or constructivist (Co) beliefs.

The total number of coded statements was considered for each teacher. Some teachers contributed many statements (>10), while others contributed fewer. For an individual teacher, the total number of statements was considered across each of the categories. If a teacher didn't mention beliefs that aligned with a traditional viewpoint, that would be categorised as not demonstrated. If a teacher commented only once on a particular belief, that was considered as only slightly demonstrated. If there were several comments relating to the belief (>2), that was considered demonstrated. Three or more comments usually indicated 'strongly demonstrated'.

The number of coded statements was then categorised into tables for each participant (see below) and within the table, the demonstrated frequency of a teacher's comments was scored as follows:

0 = not demonstrated

+ = slightly demonstrated

++ = demonstrated

+++ = strongly demonstrated

Findings

In this section, we report findings for our research questions. We report the beliefs and practices for each of the four out-of-field science teachers and any changes in their beliefs and practices over the period that they were teaching science. Secondly, the nature of the continuity of beliefs and practice across their fields of teaching is presented. Finally, we comment on the learning that occurred for each teacher crossing boundaries to teach science OOF.

Beliefs And Practices of Teachers

SETH

Seth's in-field teaching are languages, in particular Indonesian. He was crossing subject boundaries to teach junior science and other subjects, out-of-field. The interview data for Seth suggested that he exhibited beliefs and practices across all three dimensions from traditional through the process to constructivist, although he spoke more strongly with traditional views (see Table 3).,

The evidence indicated that in his in-field area, Seth demonstrated a more nuanced belief structure. He expressed process beliefs such as applied learning as being a "…*teacher that likes to be forwards thinking, use lots of modern teaching practices. Coming from the applied learning style practices of teaching, I like to do lots of hands-on activities…* He also exhibited constructivist beliefs about this in-field teaching as he "*… likes to use real experiences, authentic experiences"* and "*I really like kids to push themselves and challenge themselves."*

In his out-of-field area of science, Seth has a more traditional belief system. He discusses students' achievement: "*If I'm thinking about my out-of-subject area, it's just about seeing progress with the kids and see my impact on them as a teacher and see their growth as well,"* and his students' understanding and also their use of routine skills "*making sure they are understanding, they are picking up the skills and the understanding that we are trying teach and get them to learn." He believes that there was only one way to teach his OOF subject: "If I'm not teaching it in the correct way and they're not getting it, then it's probably pointless."*

Table 3. Seth's Beliefs About the Discipline, Learning and Teaching

SETH	Beliefs about the nature of the discipline	Beliefs about learning	Beliefs about teaching
Traditional	OOF ++	IF ++ OOF Science ++	IF + OOF +++
Process	0	IF ++	IF +++
Constructivist	0	IF +++	IF +++

Seth used a lot of experiential strategies and discusses student engagement, skills and understandings. He didn't have confidence in OOF teaching of science but did have teaching confidence ''*In field - I feel quite confident.',* and passion for his in-field area*, ''My main passion is getting kids interested in learning another language, a foreign language*''. His traditional beliefs about teaching science played out in his teaching as he indicated that he needed to be on top of his teaching practice: "*I still feel like I need that breakdown, minute by minute."* Over time, he indicated that he is gaining more knowledge of science content which allowed him to improve his teaching skill and student engagement in science.

SAMANTHA

Samantha's in-field teaching subjects are English and Media Studies. She was crossing subject boundaries to teach junior science, mathematics and history out-of-field. The evidence from Samantha's interviews indicated that she exhibits beliefs and practices across all dimensions, with a slightly stronger focus on constructivist views, particularly for her in-field teaching areas (see Table 4).

Samantha's discussions tended to focus more on her teaching approaches, and there was less evidence of her beliefs in the nature of science and in students' learning. She described a good teacher as "*someone who can create a safe space and a safe classroom where students feel like they can take both personal and academic risks and that is based on a sense of trust in the teacher that the teacher is guiding them to where they need to go."* Samantha displayed constructivist belief about the science discipline, "*Thinking scientifically- is about how the world around us works.*" She revealed her process beliefs about teaching science when discussing her own learning to teach science, "*I am trying to find out the content knowledge, I'm trying to find out different ways to get the students there."* Samantha was concerned doing things the correct way but was prepared to collaborate with students to solve the problem: "*I just want to make sure I give them the right answer and I don't automatically know the answer. So we try and work it out together or I have to pull on what tiny knowledge I have or I'll ask the other experts in the room'.*

Table 4. Samantha's beliefs about the discipline, learning, and teaching

SAMANTHA	Beliefs about the nature of the discipline	Beliefs about learning	Beliefs about teaching
Traditional	0	0	IF + OOF ++
Process	+	0	OOF +
Constructivist	OOF +	IF +	IF +++

Samantha talked about engaging students in higher-order thinking and in communicating content through differentiated teaching strategies. She believed that the same teaching skills could be used for any subject and that it was just a matter of changing the content. In her in-field area, Samantha talked about having a strong interest '*I really love history and I studied it at uni and it's a personal passion of mine*' but also stated *'I don't want to be constantly given history classes'* indicating that there was more than just a strong interest that guided the way she taught. Samantha's strong constructivist beliefs tended to impact on her OOF areas as well, as she expressed, "*… so focusing a lot on those independent learning skills, higher order thinking and preparing students to be a little bit more critical and creative."*

STEFAN

Stefan's in-field teaching subjects are humanities and junior science. He was crossing boundaries within the STEM field to teach physics in the senior years and mathematics out-of-field. The beliefs framework for Stefan provided evidence of mixed beliefs. His beliefs fell evenly across all the dimensions (See Table 5).

Interestingly, his beliefs about the nature of science and physics, and the teaching of these subjects, were spread across all dimensions. On the one hand, he held traditional views of the curriculum: "*The science curriculum's written half in terms of skills and half in terms of content, and looking at traditional teachers they tend to teach content and science traditionally focuses on content and the skills developed are kind of…inherent or assumed.*" On the other hand, he displayed constructivist views of the discipline:

> *thinking scientifically - so being scientifically literate and enquiring about problems with a scientific approach, so the way they frame the problem, the way the investigate it, the way they find evidence for the problem…and then, like, draw conclusions. But then, also thinking about how science fits within society. I suppose, so how science relates to them as a person and how it might relate to more.*

Stefan held traditional beliefs about OOF teaching as he needed to have "*clear outcomes for success (TR) that are known by the teacher and by the students"* and especially when discussing his OOF teaching of mathematics, "*I think that, like, practically you spend more time… practising skills."*

Table 5. Stefan's Beliefs About the Discipline, Learning and Teaching

STEFAN	**Beliefs about the nature of the discipline**	**Beliefs about learning**	**Beliefs about teaching**
Traditional	IF + OOF ++	IF +	IF + OOF +
Process	OOF ++	IF +	IF ++ OOF +
Constructivist	0	IF +++	OOF +++

Stefan talked about engaging students' prior knowledge so that he could start from their point of strength and use open-ended tasks to allow students to develop their own understandings. He also believed that mathematics is skills-focused through problem-solving but that science has to consider concepts and skills. He stated that he needed to generate for his students "*deep knowledge of the content area so that they can be flexible and adaptable".* He also commented that "ideally a student will be exposed to teachers who have strengths across a lot of different things," referring to both content knowledge but also flexibility and adaptability in teaching approaches.

GISELLE

Giselle's discipline specialisations are history and junior humanities. She was employed as a casual relief teacher and taught many subjects out-of-field including science. Giselle spoke mainly about her beliefs about her own teaching, which tend to be either traditional or strongly constructivist (see Table 6).

She expresses traditional beliefs about teaching OOF subjects: "*I think it does impact because there are aspects that I know nothing about (TR) maths and science it's a little bit hard but I give it a go."* Her beliefs about the nature of science or about the nature of learning were not strongly expressed, although in discussing her teaching, she often referred to students' learning through her need to engage them in discussions which also conveyed her beliefs about learning: "*The biggest thing is to have discussion with the kids,"* and "*"… things that are hands on that are group orientated, that are creative, that makes the kids feel like they are contributing, that they are unique I found works really well."*

Table 6. Giselle's beliefs about the discipline, learning and teaching

GISELLE	**Beliefs about the nature of the discipline**	**Beliefs about learning**	**Beliefs about teaching**
Traditional	0	0	IF + OOF +
Process	0	0	0
Constructivist	0	IF ++	IF +++ OOF +

Giselle discussed students' engagement as a key aspect of her teaching. As she was a casual teacher, she was frequently teaching OOF. She indicated: "*There's always going to be something new to learn."* She has found that she must work to engage students she doesn't know, so she used hands-on learning strategies and group activities. Another one of her strategies related to being able to offer choice, being prepared to approach her teaching from a different perspective and to propose "*three or four different sorts of work, based around the same concept".*

Continuity Across Subjects

Teachers made comments about how they taught both their in-field subject and their out-of-field subject, in particular, illustrating any specific approaches or adaptations they selected.

SETH

Seth commented that *"I'd still be using the same approaches no matter what subject I'm working in",* illustrating how he transfers his IF teaching practices to OOF teaching. He explained that this is because he was confident in using these practices: *"I don't have that confidence in the out of field area and I think it's just the confidence that I've got in the infield area that makes me say, well I know I can do that…"*

However, Seth did acknowledge that he learned new teaching practices through teaching science that he transferred to his in-field teaching. He indicated that he took *"different teaching strategies and different ways to go about things that I probably wouldn't have done before using probably a lot more visual aids from (sic) the students… And a lot more things …for the students to break down the work and really deconstruct it." (OOF to IF).* He spoke about how this is impacting on his own learning of engaging students, '*I think just learning about the engagement. So I can take from that out of field subject back to the subject I feel comfortable teaching.'* The professional learning that Seth received from his colleagues in the course of planning and teaching science also informed his in-field teaching, '

So there's things that I've learned from colleagues and from professional development that I can take back from other areas.'

SAMANTHA

Samantha explained that she used literacy strategies from her infield teaching of English to her OOF teaching of science, '*"The maths and science teachers are happy to incorporate literacy into their subjects as well and that's something I'm confident with and I see students' results improve when we focus on that".*

She also explained that she incorporated her approaches to teaching visual design from media studies,*… "also the creativity side of my media, so that visual representation stuff into science has been helpful."*

Overall, she indicated that there were some basic teaching skills that could be transferred across subjects, "*…you can apply the same teaching skills to any subject no matter what you're teaching, it's just change the content."* She noted that these approaches and strategies enhanced students' achievement in science and appreciated the support she received from her science teacher colleagues.

STEFAN

Stefan also spoke about how he incorporated literacy strategies from his infield teaching to his teaching of science, *"teaching science or…remembering scientific concepts I do through teaching literacy, sort of, literacy sort of strategies specifically."*

However, he also showed understandings of interdisciplinary practices and knowledge between his out-of-field teaching of mathematics and physics and in-field teaching of junior science. He stated that "*… teaching maths like that, it has improved my ability to teach physics, for example, which really sits on the, the border of (my) skills and knowledge, especially maths skills…and I was, yeah, that has really helped".* He extended his discussion to illustrate how he used science to improve maths and his maths to improve science:

> *… especially teaching subjects, like maths subjects conceptually you're going to continually rely on science ideas as ways to introduce or contextualise maths concepts and teaching physics and chemistry I'm continually relying on maths concepts to help model or help explain the stuff that's going on.*

Stefan also co-planned a Year 10 science program with a science teacher and focused on developing students' science process skills. It focused on the use of a constructivist teaching strategy. Stefan's comment on the value of science process skills indicated that in the past he had '…taught skills… with a more traditional model of teaching science'.

GISELLE

Giselle acknowledged that she did need to adapt her teaching practice according to the subject. As a casual teacher, she was aware that she had to teach differently, '*…(teaching) …in a slightly different manner. I'd have to accommodate to the differences. Like I said you can't take a map drawing thing on Ancient China into maths but you can do a linear port where they can design their own dot to dots for example."* However, Giselle did not specifically indicate any transfer of practices from her OOF teaching to her in-field teaching as she tends to be teaching OOF most of the time. This was probably due to her casual teaching status and lack of sustained teaching with one class for one subject.

Summary of Continuity in Beliefs

Stefan's beliefs appeared to fit the idea of a continuum, rather than beliefs as separate categories. His beliefs were transferred and modified across subjects. Stefan made a distinction between the discipline and the school subjects. He held a combination of both traditional and process beliefs about school science. He believed that good teaching in science "has clear outcomes for success that are known by the teacher and by the students and then has stimulus for teacher and students to engage with."

Seth had a more nuanced belief structure with a stronger focus on process and constructivist beliefs for his in-field area. However, for his out-of-field area of science, Seth demonstrated and expressed a more traditional belief system. Samantha exhibited strong constructivist views of teaching in her in-field area which tended to affect how she taught in science. She did exhibit some more traditional and process beliefs when talking about science teaching. Giselle made no comments about the nature of any of the subjects she teaches.

Continuity of Teaching Practices

Stefan drew on his humanities teaching and brought a literacy approach to his teaching of both science and mathematics. This approach was also influenced by context, that is, his interpretation of the learning needs of his students. In the science lesson that he video-taped, the students were preparing for a science test and he used a number of literacy-based tasks and strategies in this lesson.

Seth talked about transferring teaching ideas from his science teaching to his infield areas as well as the other way round. He specifically discussed the transfer of subject-specific teaching strategies from one discipline to another.

Samantha also discussed using the same skills across any teaching area and specifically about taking teaching approaches used in literacy and media to enhance science. This was spoken about in relation to engaging students in their learning and generating a positive classroom environment.

Giselle indicated that her teaching approach is the same, across different subjects, and that she accommodated differences within her teaching. As a casual teacher, she was often required to be adaptive so had developed a set of strategies which could move across discipline areas.

Discussion

This section considers the overall research questions,

1. What is the nature of the teachers' beliefs about Science and their IF subject?
2. How do the teachers describe their transfer of teaching practices between IF and science subjects?

Beliefs About the Nature of The Science and Their IF Subjects

The findings are discussed with respect to teachers' beliefs about the school subjects they teach, its teaching and its learning, how these beliefs related to their practice and what, if any differences arose for their in-field and out-of-field areas.

The four teachers were specialists in a range of discipline areas: Indonesian language, English, media studies, junior sciences, history & humanities. They were teaching science out-of-field at one or two year levels from Year 7 to Year 9 in the first year of this study. Stefan, with junior science specialism was teaching physics at year eleven. Three teachers expressed perceptions of the science disciplines, although Giselle talked in more general terms.

When discussing their pedagogy, all four provided examples of practice that represented multiple beliefs. The beliefs of the teachers in teaching science were not always nested within the discipline, rather they exhibited a pedagogical belief in how they could cross over from on subject to the next. Some teachers held beliefs that were continuous across subjects to some extent, either with respect to their beliefs about the subjects or perceptions about learning or beliefs about teaching. Their beliefs about learning and teaching were not necessarily enacted in the lessons that were video-taped and discussed.

When teachers (Seth, Samantha and Stefan) expressed views about the nature of science (or their own in-field subject), they tended to be more traditional, a finding consistent with earlier research on the study of science teachers (Luft et al., 2022; Tsai, 2002). Tsai's 'traditional' category highlighted the transfer of knowledge from teachers to students and learning as the acquisition of knowledge from credible sources (Tsai, 2002, p. 773). This is particularly evident in Stefan's beliefs where he believed that good teaching 'has clear outcomes for success that are known by the teacher and by the students…' All teachers (Seth, Samantha, Stefan, and Giselle) expressed multiple beliefs about teaching and it is more useful to consider their beliefs as being adaptive to their teaching context rather than being assigned only to one category of belief. This aligns with research by Biesta et al. (2015) and Xu et al. (2023) who indicate that contexts, particularly changing over time, impact on teachers' beliefs. The teachers' teaching practices and interpreted beliefs also seem to be related to the disciplinary context of their teaching (Biesta et al., 2015; Hancock & Gallard, 2017; Rochette, 2022) and aligned with their pedagogical knowledge (Hobbs & Quinn, 2020). There was strong evidence that their beliefs about teaching science out-of-field did influence their teaching practices (Anderson, 2015) and that the teachers in this study did gain positive learning opportunities from their OOF teaching (Hobbs, 2013; Ní Ríordáin et al., 2019), and were able to leverage these into their IF teaching. However, we also found that their teaching of science was frequently influenced by their in-field teaching experiences. The nature of this transfer and adaption is discussed below.

Transfer of Teaching Practices Between IF and Science Subjects

All four teachers indicated that they took pedagogical knowledge from their in-field teaching to their out-of-field teaching as well as from their out-of-field teaching to their in-field teaching.

Stefan, Seth and Samantha talked with confidence about taking specific strategies from their in-field area into their out-of-field area, supporting Akkerman and Bakker's (2011) research about the processes of boundary crossing using identification, coordination, reflection and transformation. The teachers also explained how teaching in the OOF subject had provided them with a broadening of their approaches. They took 'new' teaching strategies from their OOF into their IF.

Figure 2 illustrates the dialogic learning for Samantha as she crossed boundaries to teach OOF. Through her experience of teaching across subject boundaries Samantha realised that her constructivist beliefs involving developing students' independent thinking and creative and critical also applied to the teaching of science. She therefore showed that rather than transferring her beliefs, she developed a more interdisciplinary approach to her beliefs. Through her reflection on student learning and her interactions with her science specialist colleagues, she shared and transferred literacy teaching strategies and approaches to developing and using visual representations of science concepts from her media teaching. She did not however discuss transferring any teaching strategies from science to her IF teaching.

In this example with Samantha, she exhibits learning at the boundaries, (Akkerman & Bakker, 2011; Hobbs et al., 2019). She demonstrates 'Identification' when she recognises intersecting practices between her IF and OOF areas, and considers how the practices might be redefined. She displays 'Coordination', when she transfers some of her practices (and beliefs) between her IF/OOF teaching. Samantha 'reflects' on the similarity and differences between her beliefs, practices and knowledge in two different subject areas. Finally, Samantha 'transforms' her understanding and practice in her new area as she takes strategies from her IF to her OOF area, leading to the creation of a 'new, in-between practice" (Akkerman & Bakker, 2011, p. 146).

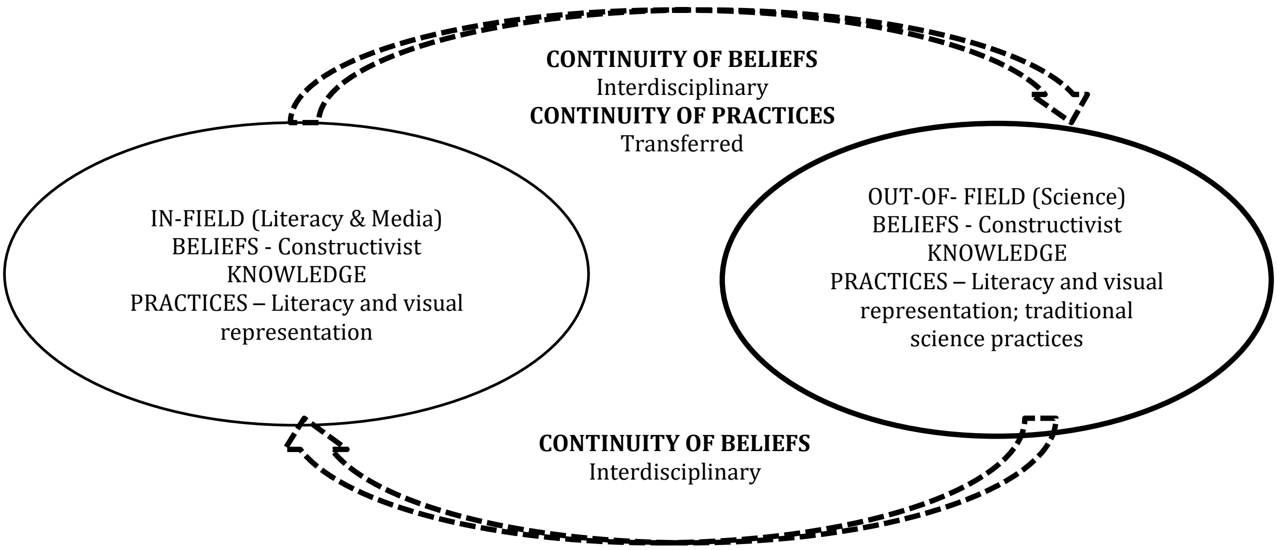

Figure 2. Dialogic learning for Samantha

As indicated by Akkerman and Bakker (2011), learning at the boundaries between the IF and OOF subjects required the teachers to be involved in identification and coordination to enable the transfer of beliefs, practices and knowledge. Crossing boundaries in teaching provides opportunities for teacher learning as the connections and relationships between disciplines and disciplinary ways of thinking are not only recognized but also involve both one-way transfers and two-way interactions across the boundary (Akkerman & Bakker, 2011). While transformation of practice may be the ultimate goal for the teachers involved in the study, the teachers exhibited changes in practices and possibly "even the creation of a new, in-between practice" (Akkerman & Bakker, 2011, p. 146). In considering the continuity of beliefs and the Continuity Model (see above), the information from the teachers suggested that they were involved in a dialogic learning process where their beliefs and practices were moving back and forth across the IF/OOF boundaries.

Conclusion

While the reality of out-of-field teaching exists, this research reveals the potential for teachers to learn, adapt and develop their practice through boundary crossing. When considering the Continuity model, all teachers exhibited some ability to cross boundaries, particularly in their teaching practice. To improve their teaching in their OOF discipline, teachers need to cross the boundaries of developing content knowledge and curriculum knowledge. The teachers involved in this research reverted to more traditional beliefs and ways of teaching when teaching out-of-field science, although they were more open and constructivist in their in-field teaching areas. There was one example of Stefan collaborating with a science teacher in the design of a course of work and the benefit he gained from this in terms of a more constructivist approach. This raises the question in relation to the support structures at the schools as Hobbs (2013) and Hobbs et al. (2022) highlight that school culture and professional learning can assist teachers to develop in their OOF areas. The findings from these four teachers' situations highlight the dilemmas of attempting to teach science out-of-field. With all the best intentions, the teachers tended to remain in more traditional modes of teaching in their OOF science. It also highlights the need to support the development of structured mechanisms and strategies to assist teachers to cross boundaries to establish new and unique interdisciplinary practices.

The retention of teachers in OOF can be problematic as most teachers in this study indicated that they had a *passion* for their infield area, which was not expressed in their OOF science teaching. While the teachers were adapting their teaching and making significant changes to accommodate teaching OOF, they indicated that it was more difficult to teach OOF, or that they had to spend longer in preparation. By the end of the three years of this study, most of the teachers had moved back into their in-field subject areas and were no longer teaching OOF. This is a conundrum for any school, as they are forever having to place teachers into OOF areas, with the expectation that they will be under-experienced, lack strength in content knowledge and specific teaching strategies and hold more traditional beliefs about its teaching that will impact their practice.

Limitations

The research study exhibited some limitations. While the overall project was conducted with twenty-two teachers over three years, for this paper we are reporting on only four of those undertaking science as an out-of-field teaching load in their first year of teaching. The responses from the teachers are representative of a larger cohort, but do not comprehensively cover the potential range of experiences and perceptions of a larger group, so we cannot draw strong conclusions. The teachers self-selected into the research, which introduces a small amount of bias. However, the research methodology was sound, using well-recognized methodologies, with questioning regimes pre-tested and interview data processed using NVIVO data analysis software.

Recommendations

Our research found that those who teach science out-of-field tend to revert to traditional ways of teaching, although they exhibit more open and adventurous practices in their in-field discipline areas. However, we also found that there were significant instances of boundary crossing with their pedagogy to support their teaching – both in-field and out-of-field. These findings support the development of structured mechanisms and strategies to assist teachers to cross boundaries to establish new and unique interdisciplinary practices. Hobbs et al. (2020) suggests that in-school support structures can be established by the school leadership team and negotiated elements of beginning teacher induction, the provision of mentors and the development of collaborative teams. Professional learning can also occur through recognised professional development programs or through professional networks of specific discipline-based teaching groups. Subject associations can provide valuable learning opportunities. Online learning is essential for busy teachers, especially those in regional or rural areas.

In addition, universities involved in the education of pre-service teachers could endeavour to provide opportunities for broader, interdisciplinary approaches to teaching, enabling earlier 'border crossings' by pre-service teachers and the development of cross-disciplinary capabilities. Finally, government policies and practices need to recognize OOF teaching and target investment to help support schools, teachers and students involved in OOF teaching. and learning.

Recommendations

Out-of-field teaching, particularly in science and mathematics, is a global concern, with researchers from many countries undertaking studies to understand this complex issue. Many are coming together to search for commonalities across contexts. However, further research needs to examine the 'success' stories for clearer understanding of how these can be generically applied to new contexts. Research that considers the out-of-field teacher in geography or out-of-field teacher of language and seeks to understand similarities or differences could make a significant contribution to future knowledge.

Conflict of Interest

The authors declare no conflict of interest.

Data Availability

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Authorship Contribution Statement

Campbell: Conceptualization, data acquisition, data analysis / interpretation design, analysis, writing. Vale: Conceptualization, data acquisition, data analysis / interpretation design, analysis, writing. Speldewinde: Data acquisition, data analysis / interpretation, editing/reviewing, writing.

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