

Research paper

A framework of subject-specific expertise for out-of-field teachers: Translated for Science and English

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ABSTRACT

While teaching is a learning profession, learning to teach out-of-field (OOF) places subject-specific demands on teacher knowledge, practice and identity. Using Shulman's 'signature pedagogies,' we examine what OOF teachers need to know (thinking), do (performing), and be (identity). Through collaborative research, nine teacher educators from various disciplines identified pertinent themes leading to a framework of subject-specific expertise. The framework invites dialogue on relationships between subject-specific teacher identity and the four salient features of specialist teaching: inquiring, knowing, connecting, and pedagogical imperatives. The framework can support professional learning for OOF teachers and set a foundation for further research into this phenomenon.

1. Introduction

Supply and demand pressures on the teaching profession and inequitable distribution of teachers have led to increased reliance on out-of-field (OOF) teaching, where teachers work outside their qualifications (Hobbs, Campbell, et al., 2022; Ingersoll, 1998). Global teacher shortages (UNESCO, 2023), attrition, recruitment challenges, and aging workforces (Allen et al., 2019) exacerbate reliance on OOF teachers, creating strain on both teachers and those supporting them (Saldivar, 2024). This worldwide phenomenon can have negative effects on student learning outcomes (Van Overschelde, 2022) and teachers can experience identity and self-efficacy challenges (Hobbs, 2013; Smith et al., 2024) from not having adequate content or pedagogical content knowledge (PCK) (Carpendale, 2018; Singh et al., 2021). Further, there are potential impacts for pre-service teacher transitions into the profession (Caldis, 2022a, 2022b).

Supporting OOF teachers requires mentors, colleagues, and leaders to understand subject-specific intricacies, enabling them to provide relevant advice on resources, knowledge, pedagogies, and assessment (Augusto, 2019). Research is needed to explore relationships between a

discipline and its related school subject and how these relationships place specific demands on teachers teaching OOF that can challenge their knowledge, practice and identity (Crisan & Hobbs, 2019). This view goes beyond simply knowing the content and how to teach it. This paper aims to inform these processes by providing a framework of subject-specific expertise that elucidates what OOF teachers need to come to know, do and be when learning to teach a new subject. Such a framework must go beyond PCK (Carlson et al., 2019) to consider broader notions of expertise and identity that arise from the disciplinary landscape informing school subject teaching.

According to Schwab (1964, p. 13), it is through the limiting or distorting lenses of the bodies of knowledge of each discipline that we look at things: "To know what structures underlie a given body of knowledge is to know what problems we face in imparting this knowledge". Specialist teachers tend to have their professional identity firmly rooted in their area of expertise (Bosse, 2016; Du Plessis et al., 2019; Hobbs, 2013; Porsch, 2016). They are likely to appreciate disciplinary practices and knowledge and recognise themselves as someone who can know, do and be a disciplinary expert, practitioner or learner of the subject (Hobbs & Törner, 2019). Secondary school teachers often

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progress from disciplinary education at university to teaching through an education qualification and methods training in preparation for the associated school subjects. In contrast, for a practising teacher, learning to teach a new subject places subject-specific demands on teachers that can challenge their knowledge, practice and identity (Crisan & Hobbs, 2019).

While professional development programs might attend to content knowledge and PCK, issues of identity, confidence, self-efficacy and commitment often arise for OOF teachers. Such issues can present as discontinuities for OOF teachers (Akkerman & Bakker, 2011; Hobbs, 2013), that is, disruptions in actions and interactions associated with their confidence, practice, knowledge or professional identities because of changing roles or contexts (Porsch & Hobbs, 2024). Discontinuities, however, offer opportunities for OOF teacher learning to occur through identity expansion and a re-conceptualization of practice (Akkerman & Bakker, 2011). Boundary objects (Star, 1989) that offer compensatory and developmental strategies are vital for helping teachers adapt their expertise and identity to OOF contexts. Collaborative spaces and supportive frameworks enable dialogue and identity reconstruction. However, existing frameworks often focus narrowly on content knowledge and pedagogy (e.g., Caldis, 2022a; Carpendale & Hume, 2020; Fraser et al., 2019), lacking a language to explore disciplinary differences.

Inspired by Shulman's (2005) signature pedagogies, the central aim of this paper is to interrogate the distinctiveness of school subjects and explore what OOF teachers need to come to know (thinking), do (performing) and be (acting and identity) when crossing these boundaries and learning to teach a new subject. As teacher educators and researchers from Science, Technology, Geography, English, and Mathematics education and their associated disciplines, we used a collaborative and interdisciplinary research methodology to invite dialogue between different disciplinary experts to explore this aim. These subjects represent the bulk of student learning in the compulsory years of schooling in Australian schools, with the latest data showing that potentially 40 % of Mathematics teachers, 36 % of Humanities teachers, 29 % of Science teachers, and 28 % of English teachers are teaching OOF (AITSL, 2021). Through this interdisciplinary dialogue, invoking boundary crossing theory, we sought to answer the following research questions.

- *What are the essential components of teaching a school subject?*
- *How can these essential components be integrated as salient features in a supportive framework of subject-specific expertise for OOF teachers?*

While all subjects identified above were included as part of our research, this paper focuses on Science and English due to their contrasting nature. For example, science investigates the natural world using evidence and logic to discover objective truths whilst English (teaching literature and creative writing), explores the human condition, meaning, and culture through interpretation and critical thought. Consequently, this paper explores how such disciplinary differences translate into school subjects and the specific challenges that these differences pose for OOF teachers.

2. Literature review

2.1. Teacher identity and learning to teach out-of-field

Teachers' backgrounds and experiences with a discipline or subject provide the sum of their "lived experiences" (van Manen, 1990) encompassing events, insights, and dispositions that they can draw upon to enrich their teaching and share with their students. While some

research highlights the negative implications of OOF teaching (Du Plessis et al., 2015; Van Overschelde & Piat, 2020), other research reveals opportunities for learning as OOF teachers are stretched in their knowledge of what and how to teach a new subject (Hobbs & Porsch, 2022), as long as there is adequate support (Hobbs, 2020; Saldívar, 2024). These experiences are not necessarily related to exposure at university level. Teachers can, for example, learn on-the-job through practice and experience (Hobbs, 2020), improve and broaden their expertise through professional development (Crisan & Rodd, 2017; Faulkner et al., 2019), and gain additional qualification leading to certification for a new subject (Ní Ríordáin et al., 2022).

Research into teacher learning by those teaching OOF provides insights into the challenges that teachers face when placed under pressure to learn enough new content and strategies to teach it (e.g., Hobbs, 2020; Nixon et al., 2017). A groundswell of research indicates that teachers' professional identities are somewhat malleable (Burke, 2006) but intertwined with teachers' practice, what they know about teaching the subject to students, and what they do in the classroom (e.g., Bosse & Törner, 2015; Crisan & Rodd, 2014; Helms, 1998; Hobbs, 2013; Luft et al., 2015). Professional identity is comprised of knowledge of events, processes or conceptual understandings, but also feelings, attitudes and values that stem from their experiences (Connelly & Clandinin, 1999). More specifically, teacher subject identity relates to the way in which a teacher connects with their specialist teaching subject and holds it as a central component of their professional identity and practice, likened to a professional compass (Brooks, 2016). A focus on understanding the nature and relevance of a subject, and sustained engagement with disciplinary thinking helps to guide the 'why' of pedagogical practice (Caldis, 2022a). According to Lave and Wenger (1991), teacher learning within a community of practice not only involves learning as becoming, but also learning as belonging to a community, learning as experience to attach meaning, and learning as doing through practice.

The transition to teaching OOF subjects presents unique challenges and opportunities. An OOF teacher with limited meaningful interaction with the subject may feel a sense of not belonging (Du Plessis et al., 2014) and might revert to traditional, less innovative teaching methods, even if they are more adventurous in their in-field subject (Campbell et al., 2023). However, some teachers adapt by drawing on their teacher-subject-identity from their in-field subject to apply and integrate beliefs and practices into their OOF teaching (Caldis, 2022a), or by creating a blended or interdisciplinary approach that aligns with the new curriculum context (Campbell et al., 2023). Research also emphasizes that teachers must acquire subject-specific content knowledge, curriculum understanding, and effective teaching approaches to succeed in OOF teaching roles (Carpendale, 2018). For example, frameworks that support OOF teachers include Fraser et al.'s (2019) STEMCrAft framework that identifies expert knowledge used in selecting appropriate resources, Carpendale and Hume's (2020) collaborative Content Representation (CoRe) designed to develop teachers' and Caldis' (2022a) social labs and use of the GEOGstandards to promote reflection for pre-service teachers. Additionally, observing students' learning difficulties in the new subject can further help OOF teachers develop a more holistic understanding of their students, including learning behaviours and interests beyond their own subject specialization (Hobbs, 2020; Olitsky, 2006).

2.2. The nature of the disciplines and subjects

Gardner (2004) describes disciplines as "the best answers that human beings have been able to give to fundamental questions about who we are, physically, biologically, and socially" (p. 233). Three

Table 1
Comparing ontology, epistemology, and axiology for Science and English.

	Science	English
Ontology	Assumes an objective reality, with a focus on what exists and what is observable, independent of human perception.	Assumes a subjective reality, with a focus on human experiences shaping interpretations and creating social constructions of literature, including texts and symbols.
Epistemology	Knowledge is obtained and validated through empirical observation, gathering evidence while prioritising repeatability and objectivity.	Knowledge is socially constructed through subjective interpretations, while appreciating the different perspectives people bring from their own knowledge, experiences, and culture.
Axiology	Approaches to objective scientific inquiry are valued, where ‘universal truth’ is prioritised, and personal bias is removed.	Diverse perspectives are valued, which draw from varied historical and cultural contexts to judge and interpret texts

Note: The table was generated using Chalmers (2013), Derrida (1976), Eagleton (1996), Fish (1980), Gauch (2003), Hirsch (1967), Kuhn (1996), Longino (1990), Nussbaum (1992), Popper (2002), and Resnik (1998).

philosophical concepts—ontology, epistemology, and axiology—shape how academic disciplines perceive, understand, and evaluate the world (Chesky & Wolfmeyer, 2015). Disciplines differ ontologically in defining what constitutes reality and existence, epistemologically in understanding the nature of knowledge and how it is acquired, and axiologically in determining what is considered ethically and aesthetically valuable. Table 1 summarises these key considerations for Science and English. These distinctions make disciplines unique in their approaches, genres, structures, and content, all of which require time and effort to master. Consequently, their corresponding school subjects are methodologically and linguistically distinct, reflecting the specialised nature of their parent disciplines. These differences are reflected in the subject matter, teaching methods, and educational goals associated with each discipline’s school-based interpretation (Beane, 1995; Niss, 1994).

School subjects reflect aspects of academic disciplines, but cannot fully mirror them (Doecke & Mead, 2023). Educators draw important ideas, behaviours and dispositions from the disciplines that should be presented to students. The representation is closer in some subjects than others, which may lead to an incorrect assumption for OOF teachers. Academic disciplines are also in a constant state of flux, negotiating the terms, conditions, and standards of inquiry, attribution, and evidence (Middledorf & Pace, 2004).

Siskin’s (1994) research and research by others (e.g., Grossman & Stodolsky, 1995; Shulman & Sherin, 2004), consistently reveal differences in discursive patterns and dominant themes in subjects as teachers talk about their work. Siskin (1994) found that these dominant themes are worth exploring because they “translate into systematically different conceptions of the tasks of teaching and learning” (p. 162). The subject matter is arguably the defining element of the culture of a subject (Siskin, 1994). Deng and Luke (2008) argue, however, that subject teaching is influenced more by the subject matter of the school subject than the subject of the discipline – it is the subject matter context that an OOF teacher needs to negotiate. Deng and Luke (2008) identify five dimensions of knowledge that define a subject: the logical (concepts and principles to be taught), the epistemological (how we know and how knowledge is generated), the psychological (interest, experience and prior knowledge of students influencing concepts and principles), the pedagogical (effective ways of representing and reformulating concepts and principles), and sociocultural (interaction with society, technology and culture). To Shulman and Quinlan (1996, p. 420), subject matter is important: “It is not only the subject qua discipline that matters. The

subject matter, which is the subject transformed, interpreted and arranged for purposes of teaching and learning, matters”.

Siskin (1994) argues that school departments organize subject cultures, with teachers in English, Science, and Mathematics speaking different “languages.” These differences go beyond jargon, reflecting the discipline’s language and epistemology, shaping teachers’ understanding of knowledge, roles, and teaching (Siskin, 1994). For OOF teachers, these disciplinary distinctions create challenges in deciding what to teach, how to teach it, and the subject’s value for students. Teaching a new subject requires understanding its language, epistemology, practices, and traditions, which guide appropriate teaching and learning. Teachers are, in a sense, inducted into the culture of the subjects by way of their own experiences of doing, using, learning and teaching that subject.

2.3. Signature pedagogies

Signature pedagogies were described by Shulman (2005) to highlight “the types of teaching that organize the fundamental ways in which future practitioners are educated for their new profession” (p. 52). Specialist subject teachers in schools are similarly inducted into their specialization during their education and/or practice in the specialist field. Shulman (2005) described signature pedagogies as forming “habits of the mind, habits of the heart, and habits of the hand” (p. 59) through socialising people into the practices and values of the profession, often through exposing them to the forms of thinking, and acting. Additionally, signature pedagogies have structures that delineate one signature pedagogy from another: (1) *Surface structure* – concrete, operational acts of teaching and learning, of showing and demonstration, of questioning and answering, or interactive and withholding, or approaching and withdrawing; (2) *Deep structure* – a set of assumptions about how best to impart a certain body of knowledge and know-how; and, (3) *Implicit structure* – a moral dimension that comprises a set of beliefs about professional attitudes, values, and dispositions.

Beyond education for the professions, the construct of signature pedagogies provides useful framing of what is core to teaching and learning in different subjects. In recent years it has been operationalised in many education subject-related contexts to define what is salient to the practice of a subject teacher, core beliefs in relation to teaching and learning, fundamental practices associated with learning, and norms of learning and certain habits of mind, head and heart in particular contexts: “signature pedagogies set out to teach the disciplinary ways of thinking (learning to know), doing (learning to do, practice), and being (learning to be, identity)” (Hobbs, McKnight, et al., 2022, p. 1280).

Efforts to identify the signature pedagogies of disciplines and their subjects in schools have emerged since 2005 (Hobbs et al., 2023). The focus of analysis has tended to be on what teachers do to “socialise students into the distinctive practice, concepts, and values of the discipline” (Seow et al., 2019). For example, signature pedagogies of science have been described as inquiry-based instruction and various styles of laboratory teaching for exploration of scientific phenomena (Crippen & Archambault, 2012; Koeper et al., 2020), and investigation that involves mathematical thinking (Quinnell et al., 2013). These specific pedagogies arise because of the nature of the knowledge under consideration, and beliefs about best ways to students to engage with that knowledge.

In this study, signature pedagogies enabled a focus on salient and fundamental pedagogies of the different subjects. As a team of experts from different disciplines, we deliberated the surface, deep, and implicit structures of our subjects, and identified what we considered to be salient for an OOF teacher to know, do, and be as they learn to teach each of our subjects. We considered differences in the operational acts of the teacher as they make decisions about what to teach and how, the deep structure as assumptions that underpin certain pedagogical imperatives that drive practice and pedagogical decisions, and an implicit structure of what it means to teach the subject which includes and is informed by the practice, beliefs, and values of the discipline. Our

assumption was that teachers bring discipline-specific values, knowledge, practices and identities into their specialist teaching. Passey (2012, p. 22) emphasizes that “teacher experience, teacher preparedness, and teacher effectiveness are all driven by these pedagogies, which also determine qualities of experiences for learning”. The reality is, however, that teachers often teach subjects OOF and therefore miss core pedagogies, attitudes, and lack specific identities that can be reflected through their teaching.

3. Methodology

We used a collaborative inquiry process (see Hobbs et al., 2023) to understand and distil the salient features for teaching and to generate the framework. This methodological approach stemmed from a foundation of interdisciplinary and collaborative research, enabling “researching ‘with’ rather than researching ‘on’” (Given, 2012, p. 2) participants. In our case, this meant generating ideas collaboratively as disciplinary experts from different disciplines, which supported advancement of our understanding through juxtaposition of what constitutes disciplinary knowledge and practice (Williams & Roth, 2019). Using signature pedagogies as a lens, along with the notion of boundary crossings from Akkerman and Bakker (2011), we explored our own lived experiences, practices, and literature to articulate and elaborate contemporary thinking to compare knowledge and expertise, practice, and identity in our respective subjects. During this process, we crossed disciplinary boundaries into other fields while negotiating salient aspects to consider when comparing disciplines, perhaps in the same way that OOF teachers need to negotiate different and similar subject matter and teaching practices.

A three-part theoretical frame (see Fig. 1) was used to structure this interdisciplinary collaborative approach, drawing from collaborative and interdisciplinary research (Given, 2012; Mansilla & Gardner, 2003), theory of collaborative advantage (Huxham, 2003), and boundary crossing (Akkerman & Bakker, 2013). When thinking about what is important for teaching a subject, including what is discipline-specific or what may be more generate in nature, we needed to consider the

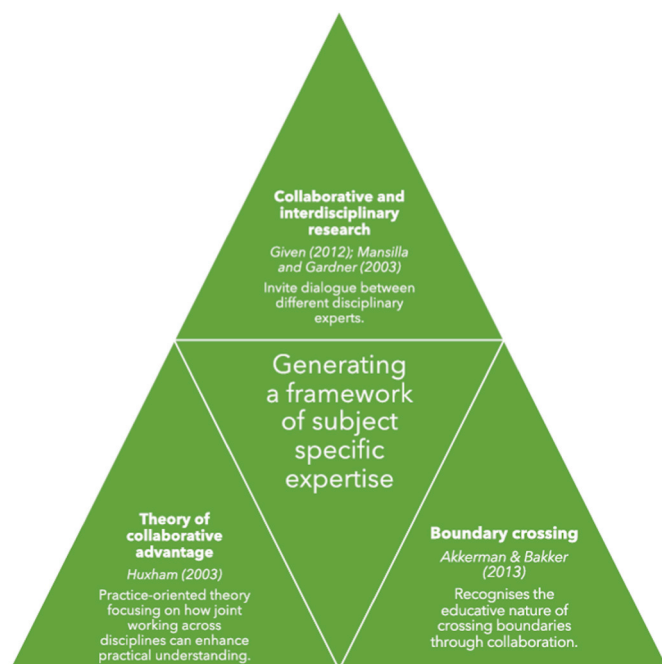


Fig. 1. Theoretical framing for this interdisciplinary collaborative inquiry about OOF teaching to generate a framework of that highlights what a teacher needs to know, do, and be, when crossing subject boundaries.

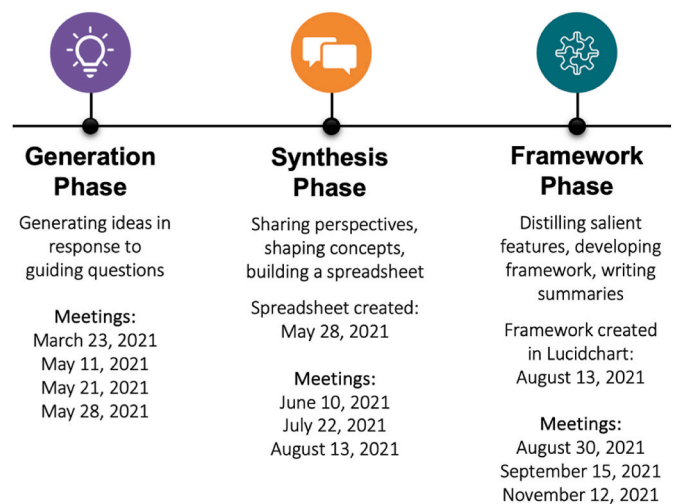


Fig. 2. Phases and timeline of framework development.

experience of teaching the OOF subject, recognizing that fundamental to teaching a subject is the disciplinary ways of knowing, doing and being.

Collaboration via Zoom meetings occurred between 2021 and 2023. Hobbs et al. (2023) outlines the process used to propose the framework, developed through discussion, debate, and documentation of subject-specific ideas aligned with what it means to know, do, and be as a teacher of the given subject. This process acknowledged difficulties that teachers can experience when learning to teach OOF. The reflective nature of the meeting spaces facilitated perspective-making (Boland & Tenaski, 1995), fostering new understanding through dialogical and creative exchange. Subject-related perspectives were shared and documented. The process involved three phases: Generation, Synthesis, and Framework (see Fig. 2). Each phase featured dialogical exchange that encouraged creative thinking and resolved interpretive differences. Meetings were audio-recorded and transcribed, with notes serving as primary data. Collaboration continued into 2023, focusing on synthesizing and representing findings. Framework development across the three phases is detailed below.

The *Generation Phase* identified key concepts that were relevant to the guiding questions as listed in Appendix 1. After meeting four, the notes and transcriptions from the four meetings were analysed by one researcher using inductive thematic approach (Bryman, 2012) to highlight recurring concepts regarding what is needed when considering teaching OOF.

Concepts were collated under ‘knowing’, ‘doing’, and ‘being’ in a spreadsheet (see Appendix 1), launching the *Synthesis Phase*. Agreed upon and refined during meetings, the spreadsheet served as an organising framework for subject-specific interpretations. Between meetings, ideas were added; during meetings, they were negotiated and adjusted. This process deepened our understanding of both our own and others’ disciplines.

Developing a coherent framework across five subjects required distilling concepts into broad themes (see Appendix 1 for guiding questions). This analytical process led to four salient themes, which became the focus of perspective-making during the *Framework Phase*.

- How we inquire and generate knowledge
- Knowledge required for subject teaching
- Connections between individual and the world
- Pedagogical imperatives

The salient themes map to the concept elaborations from the *Synthesis Phase*, and reflect the essence of knowing, doing and being in

relation to the disciplines and subjects. The salient themes were arranged into a graphical representation, and we met over several sessions to align the themes with literature across five subjects.

For this paper, the below analysis explores the salient themes using the contexts of Science and English. We acknowledge each subject has its own spectrum of research and extant knowledge. The purpose of this research was to begin with the experiences, research, and knowledge of our research team, and elaborate by drawing on additional literature to identify and unpack the salient themes. Therefore, the following theme descriptions begin with describing the emergent ideas from our discussions and theme development, elaborating on these using relevant literature, and then providing some examples of how the ideas translate into Science and English. The framework diagram is presented in the Discussion section.

4. Findings

The four salient themes refer to elements of these discipline characterisations. The accounts for each subject were written by the subject specialists during our research team conversations so the tone is reflective of how we each express ourselves in response to each other. In addition, they are written in a way that represents the dialogical nature of the way the ideas were generated, highlighting also the difficulty that can arise when seemingly general ideas are translated through different disciplinary and related school subject lenses.

4.1. How we Inquire and Generate Knowledge

Two key ideas emerged.

- Different disciplines, and their related subjects, have different modalities, or linguistically realised claims to truth.
- Defining these differences demonstrates the cognitive demands placed on OOF teachers who must move between subjects and their related disciplines.

We begin by exploring how different disciplines offer unique ways of understanding the world. Identifying these differences highlights the cognitive demands on OOF teachers. Different disciplines, and their related subjects, have different modalities, or linguistically realised claims to truth. Understanding the world can be subjective, shaped by personal perspectives, or objective, where interpretations are unbiased and independent of personal viewpoints. Subjectivity versus objectivity situates the knower in a different relationship to what is becoming known or what is being created; it also demands different ways of coming to know.

We make sense of the world through 'modes of inquiry,' which are the distinct approaches disciplines use to generate and structure knowledge. Thinking about modes of inquiry requires understanding about the complexities of subject matter and offers ways to think deeply about learning in different subjects. Modes of inquiry lowers the risk of reductive teaching based on assumptions formed when teaching in-field that do not hold up in other areas. It potentially provides a way to connect with essential underpinnings of disciplinary learning, when access is not available to the extended development of these understandings through the degree programs undertaken by in-field teachers.

4.1.1. Translation to science and English

The following translation, summarised in [Table 2](#), explores the questions: How do subject and disciplinary differences influence the way

Table 2

Modes of inquiry.

Science	English
<p><u>Discipline:</u> Science seeks to elucidate the rules that govern the natural world using empirical and "scientific method".</p> <p><u>Classroom:</u> Science has recognisable yet sometimes misrepresented translation of disciplinary modes of inquiry and disciplinary practices into schools Students can imagine themselves and/or see others as a scientist</p> <p><u>Challenges for OOF teachers:</u></p> <ul style="list-style-type: none"> • Science is exploratory, involves question posing, but scientific knowledge is to some extent contestable and changing. • Scientific inquiry is not necessarily linear, involves creativity, and not all scientists follow the same method. 	<p><u>Discipline:</u> English is at least partially focused on self-actualisation and creative expression, appreciation and analysis of literature, emulation of generic conventions, and critique of social power relations.</p> <p><u>Classroom:</u> English employs multiple ways to inquire and invites and accepts multiple answers to inquiry. Students do not imagine themselves as "Englishists", as there is no such thing.</p> <p><u>Challenges for OOF teachers:</u></p> <ul style="list-style-type: none"> • The modes of inquiry (ways of thinking critically) in English are distinguished by their multiplicity. • There is no single direct translation of disciplinary ways of inquiry into classroom activities, and teachers must develop their own broad repertoire of inquiry based on multiple disciplines

we inquire and generate knowledge, and what are the implications for OOF teachers?

4.1.1.1. Science. Science can make strong claims to particular truths based on empirical evidence, thus giving a degree of certainty as to what is right or wrong, proven or not. Science has recognisable yet sometimes misrepresented translation of disciplinary modes of inquiry and disciplinary practices into schools. Inquiry is central to teaching and learning in science, modelled after how scientists generate and validate knowledge. However, challenges arise in translating scientific practices into classrooms. OOF teachers need to appreciate that science is exploratory, involves question posing, but that knowledge is "contestable and is revised, refined and extended as new evidence arises" (VCAA, n.d., para. 1). Scientific inquiry is not necessarily linear, it involves creativity, and not all scientists follow the same method of inquiry.

Scientists and their work are often misunderstood and misrepresented by popular media. Feasey (2021) noted the challenge for science teachers asking students to emulate a group that is often distrusted. Tools like the *Draw A Scientist Test* (Chambers, 1983) challenge stereotypes and facilitate discussions about integrating science identity into classrooms. Whannell and Hobbs (2018, p. 35) highlighted the importance of students "playing the role of scientist," observing real scientists, and engaging in real-world investigations to build positive science identities.

Translating scientific practice into classroom teaching is a complex task. Meaningful experimentation, essential to science teaching, is often overshadowed by a focus on science products (Osborne, 2006) and uninspiring, recipe-style experiments (Education & Training Committee, 2006). The oversimplification of inquiry through the "scientific method" (Gauch, 2003) complicates teaching for OOF teachers, who struggle with the diversity of scientific methods (Hogben, 1938). Since 1938, a large body of literature has debated and contested the 'nature of science', 'scientific literacy' and 'science literacy', shifting the focus from acquiring science knowledge to preparing students as scientifically-informed citizens (Abd-El-Khalick & Lederman, 2000). Efforts to embed thinking and working scientifically into curricula

(Hackling, 2017) emphasize scientific practices such as “questioning, researching, challenging, debating, listening, and investigating” (Paige & Zeegers, 1999, p. 143).

A contemporary issue for science education is its connection with STEM (Leonard & Woolcott, 2017), which according to the STEM policy discourse positions STEM and its disciplines as fundamental to future innovation and prosperity (Timms, Moyle, Weldon, & Mitchell, 2018). Through this turn towards STEM, the language of STEM practices and skills, 21st Century skills, and general capabilities can be translated into science, purportedly giving it authenticity by providing contexts that link science to ‘the real world’ and society through authentic problem solving (Xu et al., 2024). New challenges arise for teachers where interdisciplinary or multiple disciplinary teaching requires teaching some content OOF (Crisan & Hobbs, 2019; Du Plessis, 2020), also OOF teachers may not appreciate the creative potential of science within this context when arts is added as STEAM (Aguilera & Ortiz-Revilla, 2021; Vieira et al., 2024).

4.1.1.2. English. For English multiple answers can be entertained. Creative or reflective writing, in English, might require a kind of truthfulness to notions of self and identity, yet each student will have a completely different answer to an inquiry question. Modality in English is individualised and is more open to exploring possibilities, not just what is or can become known.

The concept of “modes of inquiry” in this study is difficult for an English teacher to embrace. While “inquiry” into external entities is the basis of some subjects, English might be described as a subject at least partially focused on self-actualisation and creative expression, on appreciation of literature, on emulation or reinvention of generic conventions and on critique of social power relations. These might be couched as “inquiry” (such as inquiry into self, texts, genres and power relations) but this word is not widely used; it is mentioned briefly, twice, in a common textbook use for English teacher education (Locke, 2015). OOF teachers may not appreciate that the metaphorical entailments of “inquiry” suggest the law, or science, rather than English. It sets up a potential relationship of exteriority, between student and a fixed object of inquiry. In English, however, a student’s reading of a text is understood as one of many possible readings, and the process of reading itself is both creative and subjective, infinitely influenced by context.

While English teachers would be familiar with general student-centred concepts such as “inquiry-based learning”, “modes of inquiry” are not readily stated or shared. Challenges in articulating such modes may be related to the singular nature of English as a subject that is, according to the literature, unsettled, unresolved, contested and elusive, lacking any “consensus” as to its features (Dutton & Manuel, 2019, p. 10). Recognizing and accepting this phenomenon and its history are important components of English method training; the complexity of this background would not be easy for OOF teachers to grasp.

However, there are some ways of thinking critically (inquiring) that would be familiar to English teachers and the broad range of practitioners in relevant industries informed by the discipline of “literature”. These include: reflection and reflexivity; process approaches such as pre-writing, brainstorming, planning, drafting, revising, editing and publishing; interdisciplinary methods, especially from the arts; dialogue, especially oral dialogue; questioning of asymmetries of power, absences, ambivalences and contradictions; attention to intentions and effects; assumptions that there are multiple possible answers, as long as these can be supported by evidence; writerly or readerly approaches that require students to do more than rote work, but actually adopt the persona, attitudes, practices and identity of practitioners; writing as a form of inquiry itself, to generate insights; appreciation of and reference to a literary canon; interaction with stimulus or mentor texts; creative interventions as a means of inquiry; attention to authorial, textual and audience context; and reliance on multiple different readings in literary theory/criticism and troubling of generic conventions.

English is a subject that employs multiple ways to inquire and invites and accepts multiple answers to inquiry. OOF teachers may not appreciate that teaching English does not involve a straightforward translation of disciplinary ways of inquiry, or “method”, into classroom activities, but demands that teachers develop their own very broad repertoire, based on multiple disciplines. English asks students to think like a poet, journalist, debater, critic, academic, writer, public speaker, playwright, actor, citizen, reader and more.

4.2. Knowledge for Subject Teaching

Two key ideas emerged.

- Effective teachers need specialised content knowledge and knowledge of school curriculum to support student learning in meaningful ways.
- OOF teachers can be supported to understand the breadth of ideas and how they relate to each other.

In response to a move away from the domain-specificity of knowledge in the 1980s, Shulman signalled in 1986 a need to make direct links between the subject matter and what teachers know about teaching. Shulman (1986, 1987) introduced a set of hypothetical domains of knowledge, including content knowledge, curriculum knowledge, and pedagogical content knowledge (PCK).

Content knowledge refers to the understanding and skills within a specific discipline. **PCK** is a specialised form of knowledge that combines content knowledge, pedagogy, and teaching experience (Carlson et al., 2019; van Driel et al., 1998). Teachers with strong PCK can select and sequence appropriate concepts for students, adjust their teaching methods in real-time, and use strategies that foster student thinking and understanding (Carlson et al., 2019; Chan et al., 2019).

Curriculum knowledge allows teachers to understand curriculum components, including instructional tools and the history of curriculum development (Shulman, 1986). Recognizing the recursive nature of curriculum is crucial: in many subjects, content is revisited across grade levels but with increasing complexity. Teachers must be able to make connections both vertically (across grade levels) and horizontally

Table 3
Knowledge for subject teaching.

Science	English
<p><u>Classroom:</u> Science curriculum is organised in a spiral. Science curriculum focuses on content knowledge, the practices and skills of science, and the nature of science to support the development of scientific literacy. Hands-on and practical experiences such as experiments and fieldwork are needed for students to develop conceptual understanding and skills.</p>	<p><u>Classroom:</u> English curriculum is organised around the strands of Language, Literacy and Literature, yet these are not represented by any single academic discipline. English pedagogies could be understood as developing students as active, engaged and critical participants in democracies. English teachers are said to be the expert readers and writers in the room, but they also function as the expert poets, journalists, multimodal content creators and more.</p>
<p><u>OOF teachers need to appreciate:</u></p> <ul style="list-style-type: none"> • The relationship between curriculum statements and objectives with disciplinary knowledge (including skills) in science. • The relationship between grain sizes of content knowledge and moving between these. • Science-specific instructional strategies that support student learning and avoid transmissive and didactic approaches. 	<p><u>OOF teachers need to appreciate:</u></p> <ul style="list-style-type: none"> • English teachers’ work from a personal interpretation of the three paradigms of English: cultural heritage, critical literacy, personal growth and textual competence. • English teachers work from pedagogical models learnt and grounded in their preservice education, rather than in a discipline. • English is much more than “English Literature” as taught in universities.

(within a given grade) to ensure content builds progressively and meaningfully. Effective teaching involves knowing how to plan and teach in ways that anticipate new content while reinforcing previous learning (Carpendale & Hume, 2020; Loughran et al., 2006).

OOF teachers often struggle with PCK due to limited content knowledge (Singh et al., 2021), making it hard to connect concepts, identify core knowledge, and navigate curriculum progression (Loughran et al., 2006; Carpendale & Hume, 2019). This can lead to fragmented teaching and student confusion (Carpendale, 2018; Carpendale & Hume, 2019). OOF teachers must learn to use curriculum documents meaningfully and recognise learning progressions across grade levels. OOF teachers can experience anxiety or difficulty in selecting appropriate concepts to teach and tend to focus on superficial aspects of the curriculum (Hobbs & Törner, 2019). Where content knowledge and PCK are both lacking, teachers may opt for limited cognitive engagement for their students, avoid unfamiliar topics, or resort to transmissive methods that limit student engagement and responsiveness to questions (Du Plessis, 2015; Vale et al., 2020).

4.2.1. Translation to science and English

The following translation, summarised in Table 3, explores the questions: How do subject and disciplinary differences influence the knowledge for subject teaching, and what are the implications for OOF teachers?

4.2.1.1. Science. Science curricula are typically structured around specific science sub-domains and designed in a spiral progression, where concepts and skills are revisited and developed with increasing complexity over time (Carpendale & Borthwick, 2022). An example is the progression of content knowledge relating to structure and bonding where students begin by learning the particulate nature of matter—that all objects consist of tiny particles called atoms. This foundational understanding evolves into a more advanced grasp of subatomic particles and electron configuration. This progression illustrates how scientific thinking changes over time, as models of atomic structure have been refined over time through the contributions of many scientists.

Science content is based on concepts and “big ideas” that remain somewhat static over time (Loughran et al., 2006). Science content can also be understood in relation to the “grain size” of content, which can range from broad understanding to narrow ideas (Carlson et al., 2019). Effective teaching requires navigating these varying levels of content and understanding how concepts interconnect to build a coherent conceptual framework (Carpendale & Mitchell, 2023). Content-specific learning progressions can be useful, as they describe scientific practices and how to develop competence over time (Jin et al., 2019).

OOF teachers may struggle to make the connections between concepts and big ideas (i.e., moving between grain sizes) or make connections to learning from prior or future years (i.e., acknowledging the spiral curriculum nature in science). These big ideas are typically integrated into curriculum documents in broad and flexible terms, enabling teachers to interpret and adapt them to their specific contexts. For OOF teachers, this flexibility can make operationalising and implementing the curriculum particularly challenging and overwhelming.

Given the empirical nature of science, practical work is central to science teaching. However, effective implementation requires teachers to explicitly connect these activities to underlying concepts and overarching big ideas. Roth (2022, p. 43) claimed that “school laboratory activities are largely ill conceived, confused and unproductive in that many students learn little of or about science and do not engage in doing science”. Without deep understanding of the content, OOF teachers may

be reluctant to utilise practical activities when teaching, or these activities could be pedagogically ineffective. OOF teachers need to be supported to use contemporary models of practical work and reflection on learning to foster students’ deep understanding of scientific concepts. Such models can include inquiry-based learning (National Research Council, 2000) and digital tools, for example, virtual labs and simulations are increasing being used to support inquiry learning (De Jong, 2006).

4.2.1.2. English. English, in its breadth and diversity, does not necessarily map well onto any discipline. It is much more than “Literature” or “Literary Studies”, as it involves the teaching of media analysis and production, debating, speaking and listening, presentation skills and so on. It is also more than the Australian national curriculum’s Language, Literacy and Literature content organisers. English is about the preparation of literate citizens for effective participation in work and in democracies.

The idea of knowledge in English is therefore distinguished by multiplicities, which also makes the subject a challenge for OOF teachers. In-field English teachers have formulated an individual synthesis of what is described as the four versions of English: cultural heritage, critical literacy, personal growth, and textual competence. Each version traces back into the diverse disciplines informing the subject, from Literature and Literary Studies through Cultural Studies, Media Studies, Journalism, Composition Studies and Creative Writing. This understanding is threaded throughout English method courses but would not be readily accessible to OOF teachers.

The concept of “literacy” is itself frequently evolving across disciplines, and English as a subject, carries traces of all these changes. The subject’s content knowledge is therefore constantly in flux. For example, “digital literacies”, entangled with ICT, have recently had to expand to encompass prompting generative AI content tools, editing and critiquing outputs of these tools and understanding the role of generative AI in communication in society. In all these changes to literacy in English, however, there are strong antecedents in the theory and literature of the profession that empower teachers in field to adapt and adopt new literacies. As an example of this, Bill Green’s (Green & Beavis, 2012) Literacy in 3D model, which has been widely used to conceptualise both content and pedagogy for the English classroom, has been able to encompass the development of technological and digital literacies. It uses the dimensions of the operational, cultural and critical to inform pedagogy. Such schemas, while always inevitably limited, are part of the conceptual framing that in-field teachers can bring to innovation that may otherwise seem overwhelming.

In-field English teachers bring knowledge about broader “scope and sequence” framings of the subject, and their experience teaching and cross marking English work at different levels. This, along with disciplinary professional learning and intimate familiarity with relevant curriculum documents provides the background for their expectations of students’ writing, reading, and speaking and listening. The OOF teacher may not appreciate that “grain size” of content is a relatively unfamiliar concept for English, which is a looser subject. As students progress through the subject, they gain in confidence, independence, reasoning skills and capacity to deal with texts of greater complexity and intertextuality. Students revisit concepts, skills and processes “as needed” (ACARA, 2024a,b). English also requires an extraordinary breadth of knowledge, for example about what students love to read in their spare time, what their passions and interests in popular culture and beyond are, for exploring in assignments, what their circumstances and family or trauma backgrounds might be, so texts can be chosen and taught

sensitively, to just name a few.

4.3. Connections between Individual and the World

Two key ideas emerged.

- Teachers need to understand how the subject and its content connects to students’ lives, the nature of these connections, and how to make these connections.
- OOF teachers may need support in recognizing opportunities to establish connections and in building the required knowledge to identify and implement such connections effectively and appropriately within the subject context.

The connection between individuals and the world varies across subjects, shaped by how knowledge is generated, consumed, and used. Teachers operationalize this connection through relevance, reflecting what they value ethically and educationally. Ensuring the relevance of schooling to students’ lives, interests, and future pathways is essential, and this includes adopting culturally responsive teaching practices suited to diverse contexts (UNESCO, 2013). Teaching connects subjects to students’ lives (Darby-Hobbs, 2013) and is shaped by the stories teachers construct (Elbaz-Luwisch, 2002). These connections underscore the importance of aligning curriculum and pedagogy with learners’ needs and societal expectations. From the perspective of curriculum, UNESCO (2013) refers to curriculum relevance as “[a]pplicability and appropriateness of a curriculum to the needs, interests, aspirations and expectations of learners and society in general” (p. 21).

Making connections between the student and the subject requires teachers to understand “the human dimensions of learning, using, and identifying with, content” (Darby-Hobbs, 2013, p. 77). Darby-Hobbs (2013) highlights that OOF teachers may fail to “appreciate and exhibit a passion for the subject and what the subject can do for their students” (p. 95). A teacher may not be aware of the connections that can be made with latest advancements in the case of science, or which texts provide insight into certain aspects of the human experience and social issues in English.

4.3.1. Translation to science and English

The following translation, summarised in Table 4, explores the questions: How do subject and disciplinary differences influence the way connections are made between the individual and the world, and what are the implications for OOF teachers?

Table 4
Connections with the individual and the world.

Science	English
<p><u>Classroom:</u> Connecting students with the subject requires the teacher to understand the human dimensions of learning science, such as through the Science as Human Endeavour strand of the Australian Curriculum as well as connection through using and identifying with the content.</p> <p><u>OOF teachers need to appreciate:</u></p> <ul style="list-style-type: none"> • Knowing the stories, latest advancements, relevant contexts, or application of knowledge for learning science 	<p><u>Classroom:</u> English teachers act as instruments vibrating between the worlds of literature, media, culture, society and students. English teachers interpret and refine very diverse content to make it appropriate for students.</p> <p><u>OOF teachers need to appreciate:</u></p> <ul style="list-style-type: none"> • Exploring connections between the learner and the world requires us to first think about how this “world” is conceptualised and realised, and who is included and excluded in these processes. • Learning is already embedded in the represented worlds of the texts studied, and the teacher links students’ worlds to textual worlds.

4.3.1.1. *Science.* The use of recipe-style laboratory experiences, coupled with an out-dated, canonical curriculum, have tended to remove school science from the central aspirations and interests of young people (Tytler, 2014). There is a long-held belief that the quality of science education is tied to its relevance, or the value that students place on science in their lives (Newton, 1988). Connecting science to students’ lives, or humanising the subject, means situating the subject historically, culturally, socially or personally (Darby-Hobbs, 2013). Meaning making has been linked to storying as a way of “evoking a personal response to the subject” (Hobbs & Davis, 2013, p. 1290), which has implications for the value students place on the task and the subject generally. Connecting students with the subject therefore requires the teacher to understand the human dimensions of learning science, such as through the Science as Human Endeavour strand of the Australian Curriculum, as well as connection through using and identifying with the content (Darby-Hobbs, 2013). For OOF teachers, knowing the stories or relevant contexts or application of knowledge for learning science can be challenging, compared to an in-field teacher who may have personal experiences that they can draw on, or knowledge of the practical application of subject matter. Science teachers can show the relevance of the subject to students’ lives through using illustrations of familiar events or phenomena that are socially and culturally relevant to students (Darby-Hobbs, 2013), authentic contexts to challenge the students to think more deeply about the content and generate student interest (Corrigan & Fitzgerald, 2020; Darby-Hobbs, 2013), and represent disciplinary endeavours and importance to society through showcasing historical and contemporary ‘heroes’ (Darby-Hobbs, 2013).

4.3.1.2. *English.* English teachers act as a kind of instrument vibrating between the worlds of literature, media, culture, society and students. English teachers interpret and refine very diverse content to make it appropriate for students, for example, choosing extracts from texts or poems to study, based on curricula and on students’ interests and needs. Exploring connections between the learner and the world requires us to first think about what worlds we mean, and English teachers work in many! In English, learning is already embedded in the represented worlds of the texts studied, and the teacher acts as a conduit, linking students’ worlds to textual worlds through pedagogy. For example, when reading, students are encouraged to fill gaps in meaning with “their own imagination and experience” (Gold, 2019, p. 89). English also foregrounds another world: the world of the author or creator, which may or may not be the world represented in the text. In studying English, students are also immersed in the genre-based worlds of texts, worlds that are also the passions of in-field English teachers. Theatre, writers’ festivals, libraries, bookshops, slam poetry competitions, galleries, museums, films and creative social media all form a resonant cultural backdrop to learning about language and how it is used in the cultural industries. Students are likely to be encouraged into these worlds through incursions and excursions. They are likely to be active participants in digital worlds, and their expertise is therefore often drawn into English lessons. In a final dimension, the “Personal Growth” paradigm of subject English places the human at the centre of English curriculum, with emphasis on writing for self-realisation and reflection. Yet the role of this paradigm in the curriculum is responsive to how policy drives towards “literacy” rather than English, have favoured teaching of basic skills and analytical rather than personal, descriptive, narrative and reflective writing (Goodwyn, 2003).

4.4. Pedagogical Imperatives

Two key ideas emerged.

- The ways in which pedagogical imperatives are a product of subject and disciplinary differences in how one comes to know, do and be in the subject.

Table 5
Pedagogical imperatives.

Science	English
<p>Classroom: The central role of constructivism and student conceptions focuses teachers on how students make sense of new information through their existing conceptual framework. Science has an accepted way of explaining phenomena. Drawing from a constructivist view of learning, students can develop misconceptions or alternative conceptions about scientific concepts that differ from scientifically accepted explanations.</p> <p>OOF teachers need to:</p> <ul style="list-style-type: none"> • Know what to notice in student responses and how to vary their approach in the moment. • Appreciate different models of student ideas that can inform teaching. 	<p>Classroom: English has been more influenced by post structural theory (Rosenblatt, 1968), and multiplicities and complexities. Any statement a student may make about a text may be accepted if it is accompanied by persuasive evidence from that text. Four pedagogical paradigms—personal growth, cultural heritage, critical literacy, and textual competence—guide teaching, though they are contested. For example, the Genre/Skills paradigm debates grammar as a set of rules versus a creative resource</p> <p>OOF teachers need to appreciate:</p> <ul style="list-style-type: none"> • Develop the disciplinary and subject-based confidence to invite, welcome and engage with challenges to received or teacher-located wisdom. • The different paradigms and facets of English can make it difficult to generalise about pedagogical imperatives

- OOF teachers need to appreciate core pedagogical imperatives and how these change over time.

OOF teachers often struggle to identify what matters most for student learning. The theme of pedagogical imperatives emerged to capture subject-specific priorities. Initial discussions, led by science and mathematics educators, highlighted constructivism and “alternative conceptions”—terms not easily transferable to English. We adopted pedagogical imperatives as a broader construct referring to what teachers attend to in supporting student learning and engagement.

In-field teachers’ pedagogical imperatives stem from their understanding of modes of inquiry and forms of knowledge that constitute the curriculum, what is important for students to understand and do, and the type of learner/learning we want to foster in the classroom. These imperatives manifest in how teachers attend to student needs and adapt learning, especially where ambiguity or difficulty arises for the learner. These imperatives are in some ways a product of the subject/disciplinary discourses and maybe traditions of practice. They likely change both within subjects and over time, depending on dominant discourses and empirical research. Keeping up with these changes through professional learning can be challenging for in-field teachers, let alone for those teaching OOF.

4.4.1. Translation to science and English

The following translation, summarised in Table 5, explores the question: How do subject and disciplinary differences influence the pedagogical imperatives of a subject, and what are the implications for OOF teachers?

4.4.1.1. Science. For science teachers, concept development is central, and constructivism is the foundation of science teaching. Constructivism, based on Piaget (1952) and Vygotsky (1978), emphasizes that knowledge is constructed by the learner, influenced by social

interactions and personal experiences. Constructivism highlights how new information interacts with students’ existing frameworks, leading them to construct personal meanings (Carpendale & Mitchell, 2023). Constructivism became an underpinning theory of learning of science in the late 1970s (Driver & Easley, 1978), as researchers noticed students often left classrooms with different ideas than intended (Gunstone, 2000). Misconceptions of science ideas became a major research focus in the 1980s as studies showed widespread misunderstandings across student levels. These misunderstandings are variously labelled as misconceptions, preconceptions, naïve beliefs, or alternative frameworks (Driver, 1981). While “misconception” is a catch-all term (Kind, 2014), understanding the cognitive properties of student ideas (Smith et al., 1994) is now fundamental to science teaching.

This theory has led to various models of student ideas (Dodlek et al., 2024) that inform science teaching, such as conceptual change teaching approaches that require challenging misconceptions, inducing cognitive dissonance, and offering more plausible explanations. Other models of student ideas include Hammer and Elly’s (2003) resources as “Knowledge in Pieces” (KiP) that can be activated by a student, and Tytler and Prain’s (2013) multiple representations that supports the use of different representational modes and sequences of representational challenges that aim to support conceptual growth. Teaching this way requires deep content knowledge and the ability to reflect in action (Schön, 1987). OOF teachers may lack the disciplinary insight to interpret student responses or adjust instruction. For example, Kind (2014) found that non-chemistry major beginning teachers teaching chemistry in lower secondary classes held similar misconceptions to 15-year-old students.

4.4.1.2. English. From the perspective of an in-field English educator, the idea of “misconceptions” suggests an epistemological approach in science that is about rights and wrongs. This binary thinking is less common in English, which has been more influenced by post structural theory (e.g., Rosenblatt, 1968), and multiplicities and complexities. Even traditional literary criticism lays the foundations for student “independence” (Gold, 2019, p. 86) in analysis. For example, any statement a student may make about a text may be accepted if it is accompanied by persuasive evidence from that text. How persuasive this evidence is, is a matter for debate and discussion, not clear-cut judgement about what is right or wrong. While the following is increasingly contested, English has been a subject where exploratory, creative and original thinking has been encouraged as a pedagogical imperative, by in-field teachers who are have the disciplinary and subject-based confidence to invite, welcome and engage with challenges to received or teacher-located wisdom; resistance is advocated (Morgan, 1994).

In English teaching, there are four acknowledged paradigms that drive pedagogy: personal growth, cultural heritage, critical literacy, and textual competence. The extent to which an individual teacher subscribes to, or is influenced by, the various paradigms, will drive pedagogy (Macken-Horarik, 2014). An understanding of the four paradigms and their role in English is therefore essential for any OOF teacher in this area, rather than the implementation of agreed pedagogical imperatives. Practice is also therefore less likely to be common across English teachers, although in recent times this has changed due to increased pressures towards standardising practice (Goodwyn, 2003). The different paradigms and facets of English also make it difficult to generalise about pedagogical imperatives, which tends to be a challenge for OOF teachers. For example, in the Genre/Skills paradigm, rights and wrongs in relation to the mechanics of English, such as sentence

What is distinctive about the subjects?
What do out-of-field teachers need to know, do and be?

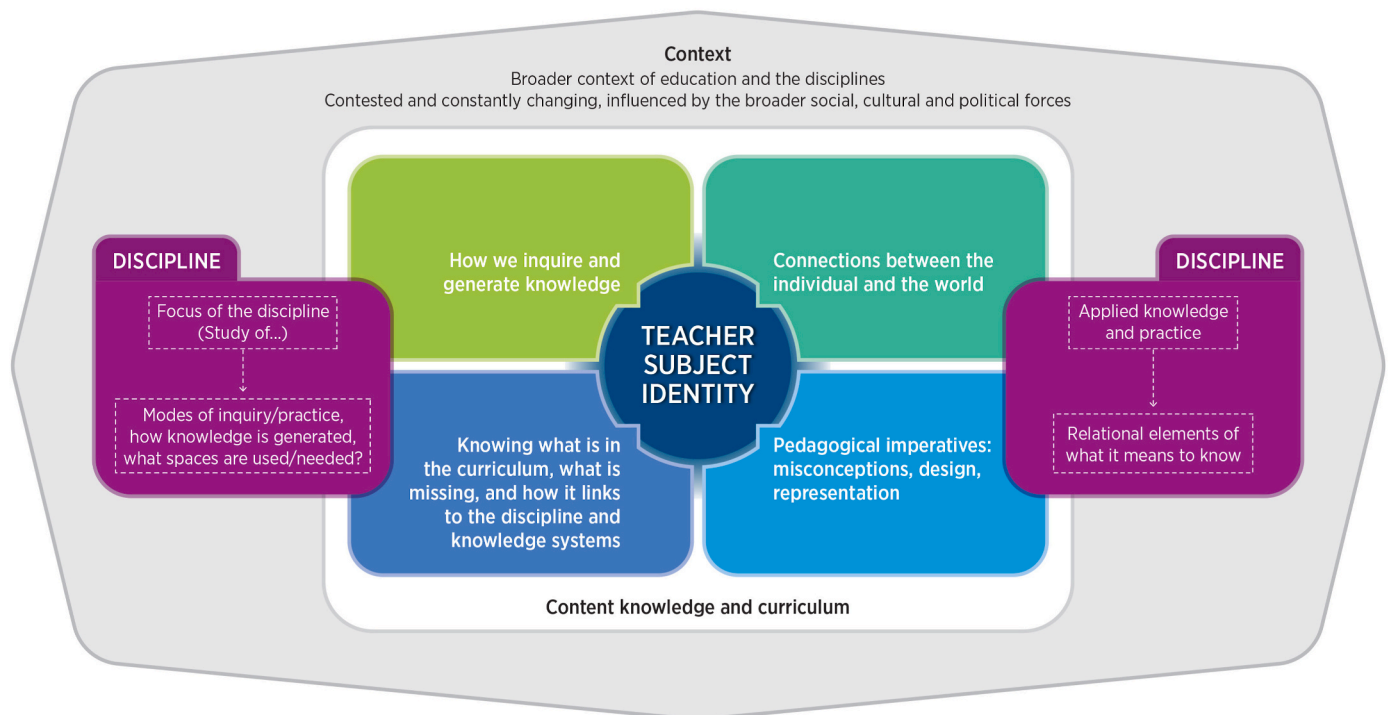


Fig. 3. Framework of subject-specific expertise for out-of-field teachers.

structure, punctuation, grammar and spelling, do play a greater role, as students are prepared for effective communication in the workplace and as citizens. Yet this is also contested, with grammar most recently recommended to be thought of as a creative resource, not a set of rules (Myhill et al., 2016).

5. Discussion

The descriptions above highlight how the disciplines and their associated subjects are distinctive (Schwab, 1964) as well as common challenges teachers encounter regarding the four salient features when learning to teach Science or English OOF. The four salient features coalesce into the framework of subject-specific expertise in Fig. 3. The framework enables reflection on what is distinctive about the subjects and what OOF teachers need to learn, appreciate and understand. Rather than including the broader knowledge teachers bring with them about teaching, the framework focuses on the subject-specific aspects of knowing, identifying and practicing as a specialist teacher. Unique to this framework and as has been shown above, these aspects go beyond just knowing the content and how to teach it; they are deeply connected to appreciating the disciplinary foundations of each subject.

The framework invites dialogue on the relationships between subject related teacher identity and the four salient features of specialist teaching expertise: inquiring (how knowledge is generated), knowing (curriculum and content), connecting (the subject to the individual and the world), and pedagogical imperatives (that drive teacher practice). These salient features sit within the broader context of education and the disciplines, which are contested and constantly changing and influenced

by social, cultural, and political forces. At the core of the framework is teacher subject identity, which research indicates is often challenged when teachers cross boundaries from their more familiar in-field subject into an OOF subject (Bosse & Törner, 2015; Hobbs, 2013). Subject-specific expertise emanating from its disciplinary roots is represented from two interrelated spheres: the ontological and epistemological on the left; and the aesthetic and relational on the right.

From the left, a specialist teacher would be expected to have (at least in part) a foundational understanding of what, how, and where knowledge is generated and applied. The assumption is that the teacher translates this disciplinary knowing and doing to the classroom through appropriate teaching approaches and contextualised and practically informed teaching, and appreciation for how these knowledges and practices are translated into curriculum and assessment. The framework therefore expands on models of teacher knowledge, such as PCK, by emphasizing disciplinary epistemology and ontology, that is, how knowledge is generated and what it means to be part of a discipline.

From the right, practicing the discipline brings applied knowledge and relational knowledge of what it means to know and be a part of the discipline. A specialist teacher would be expected to bring with them an appreciation for how to use the curriculum to connect the student to the natural world (in the case of Science) or textual world (in the case of English). What the teacher focuses on in their instruction is influenced by what they understand to be critical for learning, which is influenced by various factors, including the educational and disciplinary landscape reflecting contestations or changes in educational theory, such as the phonics debate in English (Wyse & Bradbury, 2022) and a shift from classic conceptual change theory to representation construction in

Science (Tytler & Prain, 2013). While presented as four distinct themes, these elements are deeply interconnected and collectively shape a teacher's subject identity, which lies at the core of the framework. Hobbs (2012) links teacher identity to their passion for teaching and their understanding of what and how to teach their subject. Many teachers anchor their identity in their specialist subject, often identifying as "a science teacher" or "an English teacher." We argue that subject identity emerges as an accumulation of the framework's elements and reflects a teacher's disciplinary background. For OOF teachers, however, this identity may shift, expand or transform. They might instead say, "I teach English" or "I teach Science," emphasizing their role (what they do) rather than their identity (who they are). The framework links subject-related teacher identity to disciplinary practices, suggesting that identity is not just about role but about being and knowing within a discipline. This distinction highlights the unique challenges OOF teachers face in aligning their professional identity with the subjects they teach. Identity tensions can be a barrier to effective OOF teaching (Hobbs, 2013; Pillay et al., 2005), and this framework offers a pathway to resolve these tensions through epistemic and relational engagement. Drawing from boundary crossing theory, the parts of the framework flag possible areas of discontinuities that may be experienced by OOF teachers (Akerman & Bakker, 2011; Hobbs, 2014) as they identify and overcome differences between familiar and unfamiliar ways of knowing, doing and being as a teacher of the subject. Such a framework, therefore, has the potential to act as a boundary object (Hobbs, 2013; Star, 1989) to underpin conversations between subject specialists and OOF teachers to support dialogue and negotiation of the boundary between familiar and unfamiliar fields.

6. Conclusion

Learning to teach a new subject requires more than acquiring content knowledge; it involves understanding the subject's principles, values, and practices and translating them into effective teaching strategies. For OOF teachers, the starting point is often the school subject's curriculum and pedagogies rather than direct experience with disciplinary ways of knowing and doing (Deng & Luke, 2008). Our framework responds to a growing need for sustainable models of professional learning and support by bridging school subjects and their underlying disciplines, emphasizing disciplinary ways of knowing, doing and being while highlighting subject-specific differences, such as those between Science and English. Like other frameworks such as the CoRe (Carpendale & Hume, 2019), our framework identifies the 'known unknowns'—key areas OOF teachers need to address—helping them develop a deeper understanding of what it means to know, value, and teach the subject, rather than leaving them to struggle with 'unknown unknowns.' Unlike other frameworks and tools, however, this framework considers the complexity of OOF teaching by integrating epistemological/ontological and relational/aesthetic dimensions to offer a holistic approach to developing subject-specific expertise. Our next research phase will validate this framework using empirical data across multiple subjects, incorporating insights from in-field and OOF teachers, researchers, discipline specialists and teacher educators. By mapping teachers' experiences to the framework, we aim to refine its applicability and assess its relevance as the educational and disciplinary landscapes change.

Additional research should investigate the challenges faced by OOF

teachers, extending beyond content knowledge and pedagogy to also consider the emotional and motivational (aesthetic) aspects involved in engaging with a discipline. We argue that any professional development and mentoring of teachers must immerse OOF teachers in disciplinary ways of knowing, doing and being alongside developing their content knowledge or PCK (Hobbs, 2012; Sullivan, 2003). Acknowledging these affective and aesthetics components is critical, as they are often missing for OOF teachers. The framework has practical application for mentoring contexts where teachers are supported to teach a new subject, such as initial teacher education where teachers are introduced to subject teaching theoretically through course work and practically on practicum, and through professional development as guidance for course design and content. Grounded in boundary crossing theory, which recognises the learning potential of OOF teaching (Hobbs, 2014), the framework empowers collaboration co-construction among teachers and mentors. Used alongside other resources (e.g., Caldis, 2022a; Carpendale & Hume, 2020; Fraser et al., 2019) it can enhance subject-specific dialogue between an OOF teacher and more experienced others by providing the language for identifying and foregrounding the ontological/epistemological and aesthetic/relational dimensions of teaching a subject. Our interdisciplinary dialogue has illuminated both subject differences and shared ways of thinking across disciplines. A key methodological challenge for us was identifying salient features across fields, which required developing a shared vocabulary. Comparative analysis also deepened our understanding of our own subjects, helping us articulate their requirements by contrasting them with another discipline and highlighting what we do not realise is peculiar (Middledorf & Pace, 2004). This process revealed valuable insights into the challenges OOF teachers face and possible ways to support them.

CRedit authorship contribution statement

Linda Hobbs: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Jared Carpendale:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Lucinda McKnight:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Susan Caldis:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Colleen Vale:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Seamus Delaney:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization. **Coral Campbell:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. Guiding Questions of the Generation-Synthesis-Framework Phases

GENERATION PHASE		
Overarching question		
What is core to teaching a subject? What is subject-specific and what is generic?		
Methodological questions		Questions guiding discussions
A. What is common to teaching OOF across the disciplines?		1. What expertise is core to teaching a subject, including what is subject-specific and what is common or generic?
B. How does looking across the disciplines deepen our thinking of teaching in an OOF context?		2. How does the experience of teaching OOF in one subject differ to teaching OOF in another?
C. What value is there in having a framework that provides a comparative lens for teachers and researchers?		3. What subject teaching expertise <u>do</u> teachers teaching OOF need?
D. What might be included in such a framework?		
SYNTHESIS PHASE		
Per subject questions		
<i>How are these represented for each subject?</i>		
Knowing	Doing	Being
<ul style="list-style-type: none"> • Discipline knowledge • Threshold concepts • Curriculum Saliency (e.g., VCE Study Designs) • Alternate/mis conceptions: How does a teacher pay attention to the learning needs of students, or adapt the learning to needs of their students → Pedagogical imperatives • Knowledge of students' understanding and learning • Nature of the subject, knowledge and practices • Relevance: Pedagogical beliefs about the subject, alternative ways of teaching the subject. Different ways of thinking about the subject. • Role of context in shaping what is valued, expected etc 	<ul style="list-style-type: none"> • Methods of teaching: signature modes of teaching • Modes of inquiry • Spaces where learning occurs • Role of context in shaping what is valued, expected • Making content relevant: making a connection between the student and the subject • Curriculum connections • Student Dispositions / capabilities /practices • Professional learning wants and needs 	<ul style="list-style-type: none"> • Identity as a teacher • Orientations towards teaching • Agency • Self-efficacy • Role of context in shaping what is valued, expected etc
FRAMEWORK PHASE		
Per salient features questions		
<i>For each: How does this compare across subjects? What challenges exist for out-of-field teachers?</i>		
<ul style="list-style-type: none"> • Knowing what is in the curriculum, what is missing and how does knowing link to the discipline? • What are connections between the individual and the world, connections between knowledge? • How do we inquire and generate knowledge? • What are the pedagogical imperatives? 		

Data availability

No data was used for the research described in the article.

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