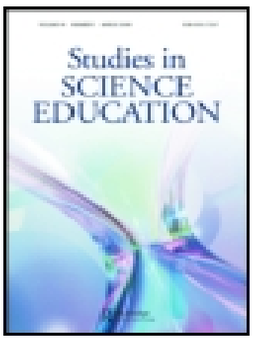

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What you find depends on how you see: examining asset and deficit perspectives of preservice science teachers' knowledge and learning

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REVIEW ARTICLE

What you find depends on how you see: examining asset and deficit perspectives of preservice science teachers' knowledge and learning

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ABSTRACT

This article explores how scholars have framed studies of preservice science teacher (PST) knowledge and learning over the past twelve years. We examined relevant studies between 2008 and 2020, coding them by theoretical perspective (cognitive or sociocultural), knowledge perspective (deficit or asset), and teaching level (elementary, secondary, or both) of the PSTs in the study. We found patterns between knowledge and theoretical perspective use, perspective use over time, and differences between studies of elementary and secondary level PSTs. We conclude with a proposed model of theoretical and knowledge perspectives as seen in the reviewed studies as well as further questions for the field.

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Preservice teacher knowledge; science education; learning theory

The catalyst for this manuscript was an academic conference the authors recently attended. During the conference, multiple researchers presented studies about preservice teachers (PSTs) learning to become science teachers. In many presentations, researchers described PST learning in terms of lacking or gaining knowledge domains, such as pedagogical, content, or pedagogical content knowledge. More specifically, such presentations noted how PSTs failed to meet the researchers' predetermined criteria for adequate learning on pre and post-assessments of these various knowledge domains. The overarching message of such presentations was clear: many researchers equated PST learning with knowledge they lacked or failed to acquire. For the authors this brought to mind Dillon and Avraamidou's (Dillon & Avraamidou, 2020) question: 'Do we really need another study that pre-service teachers don't know much about anything?' (p. 4). The message about PSTs also sparked a question of our own – Is there an underlying structure in these research studies that guides the way researchers position PSTs and their learning? This literature review is an investigation focused on addressing our question.

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Problem framing

Debates about what PSTs should know, and the relationship of such knowledge to claims about learning, are varied and long-standing in teacher education, including the preparation of new science teachers. The emphasis on linking PST learning to the acquisition of knowledge domains extends from calls for a knowledge base for teacher preparation, which aligns with literature aiming to define pedagogical content knowledge (PCK) as a unique form of teacher knowledge (i.e., Carlsen, 1999; Magnusson et al., 1999; Shulman, 1987). Yet the conference experience made us wonder why researchers described PST learning in terms of knowledge they 'gained' or 'lacked' – including knowledge that might be considered incorrect and labelled as 'misconceptions' by some researchers – signalling a deficit perspective of PSTs. A deficit perspective of PST knowledge and learning is contrasted with asset-oriented perspectives (e.g., López, 2017), in which researchers attempt to understand how PSTs' knowledge, experiences, and identities serve as resources as they learn through sense-making and participation in varied and valued cultural practices. The seeming dichotomy between how researchers see PSTs from an asset or deficit perspective suggested a literature review in which we examine research by focusing on how researchers frame their work and how they position PSTs as learners rather than broadly characterising the knowledge based that has been developed around beginning teachers' learning to teach.

Given such different possibilities for framing PSTs, we examined the literature to better understand any connections between positioning PSTs and their learning (asset or deficit), theoretical and methodological approaches guiding data collection and analysis of PSTs learning, and the description of the results and how they describe PSTs learning relative to the learning measures. Specifically, we asked:

In literature about science teacher preparation, how is PST learning described in terms of asset or deficit perspectives about knowledge?

What patterns emerge around asset and deficit framings of PST learning relative to the theoretical perspectives taken by the researchers?

Theoretical Framework

We begin by distinguishing between the way deficit and asset perspectives describe PST learning. Next, we characterise two broad theoretical perspectives – cognitive and sociocultural – that frame the majority of studies about PST learning. Finally, we explain how distinctions between cognitive and sociocultural perspectives and the way they play out in terms of methods helped us categorise studies in the literature about PST learning during science teacher preparation programmes.

Deficit and asset perspectives about knowledge

Viewing research participants with a deficit perspective is not a new phenomenon. Taking a deficit perspective is pernicious because, as Davis and Museus (2019) suggest, such a lens 'serve as tools that maintain hegemonic systems and, in doing so, fail to place accountability with oppressive structures, policies, and practices within educational settings' (p. 1). Given the implicit and pervasive nature of deficit

perspectives, our review looked for evidence of this framing in the way that researchers rhetorically position PSTs and their learning. As noted previously, researchers often frame PSTs from a deficit perspective through a comparison between the quantity or quality of PSTs' knowledge in various domains to an arbitrary and predetermined standard. Alternatively, researchers can describe PSTs from an asset perspective, in which knowledge is treated as a resource for people as they engage in sense-making and practices. We posit that researchers have explicit and tacit assumptions about knowledge and PSTs, and employ specific methodologies that reflect these assumptions (See Table 1 for comparisons).

We propose there are two important features of the assumptions about deficit and asset perspectives to note. First, in the context of teacher preparation, deficit perspectives put the onus on individual PSTs for having or lacking knowledge, whereas asset perspectives consider how an individual's knowledge serves as a resource for participation in larger learning contexts. Second, deficit perspectives assume an a priori framing of the world in which the knowledge required for teaching is defined by researchers without considering the individual understandings of the PSTs. From this perspective, the knowledge that a PST needs to engage in science teaching can be assessed on a standardised instrument. Individual PSTs can either meet or fail these predetermined standards for knowledge, and might require interventions to become aligned with the a priori defined goal state. In addition to positioning PSTs as less or incapable or in need of fixing, a deficit perspective also reinforces hegemonic notions of teacher knowledge which maintain power hierarchies by positioning PSTs, especially those in underrepresented groups, as being outside the epistemological norm. Asset perspectives, in contrast, describe how PSTs come to understand and participate in teaching using their knowledge and experiences as resources. Rather than compare the alignment of PSTs' knowledge to predetermined standards, researchers using an asset framing assume there will be an inherent difference between PSTs' understandings and the tentative implicit and explicit goals of a study. However, PSTs' learning, and ideally the study designed by researchers, should be responsive to the PSTs' current understandings.

Table 1. Assumptions in studies of preservice teacher knowledge.

	Assumptions by researchers and methodologies
Deficit perspective	• Tacitly or explicitly take the researcher's perspective/framing/knowledge as the 'correct' perspective/framing/knowledge, and holds participants to that standard. • Place the responsibility for a lack of knowledge or action on preservice teachers rather than on contextual features, an absence of opportunities to develop different understandings, or an incorrect understanding of the assessment or task designed to evaluate knowledge gain. • Propose future research that posits interventions needed to fix/remedy participants' incorrect knowledge.
Asset perspective	• Tacitly or explicitly use a perspective that examines what/how/why participants view and act in the world in the ways that they do. • Place the responsibility for learning on the context, learning environment via absence of opportunities to develop different understandings. • Suggest future research that focuses on how the context can shift, or how researchers and participants can work together to redesign the learning environment to take advantage of the resources learners bring so that individuals have opportunities to productively participate in their own learning.

Theoretical perspectives on learning

Given a brief summary of deficit and asset perspectives on science PSTs' knowledge, we now describe cognitive and sociocultural perspectives on learning, and note how such lenses characterise PST learning (see Table 2 for a summary of key points, Danish & Gresalfi, 2018). We recognise there are other perspectives on PST learning, such as behaviourist or critical perspectives; however, we choose to focus on cognitive and sociocultural perspectives given their historical prominence in literature about science teacher preparation.

Cognitive perspectives view learning as an individual process in which information is acquired from local contexts and environments, organised into internal structures such as concepts or schema, and change states over time (Danish & Gresalfi, 2018). Often grounded in foundational work by Piaget, learning is described as the growth in terms of the number, complexity, and interconnectedness of knowledge structures in the brain, which are later accessed by the individual when relevant. Higher order learning and knowledge are seen as more general(izable) and abstract, so that concepts of this kind are useful across a variety of contexts. Sometimes, learning is described in terms of stable knowledge transfer and application across contexts (e.g., high/low, near/far transfer). In other cases, differences between individuals' ability to access knowledge across context is thought of in terms more dynamic and in-the-moment processes (e.g., p-prims, diSessa, 1993), in which concepts are constructed out of constituent parts as needed to engage in activities.

A foundational assumption of cognitive perspectives is that knowledge and learning are relatively context independent, and the main function of the learning context is the activation, addition to, or change of an individuals' set of knowledge objects. Thus, knowledge is given the primary role in characterising learning, and context is a secondary factor that impacts changes in knowledge (learning) or access to knowledge (application). Measures of knowledge tend to focus on benchmarks established by researchers in the form of instruments prior to engaging learners in some form of intervention, and then measuring with the same instrument again at the end to determine change (learning) and efficacy of the intervention.

Table 2. *Cognitive and sociocultural learning theories (adapted from* Danish & Gresalfi, 2018).

Cognitive	Sociocultural
Focuses on mental processes of individual learners	Focuses on participation of learners in the social practices within a particular context
Knowledge is representations of information in an individual mind	Knowledge and engaging knowledge stem from the cultural and historical practices in which the individual is immersed
Knowledge is inferred from observable behaviours connected by models of the mind	How one comes to know is inseparable from what one comes to know. Cognition and knowing are a joint accomplishment between individual and their participatory context
Knowledge should be represented abstractly to allow for application across contexts	Transfer is seen as a pairing of individual and context and considers both in terms of overlap between learning context and transfer context
Motivation is an individual trait tied to existing individual interests, has stability, and can be investigated independent of context	People are not motivated or unmotivated, but act in those ways in relation to the practices of the context

Sociocultural perspectives generally view learning in terms of on-going changes in practice (Danish & Gresalfi, 2018). Such perspectives see knowledge and participation as inextricably linked to the context in which individuals interact with actors, practices, and tools whose roles have been negotiated over time and thus are both historical and cultural. Learning, then, embodies complex processes by which people develop discourses and practices that involve speaking, acting, and being in the world. Rather than framing knowledge as concrete entities that an individual can transfer from setting to setting, sociocultural perspectives view knowledge as mediated between actors who create, shape, and negotiate meaning and practices in social activity. Importantly, sociocultural perspectives describe a family of theories that share similar features but also exhibit variations. For example, various sociocultural perspectives might emphasise communities, activities, tools, practices, and the role of individuals in different ways. However, each of these theory views learning as something different than a change in an individual's knowledge of domains.

Examples of scholars' work from cognitive and sociocultural perspectives on learning is evident in the literature about teacher preparation and teacher learning over the last few decades. For example, a cognitive perspective is clearly represented in work that emerged from Shulman's (1987) notion of PCK, which was his effort to characterise a specialised form of teacher knowledge independent of the content knowledge being taught. PCK had a profound impact on research about teacher preparation, and has provided the foundation for on-going analysis of teacher knowledge and the characterisation of further proposed knowledge domains, such as technological pedagogical content knowledge (TPCK), as well as the development of a variety of increasingly complex knowledge models that attempt to characterise requisite knowledge for teaching (for example, see Figure 1). These knowledge models are representative of the cognitive perspective on understanding teacher knowledge through a process of researchers defining and operationalising different knowledge domains within identified aspects of teaching practice.

The relationship between teaching practice and teacher knowing in sociocultural perspectives on teacher learning are most clearly instantiated in the practice-turn in teacher education, in which PSTs simultaneously begin to develop identities as teachers, encounter suites of daily and important practices used by teachers, participate in pedagogical rehearsals designed to represent classrooms, interact with their future students' communities and valued practices, and generally engage in increasingly authentic approximations of teaching practice (Grossman et al., 2009; Lampert, 2010; McDonald et al., 2013). These models emphasise the contextual and cultural nature of teaching and tend to focus analysis on the processes and practices of teaching as the locus of teacher knowing.

Methods

As noted, this review is not attempting to capture what PSTs know (or do not), nor what constitutes teacher learning across a broad segment of the field. Our focus is understanding the relationship between the two key theoretical perspectives on PST science teaching knowledge and learning (cognitive and sociocultural), as well as the framing of PST learning through deficit or asset lenses. Thus, we conducted a systematic and analytical review of the relevant literature. A systematic review is a method of making

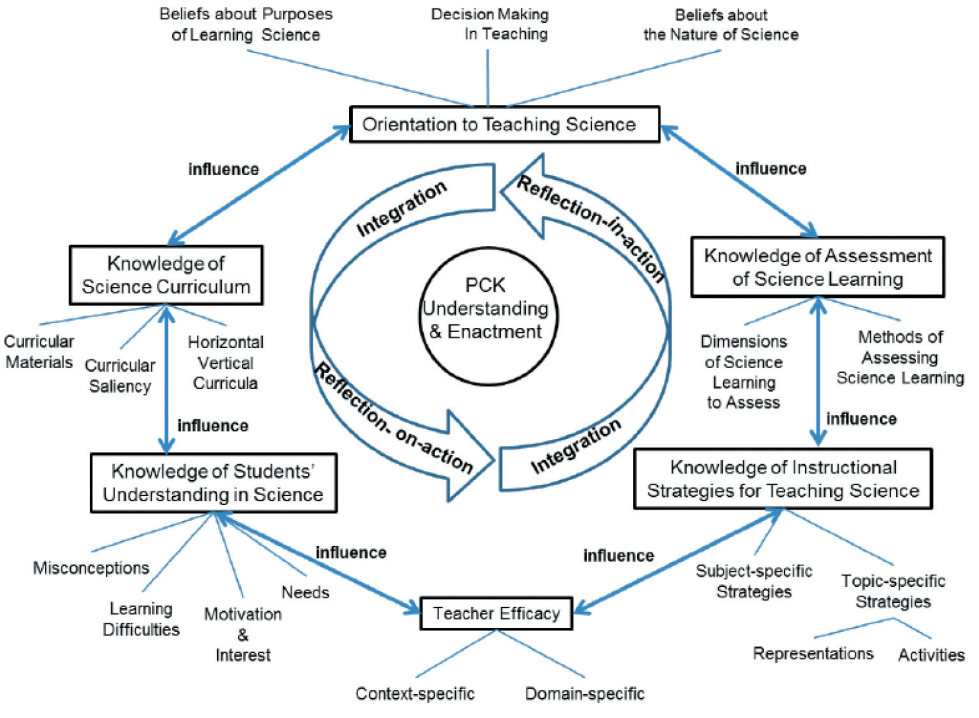

Figure 1. *Model of Pedagogical Content Knowledge from* Park and Oliver (2008).

sense of large bodies of information and may include both qualitative and quantitative analyses (Petticrew & Roberts, 2006). For this review, we did not attempt to be exhaustive given the vast literature base on PST learning. Instead, we sampled key journals in the field to look for patterns. Our review is informed by the steps suggested by Cooper (2010) and in PRISMA (Moher et al., 2009), which we describe below.

Phase 1: Identifying relevant articles

We first identified relevant articles using the Web of Science academic database, focusing on peer-reviewed journals chosen for their visibility and impact in the fields of science education and field of teacher education (see Table 3 for journals). We compiled a list of keywords (see Table 4) by adapting and extending words used in prior literature reviews on teacher knowledge (e.g., Davis et al., 2006; Van Driel et al., 2014). For example, van Driel,

Table 3. Academic journals included in search.

Science Education Journals	Education Journals
Cultural Studies of Science Education	Cognition and Instruction
International Journal of Science Education	Journal of Teacher Education
Journal of Research in Science Teaching	Journal of the Learning Sciences
Journal of Science Teacher Education	Teachers College Record
Research in Science Education	Teaching and Teacher Education
Science Education	
Science & Education	

Table 4. *Search term combinations (comparison of this study and* Van Driel et al., 2014).

Primary search terms	Van Driel et al. (2014) **search terms**
'science' and **'preservice' or 'student teach*'** and 'teacher knowledge' or 'teacher learning' or **'teacher development' or 'teaching practices' or 'teacher education'**	'science' and 'teacher knowledge' or 'pedagogical content knowledge'
Web of Science full query ((TS = (science) AND TS = (preservice OR 'student teach*') AND TS = ('teacher knowledge' OR 'teacher learning' OR 'teacher development' OR 'teaching practices' OR 'teacher education'))) AND LANGUAGE: (English) AND DOCUMENT TYPES: (Article) Refined by: SOURCE TITLES: (JOURNAL OF SCIENCE TEACHER EDUCATION OR TEACHING AND TEACHER EDUCATION OR INTERNATIONAL JOURNAL OF SCIENCE EDUCATION OR RESEARCH IN SCIENCE EDUCATION OR SCIENCE EDUCATION OR JOURNAL OF RESEARCH IN SCIENCE TEACHING OR JOURNAL OF TEACHER EDUCATION OR TEACHERS COLLEGE RECORD OR CULTURAL STUDIES OF SCIENCE EDUCATION OR COGNITION AND INSTRUCTION) Timespan: 2008–2020. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.	

Berry, and Meirink's (Van Driel et al., 2014) review of science teacher knowledge was meant to extend Abell's (2007) chapter, using the same analytic criteria: 'science,' 'teacher knowledge,' and 'pedagogical content knowledge.' Their analysis was framed around a particular model of teacher knowledge (see Van Dijk & Kattman, Van Dijk & Kattmann, 2007) in which PCK is treated as a distinct knowledge domain. Early in our search for literature, however, we realised the keywords used in previous reviews limited the scope of articles that might describe PST learning. Therefore, we added additional keywords as shown in bold in Table 4 (e.g., 'teaching practices' and 'teacher development') to better match our definition of teacher knowledge as described above and to more fully include sociocultural perspectives.

We further refined our search to English language articles published between the years 2008 and 2020. We chose the starting date of 2008 because a seminal publication in the field of science education, *Taking Science to School* (National Research Council, 2007), was published in the US the previous year. Therefore, we began with a date of 2008 to identify articles about PST learning that appeared in the years since *Taking Science to School* informed science teacher preparation and research. The search was conducted in October 2020, and the parameters generated 224 studies which we considered sufficiently large enough for our analysis.

Phase 2: Refining and categorising the results

For the initial analysis, each author independently examined the abstracts of one-third of the identified studies. We coded each study as using a deficit or asset perspective based on the characteristics described in the theoretical framing sections, and the teaching level (elementary, secondary, or both) of the PSTs in the study. We used citations in the theoretical framework and characteristics of the data collection and analysis to code the theoretical perspective of each publication. For example, if a study tacitly or explicitly took the researcher's perspective/framing/knowledge as 'correct', and described whether participants met that standard (or not), we coded the study as a deficit perspective. Alternatively, if a study tacitly or explicitly used a perspective that attempted to understand what/how/why participants viewed and acted in the world and placed the onus on learning to the context or absence of opportunities to develop different understandings

rather than on incorrect ideas of the individual, we coded the study as having an asset perspective.

To determine the theoretical perspective of each study, we utilised the features of cognitive or sociocultural frameworks described in the theoretical perspectives section. For example, studies were coded as cognitive if the phenomenon of interest (e.g., learning to teach) defined a measure (e.g., an instrument) and then the value of that measure for an individual was an evaluation of the individual's quality/ability to produce some future social practice (e.g., teaching science to children). These studies often included measures of some domain, such as content knowledge, PCK, nature of science knowledge, or misconceptions. We coded studies as sociocultural that focused PSTs shifting participation in activities or practices, how context played a role in describing the phenomenon of interest, and how PSTs ideas and experiences were treated as resources (rather than misconceptions). Such studies employed data collection and analysis that focused on how and why PSTs shifted participation, such as agency, identity, and power.

Studies in which we had difficulty in coding according to the categories were retrieved and examined in further detail by all three authors. If we were unsure of how to categorise a study, it was marked for discussion through which we came to a consensus on the appropriate categorisation. In addition, each author reviewed a random selection of eight articles from the other two reviewers to ensure the reliability of our individual coding. Any discrepancies were discussed and consensus reached.

During the in-depth analysis of literature, we eliminated 78 studies that did not match our initial criteria. To be included, articles needed to have a primary focus on elementary or secondary PSTs' learning, be included in peer-reviewed journals, and be empirical with clearly articulated research questions or purposes. Articles from the original search were removed that focused on inservice teachers (e.g., Hutner & Markman, 2017), mentorship (e.g., Bradbury & Koballa, 2008), teacher educators or pedagogies (e.g., Scantlebury et al., 2008) or PSTs from other fields (e.g., Cáceres et al., 2010) as were commentaries (e.g., Treagust et al., 2015), review articles (e.g., Levy et al., 2013), and issue introductions (e.g., Mikeska et al., 2009). This resulted in a final selection of 146 published articles from the previous twelve years (see Table 5).

After coding, we sorted the articles into one of three categories: cognitive deficit, cognitive asset, and sociocultural asset. No examples of sociocultural deficit papers were found in the analysis. Below, we provide an example of each of the three categories of studies found in the analysis for context.

Cognitive deficit example

An example of a cognitive deficit paper is Demirdöğen et al. (2016) from the journal *Research in Science Education* titled 'Development and nature of preservice chemistry teachers' pedagogical content knowledge for nature of science.' From the paper's abstract, the authors state that '[T]he purpose of this case study is to delve into the complexities of the early development of preservice chemistry teachers' science teaching orientations, knowledge of learners, knowledge of instructional strategies, and knowledge of assessment during a two-semester intervention designed to enhance their pedagogical content knowledge (PCK) for teaching nature of science (NOS)' (p. 575).

Table 5. Preservice science teacher knowledge articles included in the analysis arranged by year.

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
The use of a computer simulation to promote scientific conceptions of moon phases	Bell, RL; Trundle, KC	2008	*Journal of Research in Science Teaching*	deficit	cognitive	elementary
The development of preservice elementary teachers' curricular role identity for science teaching	Forbes, CT; Davis, EA	2008	*Science Education*	asset	sociocultural	elementary
Learning to teach science: Personal epistemologies, teaching goals, and practices of teaching	Kang, NH	2008	*Teaching and Teacher Education*	asset	sociocultural	secondary
Exploring pedagogical content knowledge in science teacher education	Loughran, J; Mulhall, P; Berry, A	2008	*International Journal of Science Education*	deficit	cognitive	secondary
Agency, Identity, and Social Justice Education: Preservice Teachers' Thoughts on Becoming Agents of Change in Urban Elementary Science Classrooms	Moore, FM	2008	*Research in Science Education*	asset	sociocultural	elementary
Teaching for understanding: The complex nature of pedagogical content knowledge in pre-service education	Nilsson, P	2008	*International Journal of Science Education*	asset	cognitive	elementary
Preservice elementary teachers' views of their students' prior knowledge of science	Otero, VK; Nathan, MJ	2008	*Journal of Research in Science Teaching*	asset	cognitive	elementary
What can be learned from writing about early field experiences?	Trumbull, DJ; Fluet, K	2008	*Teaching and Teacher Education*	deficit	cognitive	elementary
Turning crisis into opportunity: Enhancing student-teachers' understanding of nature of science and scientific inquiry through a case study of the scientific research in severe acute respiratory syndrome	Wong, SL; Hodson, D; Kwan, J; Yung, BHW	2008	*International Journal of Science Education*	deficit	cognitive	secondary
Personalising and Contextualising Multimedia Case Methods in University-based Teacher Education: An Important Modification for Promoting Technological Design in School Science	Bencze, L; Hewitt, J; Pedretti, E	2009	*Research in Science Education*	asset	sociocultural	secondary
The Nature of Relationships among the Components of Pedagogical Content Knowledge of Preservice Science Teachers: 'Ozone layer depletion' as an example	Kaya, ON	2009	*International Journal of Science Education*	deficit	cognitive	secondary
Novice Teachers' Attention to Student Thinking	Levin, DA; Hammer, D; Coffey, JE	2009	*Journal of Teacher Education*	asset	sociocultural	secondary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Confronting Assumptions, Biases, and Stereotypes in Preservice Teachers' Conceptualisations of Science Teaching through the Use of Book Club	Mensah, FM	2009	*Journal of Research in Science Teaching*	asset	sociocultural	elementary
Developing Preservice Elementary Teachers' Knowledge and Practices Through Modelling-Centered Scientific Inquiry	Schwarz, C	2009	*Science Education*	asset	sociocultural	elementary
Constructing a Doubt-Free Teaching Self: Self-Efficacy, Teacher Identity, and Science Instruction Within Diverse Settings	Settlage, J; Southerland, SA; Smith, LK; Ceglie, R	2009	*Journal of Research in Science Teaching*	deficit	cognitive	elementary
Enhancement of Pre-Service Teachers' Teaching Interventions with the Aid of Historical Examples	Spiliotopoulou-Papantoniou, V; Agelopoulos, K	2009	*Science & Education*	deficit	cognitive	secondary
Learning to Teach Elementary School Science as Argument	Zembal-Saul, C	2009	*Science Education*	asset	sociocultural	elementary
In Search of Well-Started Beginning Science Teachers: Insights from Two First-Year Elementary Teachers	Avraamidou, L; Zembal-Saul, C	2010	*Journal of Research in Science Teaching*	asset	cognitive	elementary
Teaching about Ethics through Socioscientific Issues in Physics and Chemistry: Teacher Candidates' Beliefs	Barrett, SE; Nieswandt, M	2010	*Journal of Research in Science Teaching*	deficit	cognitive	secondary
Learning to Teach About Ideas and Evidence in Science: The Student Teacher as Change Agent	Braund, M; Campbell, B	2010	*Research in Science Education*	deficit	cognitive	secondary
Prospective Teachers' Difficulties in Interpreting Elementary Phenomena of Electrostatic Interactions: Indicators of the status of their intuitive ideas	Criado, AM; Garcia-Carmona, A	2010	*International Journal of Science Education*	deficit	cognitive	elementary
Examining How Preservice Science Teachers Navigate Simulated Parent-Teacher Conversations on Evolution and Intelligent Design	Dotger, S; Dotger, BH; Tillotson, J	2010	*Science Education*	asset	sociocultural	elementary
Curriculum Design for Inquiry: Preservice Elementary Teachers' Mobilisation and Adaptation of Science Curriculum Materials	Forbes, CT; Davis, EA	2010	*Journal of Research in Science Teaching*	asset	sociocultural	elementary
Teaching together and learning together – Primary science student teachers' and their mentors' joint teaching and learning in the primary classroom	Nilsson, P; van Driel, J	2010	*Teaching and Teacher Education*	deficit	cognitive	elementary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Collaborative Reflection through Dilemma Cases of Science Practical Work during Practicum	Yoon, HG; Kim, M	2010	*International Journal of Science Education*	asset	cognitive	elementary
Impacts of Contextual and Explicit Instruction on Preservice Elementary Teachers' Understandings of the Nature of Science	Bell, RL; Matkins, JJ; Gansneder, BM	2011	*Journal of Research in Science Teaching*	deficit	cognitive	elementary
Preservice Elementary Teachers' Adaptation of Science Curriculum Materials for Inquiry-Based Elementary Science	Forbes, CT	2011	*Science Education*	asset	sociocultural	elementary
Constructing CoRes-a Strategy for Building PCK in Pre-service Science Teacher Education	Hume, A; Berry, A	2011	*Research in Science Education*	deficit	cognitive	secondary
Confidence and Perceived Competence of Preservice Teachers to Implement Biodiversity Education in Primary Schools-Four comparative case studies from Europe	Lindemann-Matthies, P; Constantinou, C; Lehnert, HJ; Nagel, U; Raperf, G; Kadji-Beltran, C	2011	*International Journal of Science Education*	deficit	cognitive	elementary
How Will We Understand What We Teach? – Primary Student Teachers' Perceptions of their Development of Knowledge and Attitudes Towards Physics	Nilsson, P; van Driel, J	2011	*Research in Science Education*	deficit	cognitive	elementary
The Progression of Prospective Primary Teachers' Conceptions of the Methodology of Teaching	Rivero, A; Azcarate, P; Porlan, R; del Pozo, RM; Harres, J	2011	*Research in Science Education*	deficit	cognitive	elementary
Inquiry-based Instruction with Archived, Online Data: An Intervention Study with Preservice Teachers	Ucar, S; Trundle, KC; Krissek, L	2011	*Research in Science Education*	deficit	cognitive	both
Learning to critique and adapt science curriculum materials: Examining the development of preservice elementary teachers' pedagogical content knowledge	Beyer, CJ; Davis, EA	2012	*Science Education*	deficit	cognitive	elementary
Balancing Teacher and Student Roles in Elementary Classrooms: Preservice elementary teachers' learning about the inquiry continuum	Biggers, M; Forbes, CT	2012	*International Journal of Science Education*	asset	cognitive	elementary
From Teaching Physics to Teaching Children: Beginning teachers learning from pupils	Findlay, M; Bryce, TGK	2012	*International Journal of Science Education*	deficit	cognitive	secondary
Using self-generated analogies in teaching of thermodynamics	Haglund, J; Jeppsson, F	2012	*Journal of Research in Science Teaching*	deficit	cognitive	secondary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Cultural Memory Banking in Preservice Science Teacher Education	Handa, VC; Tippins, DJ	2012	*Research in Science Education*	asset	sociocultural	secondary
Primary Connections: Simulating the Classroom in Initial Teacher Education	Hume, AC	2012	*Research in Science Education*	deficit	cognitive	elementary
Designing for the Future: How the Learning Sciences Can Inform the Trajectories of Preservice Teachers	Jurow, AS; Tracy, R; Hotchkiss, JS; Kirshner, B	2012	*Journal of Teacher Education*	asset	sociocultural	elementary
Assessing Elementary Science Methods Students' Understanding About Global Climate Change	Lambert, JL; Lindgren, J; Bleicher, R	2012	*International Journal of Science Education*	deficit	cognitive	elementary
Exploring Relations Among Preservice Elementary Teachers' Ideas About Evolution, Understanding of Relevant Science Concepts, and College Science Coursework	Rice, DC; Kaya, S	2012	*Research in Science Education*	deficit	cognitive	elementary
Opening the black box of field experiences: How cooperating teachers' beliefs and practices shape student teachers' beliefs and practices	Rozelle, JJ; Wilson, SM	2012	*Teaching and Teacher Education*	asset	sociocultural	secondary
Prospective Elementary Teachers' Science Teaching Orientations and Experiences that Impacted their Development	Avraamidou, L	2013	*International Journal of Science Education*	asset	sociocultural	elementary
Providing a Set of Research-Based Practices to Support Preservice Teachers' Long-Term Professional Development as Learners of Science Teaching	Aydin, S; Demirdogen, B; Tarkin, A; Kutucu, S; Ekiz, B; Akin, FN; Tuysuz, M; Uzuntiryaki, E	2013	*Science Education*	deficit	cognitive	secondary
A Self-Study of a Thai Teacher Educator Developing a Better Understanding of PCK for Teaching about Teaching Science	Faikhamta, C; Clarke, A	2013	*Research in Science Education*	deficit	cognitive	both
Potential Teachers' Appropriate and Inappropriate Application of Pedagogical Resources in a Model-Based Physics Course: A 'Knowledge in Pieces' Perspective on Teacher Learning	Harlow, DB; Bianchini, JA; Swanson, LH; Dwyer, HA	2013	*Journal of Research in Science Teaching*	asset	sociocultural	secondary
Realising the Potential of an Authentic Context to Understand the Characteristics of NOS and NOT: You, me and UV	Heap, R; France, B	2013	*International Journal of Science Education*	deficit	cognitive	elementary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Teachers' Nature of Science Implementation Practices 25 Years After Having Completed an Intensive Science Education Programme	Herman, BC; Clough, MP; Olson, JK	2013	*Science Education*	deficit	cognitive	secondary
Teachers' Concepts of Spatial Scale: An international comparison	Jones, MG; Paechter, M; Yen, CF; Gardner, G; Taylor, A; Tretter, T	2013	*International Journal of Science Education*	deficit	cognitive	secondary
Science Teaching Efficacy of Preservice Elementary Teachers: Examination of the Multiple Factors Reported as Influential	Kirik, OT	2013	*Research in Science Education*	deficit	cognitive	elementary
Learning to Assess Science in Linguistically Diverse Classrooms: Tracking Growth in Secondary Science Preservice Teachers' Assessment Expertise	Lyon, EG	2013	*Science Education*	deficit	cognitive	secondary
Teachers' Pedagogical Content Knowledge of Scientific Argumentation: The Impact of Professional Development on K-12 Teachers	McNeill, KL; Knight, AM	2013	*Science Education*	deficit	cognitive	secondary
Preservice teachers' capacity to teach self-regulated learning: Integrating learning from problems and learning from successes	Michalsky, T; Schechter, C	2013	*Teaching and Teacher Education*	deficit	cognitive	secondary
Exploring the Development of Preservice Science Teachers' Views on the Nature of Science in Inquiry-Based Laboratory Instruction	Ozgelen, S; Yilmaz-Tuzun, O; Hanuscin, DL	2013	*Research in Science Education*	deficit	cognitive	elementary
Exploring How Engaging with Reflection on Learning Generates Pedagogical Insight in Science Teacher Education	Parker, J; Heywood, D	2013	*Science Education*	asset	cognitive	elementary
Primary School Student Teachers' Understanding of Climate Change: Comparing the Results Given by Concept Maps and Communication Analysis	Ratinen, I; Viiri, J; Lehesvuori, S	2013	*Research in Science Education*	deficit	cognitive	elementary
Exploring the Progression in Preservice Chemistry Teachers' Pedagogical Content Knowledge Representations: The Case of 'Behavior of Gases'	Adadan, E; Oner, D	2014	*Research in Science Education*	deficit	cognitive	secondary
All We Did was Things Like Forces and Motion . . . ': Multiple Discourses in the development of primary science teachers	Danielsson, A; Warwick, P	2014	*International Journal of Science Education*	asset	sociocultural	elementary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
'You Have to Give Them Some Science Facts': Primary Student Teachers' Early Negotiations of Teacher Identities in the Intersections of Discourses About Science Teaching and About Primary Teaching	Danielsson, AT; Warwick, P	2014	*Research in Science Education*	asset	sociocultural	elementary
Effectiveness of a Curricular and Professional Development Intervention at Improving Elementary Teachers' Science Content Knowledge and Student Achievement Outcomes: Year 1 Results	Diamond, BS; Maerten-Rivera, J; Rohrer, RE; Lee, O	2014	*Journal of Research in Science Teaching*	deficit	cognitive	elementary
Confronting Conceptual Challenges in Thermodynamics by Use of Self-Generated Analogies	Haglund, J; Jeppsson, F	2014	*Science & Education*	deficit	cognitive	secondary
The Practical Turn in Teacher Education Designing a Preparation Sequence for Core Practice Frames	Janssen, F; Westbroek, H; Doyle, W	2014	*Journal of Teacher Education*	deficit	cognitive	secondary
Juggling Our Mindsets: Learning from Success as a Complementary Instructional Framework in Teacher Education	Schechter, C; Michalsky, T	2014	*Teachers College Record*	deficit	cognitive	secondary
The distinction between inquiry-based instruction and non-inquiry-based instruction in higher education: A case study of what happens as inquiry in 16 education courses in three universities	Aulls, MW; Magon, JK; Shore, BM	2015	*Teaching and Teacher Education*	deficit	cognitive	both
The nature and development of interaction among components of pedagogical content knowledge in practicum	Aydin, S; Demirdogen, B; Akin, FN; Uzuntiryaki-Kondakci, E; Tarkin, A	2015	*Teaching and Teacher Education*	deficit	cognitive	secondary
Studying teacher noticing: Examining the relationship among pre-service science teachers' ability to attend, analyse and respond to student thinking	Barnhart, T; van Es, E	2015	*Teaching and Teacher Education*	deficit	cognitive	secondary
Exploring the Impact of TeachME (TM) Lab Virtual Classroom Teaching Simulation on Early Childhood Education Majors' Self-Efficacy Beliefs	Bautista, NU; Boone, WJ	2015	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Student Teachers' Approaches to Teaching Biological Evolution	Borgerding, LA; Klein, VA; Ghosh, R; Eibel, A	2015	*Journal of Science Teacher Education*	asset	sociocultural	secondary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Learning to Teach Elementary Science Through Iterative Cycles of Enactment in Culturally and Linguistically Diverse Contexts	Bottoms, SI; Ciechanowski, KM; Hartman, B	2015	*Journal of Science Teacher Education*	asset	sociocultural	elementary
Developing Preservice Teachers' Knowledge of Science Teaching Through Video Clubs	Johnson, HJ; Cotterman, ME	2015	*Journal of Science Teacher Education*	asset	sociocultural	secondary
Preservice Teacher Agency Concerning Education for Sustainability (EfS): A Discursive Psychological Approach	Martin, J; Carter, L	2015	*Journal of Research in Science Teaching*	asset	sociocultural	elementary
Prompting Reflections for Integrating Self-Regulation into Teacher Technology Education	Michalsky, T; Kramarski, B	2015	*Teachers College Record*	deficit	cognitive	secondary
Promoting Prospective Elementary Teachers' Learning to Use Formative Assessment for Life Science Instruction	Sabel, JL; Forbes, CT; Zangori, L	2015	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Discovering Plate Boundaries in Data-integrated Environments: Preservice Teachers' Conceptualisation and Implementation of Scientific Practices	Sezen-Barrie, A; Moore, J; Roig, CE	2015	*International Journal of Science Education*	asset	sociocultural	secondary
Problems Without Ceilings: How Mentors and Novices Frame and Work on Problems-of-Practice	Thompson, J; Hagenah, S; Lohwasser, K; Laxton, K	2015	*Journal of Teacher Education*	asset	sociocultural	secondary
Influence of an Intensive, Field-Based Life Science Course on Preservice Teachers' Self-Efficacy for Environmental Science Teaching	Trauth-Nare, A	2015	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Outcomes of nature of science instruction along a context continuum: preservice secondary science teachers' conceptions and instructional intentions	Bell, RL; Mulvey, BK; Maeng, JL	2016	*International Journal of Science Education*	deficit	cognitive	secondary
Using tools to promote novice teacher noticing of science teaching practices in post-rehearsal discussions	Benedict-Chambers, A	2016	*Teaching and Teacher Education*	asset	sociocultural	elementary
Preservice Elementary Teachers' Instructional Practices and the Teaching Science as Argument Framework	Boyer, E.	2016	*Science & Education*	asset	sociocultural	elementary
Interaction Between Science Teaching Orientation and Pedagogical Content Knowledge Components	Demirdogen, B	2016	*Journal of Science Teacher Education*	deficit	cognitive	secondary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Development and Nature of Preservice Chemistry Teachers' Pedagogical Content Knowledge for Nature of Science	Demirdöğen, B; Hanuscin, DL.; Uzuntiryaki-Kondakci, E; Köseoğlu, F	2016	*Research in Science Education*	deficit	cognitive	secondary
The Principle-Practical Discourse Edge: Elementary Preservice and Mentor Teachers Working Together on Colearning Tasks	Gunckel, KL; Wood, MB	2016	*Science Education*	asset	sociocultural	elementary
Tools for Reflection: Video-Based Reflection Within a Preservice Community of Practice	Hawkins, S; Park Rogers, M	2016	*Journal of Science Teacher Education*	asset	sociocultural	elementary
The Use of Lesson Study Combined with Content Representation in the Planning of Physics Lessons During Field Practice to Develop Pedagogical Content Knowledge	Juhler, MV	2016	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Preservice Science Teachers' Science Teaching Orientations and Beliefs About Science	Kind, V	2016	*Science Education*	deficit	cognitive	secondary
Reasoning About Race and Pedagogy in Two Preservice Science Teachers: A Critical Race Theory Analysis	Larkin, DB; Maloney, T; Perry-Ryder, GM	2016	*Cognition and Instruction*	asset	sociocultural	secondary
Preservice Elementary Teachers' Science Self-Efficacy Beliefs and Science Content Knowledge	Menon, D; Sadler, TD	2016	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Changing Preservice Science Teachers' Views of Nature of Science: Why Some Conceptions May be More Easily Altered than Others	Mesci, G; Schwartz, RS	2016	*Research in Science Education*	deficit	cognitive	both
Preservice Teachers' Professional Knowledge and Its Relation to Academic Self-Concept	Paulick, I; Großschedl, J; Harms, U; Möller, J	2016	*Journal of Teacher Education*	deficit	cognitive	secondary
Supporting Reform-Oriented Secondary Science Teaching Through the Use of a Framework to Analyse Construction of Scientific Explanations	Richmond, G.; Parker, JM; Kaldaras, L	2016	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Elementary teachers' use of content knowledge to evaluate students' thinking in the life sciences	Sabel, JL; Forbes, CT; Flynn, L	2016	*International Journal of Science Education*	deficit	cognitive	elementary
They might know a lot of things that I don't know': investigating differences in preservice teachers' ideas about contextualising science instruction in multilingual classrooms	Tolbert, S; Knox, C	2016	*International Journal of Science Education*	asset	sociocultural	elementary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Supporting children to construct evidence-based claims in science: Individual learning trajectories in a practice-based programme	Arias, AM; Davis, EA	2017	*Teaching and Teacher Education*	asset	sociocultural	elementary
Developing Preservice Secondary Science Teachers' Pedagogical Content Knowledge Through Subject Area Methods Courses: A Content Analysis	Bailie, AL	2017	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Influences on the Development of Inquiry-Based Practices Among Preservice Teachers	Cian, H; Dsouza, N; Lysons, R; Cook, M	2017	*Journal of Science Teacher Education*	asset	sociocultural	secondary
A longitudinal investigation of the science teaching efficacy beliefs and science experiences of a cohort of preservice elementary teachers	Deehan, J; Danaia, L; McKinnon, DH	2017	*International Journal of Science Education*	deficit	cognitive	elementary
Developing Elementary Preservice Teacher Subject Matter Knowledge Through the Use of Educative Science Curriculum Materials	Donna, JD; Hick, SR	2017	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Wonder as a tool to engage preservice elementary teachers in science learning and teaching	Gilbert, A; Byers, CC	2017	*Science Education*	asset	sociocultural	elementary
Linking practice to theory in teacher education: A growth in cognitive structures	Hennissen, P; Beckers, H; Moerkerke, G	2017	*Teaching and Teacher Education*	deficit	cognitive	elementary
The Use of Culturally Responsive Teaching Strategies Among Latina/o Student Teaching Interns During Science and Mathematics Instruction of CLD Students	Hernandez, C; Shroyer, MG	2017	*Journal of Science Teacher Education*	asset	sociocultural	secondary
Assessment of Understanding: Student Teachers' Preparation, Implementation and Reflection of a Lesson Plan for Science	Juhler, MV	2017	*Research in Science Education*	deficit	cognitive	secondary
Preservice Teachers' Learning to Plan Intellectually Challenging Tasks	Kang, H	2017	*Journal of Teacher Education*	asset	sociocultural	secondary
Student Teachers' Perspectives on Chemistry Education in South Africa and Finland	Keinonen, T; de Jager, T	2017	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Exhibitions and Beyond: The Influence of an Optional Course on Student Teachers' Perceptions and Future Usage of Natural History Museums	Kreuzer, P; Dreesmann, D	2017	*Journal of Science Teacher Education*	deficit	cognitive	secondary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Planning for the Elicitation of Students' Ideas: A Lesson Study Approach With Preservice Science Teachers	Larkin, D	2017	*Journal of Science Teacher Education*	asset	sociocultural	secondary
Capturing the Transformation and Dynamic Nature of an Elementary Teacher Candidate's Identity Development as a Teacher of Science	Naidoo, K	2017	*Research in Science Education*	asset	sociocultural	elementary
Preservice Science Teachers' Epistemological Beliefs and Informal Reasoning Regarding Socioscientific Issues	Ozturk, N; Yilmaz-Tuzun, O	2017	*Research in Science Education*	deficit	cognitive	elementary
What Are the Effects of Science Lesson Planning in Peers?-Analysis of Attitudes and Knowledge Based on an Actor-Partner Interdependence Model	Smit, R; Rietz, F; Kreis, A	2017	*Research in Science Education*	deficit	cognitive	secondary
Improving preservice chemistry teachers' content knowledge through intervention activities	Wheeldon, R	2017	*International Journal of Science Education*	deficit	cognitive	secondary
Using the Practice of Modelling to Support Preservice Teachers' Reflection on the Process of Teaching and Learning	Zangori, L; Friedrichsen, PJ; Wulff, E; Womack, AJ	2017	*Journal of Science Teacher Education*	deficit	cognitive	both
Dialogic processes that enable student teachers' learning about pupil learning in mentoring conversations in a Lesson Study field practice	Bjuland, R; Helgevold, N	2018	*Teaching and Teacher Education*	asset	sociocultural	elementary
Preservice science teachers' concerns and approaches for teaching socioscientific and controversial issues	Borgerding, LA; Dagistan, M	2018	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Student teachers' prior knowledge as prerequisite to learn how to assess pupils' learning strategies	Glogger-Frey, I; Deutscher, M; Renkl, A	2018	*Teaching and Teacher Education*	deficit	cognitive	secondary
Eliciting, Identifying, Interpreting, and Responding to Students' Ideas: Teacher Candidates' Growth in Formative Assessment Practices	Gotwals, AW; Birmimngham, D	2018	*Research in Science Education*	asset	sociocultural	secondary
Improving the preparation of novice secondary science teachers for English learners: A proof of concept study	Lyon, EG; Stoddart, T; Bunch, GC; Tolbert, S; Salinas, I; Solis, J	2018	*Science Education*	asset	sociocultural	secondary
Preservice and Inservice Teachers' Ideas of Multiculturalism: Explorations Across Two Science Methods Courses in Two Different Contexts	Mensah, FM; Brown, JC; Titu, P; Rozowa, P; Sivaraj, R; Heydari, R	2018	*Journal of Science Teacher Education*	deficit	cognitive	elementary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Whiteness as Property in Science Teacher Education	Mensah, FM; Jackson, I	2018	*Teachers College Record*	asset	sociocultural	elementary
Preservice Science Teachers' Practices of Critiquing and Revising 5E Lesson Plans	Namdar, B; Kucuk, M	2018	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Preservice teachers' self-efficacy to teach primary science based on 'science learner' typology	Norris, CM; Morris, JE; Lummis, GW	2018	*International Journal of Science Education*	deficit	cognitive	elementary
It's 1000 Degrees in Here When I Teach: Providing Preservice Teachers with an Extended Opportunity to Approximate Ambitious Instruction	Stroupe, D; Gotwals, AW	2018	*Journal of Teacher Education*	asset	sociocultural	secondary
Student Teachers' Images of Science Instruction in Informal Settings: A Focus on Field Trip Pedagogy	Subramaniam, K; Asim, S; Lee, EY; Koo, Y	2018	*Journal of Science Teacher Education*	asset	sociocultural	Elementary
Persistence of the two-worlds pitfall: Learning to teach within and across settings	Braaten, M	2019	*Science Education*	asset	sociocultural	secondary
Explanations in STEM Areas: An Analysis of Representations Through Language in Teacher Education	Cabello, VM; Real, C; Impedovo, MA	2019	*Research in Science Education*	asset	sociocultural	secondary
A Long-Term Investigation of the Science Teaching Efficacy Beliefs of Multiple Cohorts of Preservice Elementary Teachers	Deehan, J; McKinnon, DH; Danaia, L	2019	*Journal of Science Teacher Education*	deficit	cognitive	elementary
A Qualitative Case Study of Field-Based Teacher Education: One Candidate's Evolving Expertise of Science Teaching for Emergent Bilinguals	Heineke, AJ; Smetana, L; Sanei, JC	2019	*Journal of Science Teacher Education*	asset	sociocultural	secondary
Preservice Science Teachers' Opportunities for Learning Through Reflection When Planning a Microteaching Unit	Kadstrom, M; Hamza, K	2019	*Journal of Science Teacher Education*	asset	sociocultural	secondary
Assessing Science Teaching Explanations in Initial Teacher Education: How Is This Teaching Practice Transferred Across Different Chemistry Topics?	Marzabal, A; Merino, C; Moreira, P; Delgado, V	2019	*Research in Science Education*	deficit	cognitive	secondary
Capturing student teachers' pedagogical content knowledge (PCK) using CoRes and digital technology	Nilsson, P; Karlsson, G	2019	*International Journal of Science Education*	deficit	cognitive	secondary
Elementary teachers' science subject matter knowledge across the teacher career cycle	Nixon, RS; Smith, LK; Sudweeks, RR	2019	*Journal of Research in Science Teaching*	deficit	cognitive	elementary

(*Continued*)

Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
A Role-Play-Based Tutor Training in Preservice Teacher Education for Developing Procedural Pedagogical Content Knowledge by Optimising Tutor-Student Interactions in the Context of an Outreach Lab	Scharfenberg, FJ; Bogner, FX	2019	*Journal of Science Teacher Education*	deficit	cognitive	secondary
The Promises and Realities of Implementing a Coteaching Model of Student Teaching	Soslau, E; Gallo-Fox, J; Scantlebury, K	2019	*Journal of Teacher Education*	asset	sociocultural	both
Framing, Adapting, and Applying: Learning to Contextualise Science Activity in Multilingual Science Classrooms	Tolbert, S; Knox, C; Salinas, I	2019	*Research in Science Education*	asset	sociocultural	secondary
The development of student-teachers' professional identity while team-teaching science classes using a project-based learning approach: A multi-level analysis	Tsybulsky, D; Muchnik-Rozanov, Y	2019	*Teaching and Teacher Education*	asset	sociocultural	elementary
Exploring the Design of Scaffolding Pedagogical Instruction for Elementary Preservice Teacher Education	Wang, JL; Sneed, S	2019	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Analysing the role of metacognitive awareness in preservice chemistry teachers' understanding of gas behaviour in a multirepresentational instruction setting	Adadan, E	2020	*Journal of Research in Science Teaching*	deficit	cognitive	secondary
Preservice Secondary Science Teachers' Implementation of an NGSS Practice: Using Mathematics and Computational Thinking	Aminger, W; Hough, S; Roberts, SA; Meier, V; Spina, AD; Pajela, H; McLean, M; Bianchini, JA	2020	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Negotiating Dissonant Identities as a Teacher of Science During Student Teaching	Canipe, MM	2020	*Journal of Science Teacher Education*	asset	sociocultural	elementary
Exploring Australian Preservice Primary Teachers' Attitudes Towards Teaching Science Using the Dimensions of Attitude towards Science (DAS)	McDonald, CV; Klieve, H; Kanasa, H	2020	*Research in Science Education*	deficit	cognitive	elementary
Preservice secondary science teachers' understanding of academic language: Moving beyond just the vocabulary	Meier, V; Aminger, W; McLean, M; Carpenter, SL; Moon, S; Hough, S; Bianchini, JA	2020	*Science Education*	deficit	cognitive	secondary

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Table 5. (Continued).

Title	Authors	Year	Journal	Deficit or Asset Framing	Theoretical Perspective	Grade Level
Influence of the Sources of Science Teaching Self-Efficacy in Preservice Elementary Teachers' Identity Development	Menon, D	2020	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Enabling Factors of Preservice Science Teachers' Pedagogical Content Knowledge for Nature of Science and Nature of Scientific Inquiry	Mesci, G; Schwartz, RS; Pleasants, BAS	2020	*Science & Education*	deficit	cognitive	secondary
Simulations as practice-based spaces to support elementary teachers in learning how to facilitate argumentation-focused science discussions	Mikeska, JN; Howell, H	2020	*Journal of Research in Science Teaching*	asset	sociocultural	elementary
Exploring Preservice Teachers' Beliefs about Effective Science Teaching through Their Collaborative Oral Reflections	Min, M; Akerson, V; Aydeniz, F	2020	*Journal of Science Teacher Education*	deficit	cognitive	elementary
Developing Secondary Pre-Service Science Teachers' Instructional Planning Abilities for Language- and Literacy-Integrated Science Instruction in Linguistically Diverse Classrooms	Rutt, AA; Mumba, FM	2020	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Professional Knowledge for Teaching in Student Teachers' Conversations about Field Experiences	Sjoberg, M; Nyberg, E	2020	*Journal of Science Teacher Education*	deficit	cognitive	secondary
Learning to Plan During the Clinical Experience: How Visions of Teaching Influence Novices' Opportunities to Practice	Windschitl, M; Lohwasser, K; Tasker, T	2020	*Journal of Teacher Education*	asset	sociocultural	secondary

This paper has six features that align with cognitive and deficit perspectives of PST knowledge:

Feature 1: All units of analysis exist inside a PST's head (knowledge).

Feature 2: Data collection and analysis focused on comparing the PSTs' knowledge and answers to predetermined outcomes established by the researchers.

Feature 3: The authors claim there is a 'prerequisite amount' of knowledge that PSTs must acquire prior to becoming successful.

Feature 4: The authors link PSTs' acquisition of the 'correct' knowledge established by the researchers to better teaching and learning outcomes.

Feature 5: The authors make claims about PST learning in terms of whether they met predetermined criteria about knowledge set by researchers.

Feature 6: The researchers call for new or modified opportunities for PSTs to acquire more knowledge in order to meet the predetermined standard.

Cognitive asset example

An example of a cognitive asset paper is Avraamidou and Zembal-Saul (2010) from the *Journal of Research in Science Teaching* titled '[I]n search of well-started beginning science teachers: Insights from two first-year elementary teachers.' From the paper's abstract, the authors state that 'The purpose of this qualitative case study was to explore what aspects of two first-year elementary teachers' practices were most consistent with an inquiry-based approach, what PCK served as a mechanism for facilitating these practices, and what experiences have mediated the nature and development of these teachers' PCK' (p. 661). This paper has six features that align with cognitive and asset perspectives of PST knowledge:

Feature 1: The authors attempt to ascertain PST knowledge by asking participants which components of instruction led to their improved understandings, rather than as compared to a standard set by the researchers.

Feature 2: The authors explicitly do not attempt to disentangle PST beliefs and knowledge.

Feature 3: The authors' goals are not to assist PSTs in constructing all the knowledge they will need, but are attempting to provide knowledge to PSTs to become well-started beginners.

Feature 5: The results of the study are framed in terms of what the PSTs accomplished or knew, rather than what they unable to accomplish or know.

Feature 6: The implications of the study include the need for the design of university-based courses and interventions by which teacher preparation and professional development programmes support teachers in developing PCK for scientific inquiry and enacting instructional practices that are congruent with reform initiatives.

Sociocultural asset example

An example of a sociocultural asset paper is Arias and Davis (2017) from the journal *Teaching and Teacher Education* titled 'Supporting children to construct evidence-based claims in science: Individual learning trajectories in a practice-based program.' From the paper's abstract, the authors state that '[t]his study examines four PSTs' learning pathways for one science teaching practice, *supporting students to construct evidence-based claims* [italics in original], during a two-year practice-based teacher education programme. Analyses uncovered variation and similarities across and within the teachers' pathways' (p. 204). This paper has six features that align with sociocultural and asset perspectives of PST knowledge:

Feature 1: The authors constructed a model of teacher practice aimed at supporting elementary children to construct evidence-based claims in science.

Feature 2: The authors asked questions about *how* PSTs' 'knowledge and practice' changed over time in terms contextual mechanisms and opportunities.

Feature 3: The authors describe variation and similarities across and within the teachers' learning pathways.

Feature 4: The authors note how participants' experiences and histories impacted their learning.

Feature 5: The authors' methodology linked data collection to theory in terms of observing how knowledge was embedded in practices over time.

Feature 6: The implications of the study focus on how teacher educators must provide better opportunities for PSTs to learn through participation in practices.

Once we identified and described each of the example papers, they became reference points to use when we did not initially agree on the classification of other articles.

Phase 3: Synthesising across categories

After identifying the empirical articles for analysis and completing the coding, we began looking for patterns related to our research question by calculating descriptive statistics. Specifically, we looked at the percentage of published studies over the ten-year period in each of the main categories: cognitive deficit, cognitive asset, and sociocultural asset. We also examined these data longitudinally to identify patterns over time. Finally, we recorded the number of studies focused on elementary, secondary, or both levels and the percentage of studies at each level in each of the four main categories.

Limitations

Any process to examine a large body of literature has limitations, and we identify three for this paper. First, our search and selection process for empirical, peer-reviewed articles necessarily did not include studies from conference proceedings, books, and theses/dissertations. Second, by limiting our search to a single database (Web of Science) and only the high impact journals found in Table 1, we potentially excluded articles that may have been relevant to the analysis. Third, our exclusion of non-English published articles might have excluded relevant articles. We contend, however, that the selection of studies generated is sufficient as our goal was not to provide an exhaustive literature review but rather to uncover patterns of deficit and asset framing in studies of science PSTs given two families of learning theories across the literature over the past twelve years (2008–2020).

Results

In this section, we discuss four themes that arose from our analysis of the 146 empirical articles on science PSTs' knowledge and learning between 2008 and 2020. Note that these themes are not a meta-analysis of the findings from the empirical articles; rather, we examined how learning theories (cognitive and sociocultural) align with perspectives of PST knowledge (deficit and asset).

Pattern between knowledge perspectives and theoretical perspectives

We began by examining the data for general patterns between the knowledge perspectives (deficit and asset) and theoretical perspectives (cognitive and sociocultural). When examining our coding categories for each article (see Table 5) we found that the majority of studies coded as cognitive were also coded as having a deficit knowledge perspective (87 of 93 studies) with a small number of cognitive studies (6 of 93) coded as asset-framed (see Table 7). For studies coded as sociocultural, all studies (53) were coded as having an asset knowledge perspective with none coded as deficit-framed. Therefore, we found a pattern of alignment between cognitive studies framed from a deficit perspective and sociocultural studies framed from an asset perspective (see Table 6 for a breakdown of articles coded by journal source).

Table 6. Article selection by journal.

	Cognitive deficit	Cognitive asset	Sociocultural deficit	Sociocultural asset	Total
Journal of Science Teacher Education	23	0	0	11	34
Research in Science Education	19	0	0	8	27
International Journal of Science Education	15	3	0	4	22
Science Education	7	1	0	9	17
Teaching and Teacher Education	7	0	0	6	13
Journal of Research in Science Teaching	8	1	0	5	14
Journal of Teacher Education	2	0	0	7	9
Science & Education	3	0	0	1	4
Teachers College Record	2	0	0	1	3
Cognition and Instruction	0	0	0	1	1
Cultural Studies of Science Education	0	0	0	0	0
Journal of the Learning Sciences	0	0	0	0	0

Table 7. Comparison of learning theories and knowledge perspectives.

	Cognitive	Sociocultural
Deficit	87	0
Asset	6	53

Perspective use in literature about science teacher preparation

Next, we looked across the studies to determine which perspectives were most frequently used over the twelve-year period (2008–2020) of the study. Overall, we found the cognitive deficit perspective was most frequently used in studies of science PST knowledge and learning. As shown in Table 8 and Figure 2, cognitive studies accounted for 64% and cognitive deficit studies 60% of the overall studies of PST knowledge and learning over the study period. For a more fine-grained analysis, we examined the data over time (Figure 3). Here we observed the frequent use of cognitive deficit coded studies continuing into the last year of literature we examined (2020). Overall, there has been a trend of gradual increase in sociocultural asset coded studies over the study period resulting in a majority of studies in the last full year of the study (2019). Studies from 2020 represent an incomplete record as the literature search was completed in October of that year.

Relative differences between studies of elementary and secondary levels

Finally, we examined the data for possible trends in studies across elementary and secondary teacher preparation contexts. As shown in Figure 4, we found that the majority

Table 8. Number of studies from each coding category.

Perspective	#	% Total
Sociocultural asset	53	36%
Sociocultural deficit	0	0%
Cognitive asset	6	4%
Cognitive deficit	87	60%

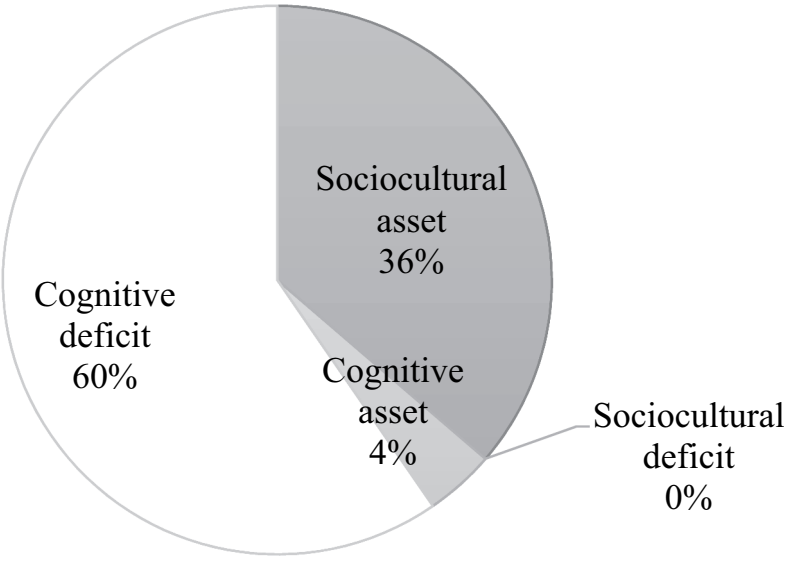

Figure 2. Percentages of coding categories between 2008–2020.

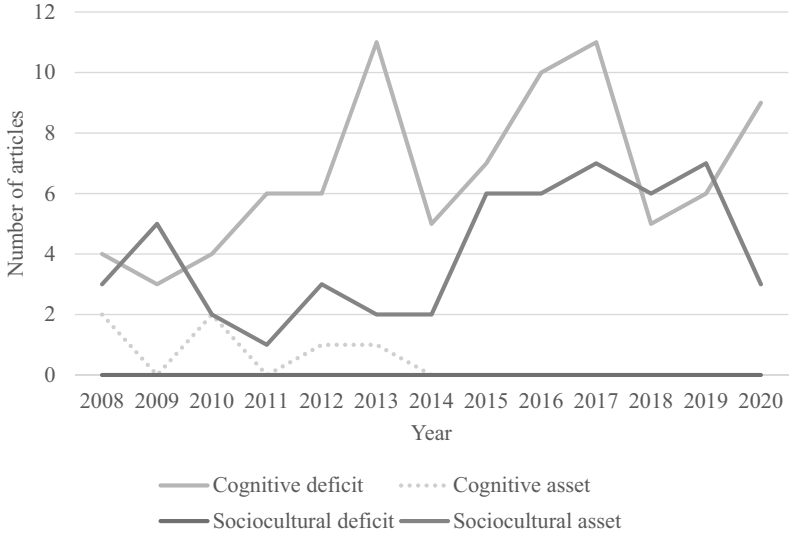

Figure 3. Number of articles in coding categories across time.

of studies of secondary PSTs were coded as cognitive deficit (66%). Studies of elementary PSTs, however, drew upon different perspectives more evenly than studies of secondary PSTs. Interestingly, all studies coded as cognitive asset (six in total across the studies) focused on elementary PSTs.

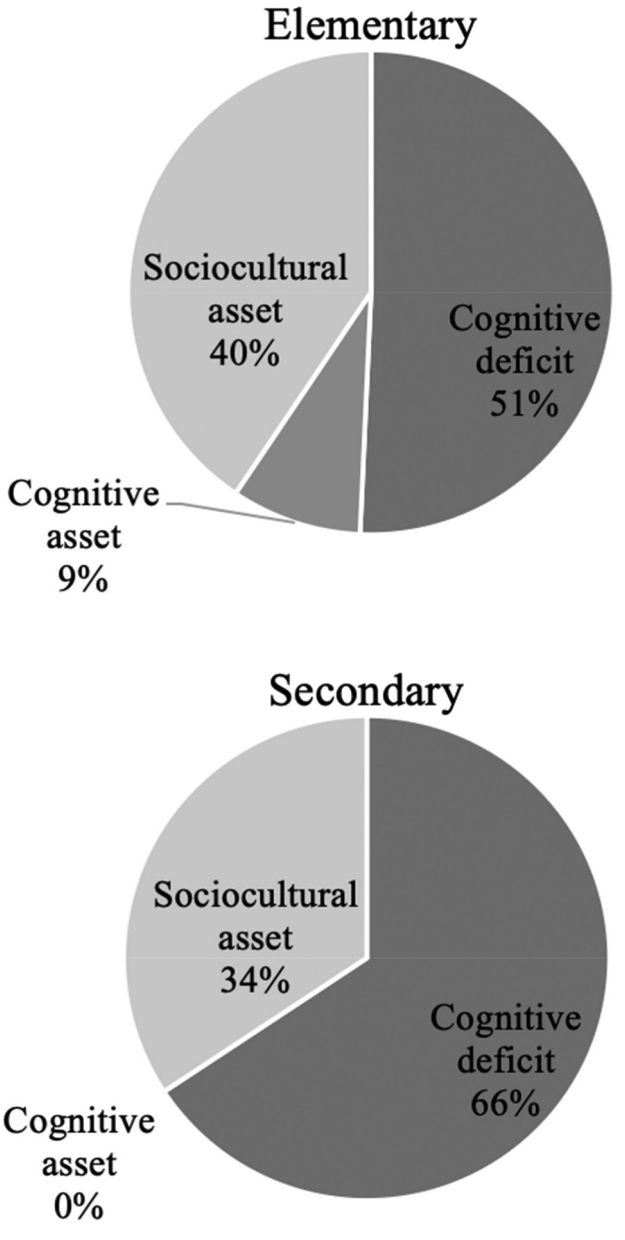

Figure 4. Breakdown of framing codes by grade level.

Emergence of a critical studies category

While we bounded the focus of our analysis to studies from cognitive and sociocultural perspectives, we also noticed the emergence of critical perspectives on science PSTs' knowledge and learning. In general terms, critical theories unpack assumptions about the nature of knowledge and power, challenge existing forms of knowledge, and introduce new epistemologies (McLaren, 2003). In our analysis, we found two studies that were framed from a critical perspective and met all other criteria for inclusion. In the first,

Bottoms et al. (2017) examined 'how elementary teacher candidates experience Family Math and Science Nights with culturally and linguistically diverse children and families' (p. 1) from a culturally responsive teaching framework. In the second example, Milne (2009) utilised Foucault and feminist theories of power and knowledge to examine 'themes of surveillance, discipline structure, and criticality' (p. 758) in PSTs' self-assessments. We highlight these studies to both lament the lack of critical studies of PST knowledge and learning in the field, and to note that such crucial research will benefit the field as more scholars take up such a perspective.

Discussion

We attempt to characterise the larger pattern we found across the different empirical articles about PST learning between theoretical and knowledge perspectives in Figure 5. In each case, the model captures the relationship between the phenomenon of learning – the PST activities researchers investigated (e.g., teaching, lesson planning, university class-based tasks) – and the changes that were labelled as indicators of learning by researchers. In the work framed from sociocultural perspectives, the indicators of learning tended to focus on collecting direct evidence of the activities or practices, such as observations of teaching, artefacts from learning environment, or video or audio recordings of university classrooms. Studies framed from cognitive perspectives tended to uses measures of PST attributes identified as mediators or indicators of the ability to engage in activities or practices. Cognitive studies most commonly utilised the construct of PCK specifically, or knowledge and beliefs in a more general sense. Some studies measured knowledge

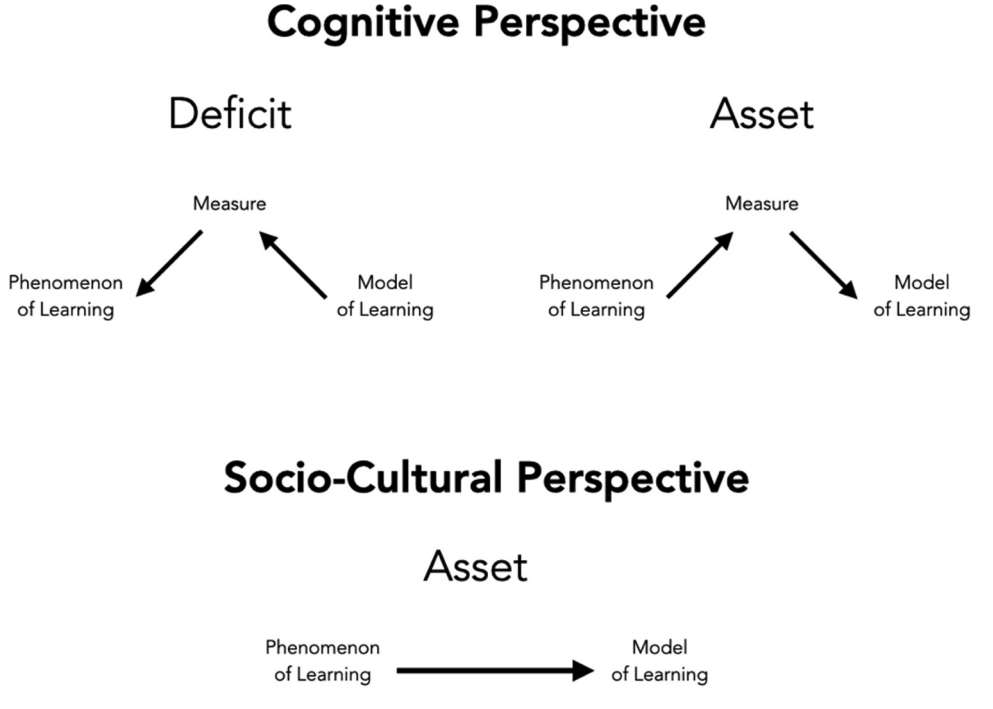

Figure 5. Deficit and asset models in different theoretical perspectives.

constructs using an instrument that PSTs often completed at multiple timepoints. In other studies, researchers collected more observational data (e.g., video of teaching, samples of work) that was analysed as a source of inferential representation of knowledge and beliefs. Therefore, cognitive studies included a measure of some variable(s) that describes an individual attribute that was seen as a mediating PSTs' ability to carry out the instructional decisions and/or actions under investigation.

The models in Figure 5 use arrows to indicate a relationship implied by researchers when taking either an asset or deficit perspective on PSTs as learners. The directionality of the arrow expresses the researchers' perspectives on which of the two main components (the model or the phenomena) is primary, and thus assumed to be the benchmark. If data indicates a PST has a certain level of proficiency with a practice described by the researchers as not reaching the researchers' standard, this constitutes a deficit perspective. If the difference between performance and standard is interpreted as appropriate given the trajectory of the PSTs (e.g., well-started beginners) or as a deficiency in the learning support provided to PSTs, this constitutes an asset perspective. There is complexity here, as in studies that take an asset-based frame on learning the standard is not always explicitly stated, at least in part because of an assumption that the standard is not known a priori. However, when the phenomenon of PST learning is given priority, this was reflected in asset language being used to describe PSTs – for example, that they brought productive ideas about science teaching and learning with them or they developed productive teaching practices as part of their learning. When the researchers' model was treated as the benchmark, this was reflected in language that positioned the PSTs as having or missing something, or in terms of a potential deficit in knowledge or practice. Thus, while for both cognitive and sociocultural perspectives there was potential for both a deficit and asset version of how researchers portrayed their analysis and results, in practice there were no examples of socio-cultural studies that took a deficit perspective, so no model was included for this in Figure 5.

Conclusion

The study of science teachers' knowledge and learning, in particular the learning of PSTs in teacher education programmes, is a central focus of research in our field. We hope this literature review can help open the scholarly conversation about the kinds of knowledge we value with regard to PSTs, and also how best to investigate their learning. We conclude with four lingering questions and suggestions for future research.

First, we noticed the few cognitive asset studies all focused on elementary science PSTs. Why is such a perspective limited to elementary PSTs? Could elementary researchers frame studies around helping PSTs learn to teach children, while secondary researchers care more about whether PSTs know 'correct' science? We wonder if conversations across arbitrary boundaries of research might help teacher educators design better learning opportunities for all PSTs.

Second, we initially expected to notice an historical decline in cognitive papers given the 'practice turn' in education research that occurred at the dawn of the millennium (1999/2000). However, in literature about science PST learning and knowledge, cognitive deficit papers have dominated the literature over the last twelve years. Thus, we ask: Why are cognitive deficit studies still a primary means to frame research about PSTs'

knowledge and learning? Is there a potential publishing bias that prioritises certain types of studies, such as those framed from a cognitive deficit perspective? Rather than perpetuate a pervasive deficit framing of people in which 'misconceptions' are treated as barriers to learning, we suggest that colleagues take an asset-based approach to framing PST knowledge, such as our example paper from Avraamidou and Zembal-Saul (2010), in which PSTs' ideas and experiences are treated as resources rather than incorrect notions in need of repair or replacement.

Third, we wonder what, if anything, research about PST knowledge domains can still provide our field that might help advance science teacher preparation. While the recognition and advocation of teacher knowledge was crucial to responding to calls for deprofessionalization in the 1980s, we worry that positioning learning to teach as successfully completing 'correct answers' on assessments creates a culture in which PSTs are perpetually positioned as deficit and outside the norm given how powerful researchers choose to frame them.

We also wonder who the atomisation of professional knowledge into more and more pieces (see Figure 1) serves, preservice teachers or researchers? For example, the research agendas around characterising PCK do not seem to have clarified or unified our collective understanding of how to better prepare teachers for the complex work of teaching, which we know to be grounded in histories and cultures of schools, as well as relational work between teachers and students. In fact, the continuing attempts to further 'clarify' the PCK construct through detailed description of new sub-constructs or super-constructs (such as Technological Pedagogical Content Knowledge; Mishra & Koehler, 2006) seem largely to be speaking to the esoteric agendas of those scholars, resulting in an increasingly labyrinthian echo chamber. Given emerging and overlapping crises of climate change, COVID, science communication, and the need to focus on equity, social justice, and anti-racism in teacher preparation programmes, we question whether the continual subdivision of PST knowledge domains is needed or useful. Perhaps, as Settlage (2013) noted, framing teacher preparation around PCK and other knowledge domains has been 'usefully wrong' (p. 11) in the sense that such literature has provided a foundation for examinations of teacher learning, but has also reached the limits of its usefulness as a research construct.

Fourth, and related to the questions above, we wonder about the future of PST knowledge and the daily work of teacher preparation. Looking across the literature for this review, we noticed that framing teacher preparation around knowledge domains alone, especially from a deficit perspective, does not result in substantive shifts in PST thinking or actions. Instead, such research begins to sound like a proverbial broken record, repeating the same theme – PSTs lack a particular knowledge domain and thus teacher preparation should focus more on that domain – without considering how to restructure pedagogies of teacher preparation to help PSTs. Rather than continue to blame PSTs for knowledge they have not yet developed (would we blame pre-K – high school students in similar ways?), teacher educators must take on the onus for providing opportunities for PSTs to shift their thinking and actions. To be blunt: Rather than succumbing to the siren call of publishing about knowledge that PSTs lack (Settlage, 2013) – which might seem easy and externalises responsibility for PST learning – we urge teacher educator

colleagues to examine PST learning in relation to the opportunities that are provided, or denied, in the preparation programmes we design and enact. If PSTs do not develop the knowledge and practices that help students learn, blame and responsibility falls on us, the teacher educators, and not on novices who are desperately needed in classrooms and who look to us for guidance in learning to teach.

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