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# Toward assessment for playful learning in early childhood: Influences on teachers' science assessment practices

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**Abstract**
In many countries, play is the vehicle for teaching and learning, requiring early childhood teachers to recognize and assess children's demonstrations of knowledge and capabilities as they are displayed during play. In the context of science learning, assessing what children know already, referred to as "assessment for learning," equips teachers with the knowledge required to make purposeful decisions during these playful experiences and guide children's science process skill development while following their interests. Consistent evidence since the introduction of national quality standards in Australia has identified a need to strengthen teacher capabilities in assessment. This research investigated teachers' assessment practices, and the influences on these practices, during the implementation of a suite of playful science experiences in long day care and preschool settings in the Northern Territory (NT), Australia. Teachers were introduced to the NT Preschool Science Games and were supported to apply an assessment tool designed for the observation and development of science process skills. Adopting a multiple case study approach, semistructured interviews from three cases were thematically analyzed. Our findings demonstrate that despite

having specific tools to support assessment for learning these were inconsistently applied. Thematic analysis of semistructured interviews revealed that assessment practice was influenced by contextual influences, affective responses and teaching practice. Unpacking these themes further, we identified that following children's interests was associated with the absence of systematic assessment of scientific thinking to inform planning for learning within the informal curriculum. To support teacher practice in early childhood science, and promote the assessment of children's capabilities within playful learning, we propose a model of Assessment *for* playful learning.

**KEYWORDS**
assessment, learning progressions, preschool, science process skills

## 1 | INTRODUCTION

Children are capable of scientific thinking and learning from a young age (McClure et al., 2017) when they participate in a learning environment or cultural context that provides them with the relevant tools to develop this thinking (Zimmerman & Klahr, 2018). When these cultural tools are provided through playful science learning experiences in early childhood, children develop positive beliefs about science, thus building the foundation for formal studies of science in later stages of schooling (Eshach & Fried, 2005; Oppermann et al., 2018). Unfortunately, research has demonstrated that the amount of time dedicated to teaching science in early childhood settings is limited (Early et al., 2010; Harrison et al., 2019), with minimal teacher interaction in science experiences (Tu, 2006), resulting in limited impact on later science achievement (Saçkes et al., 2011). Here, we investigate the implementation of the Northern Territory (NT) Preschool Science Games (Guarrella et al., 2018), a teaching resource that promotes the introduction of science learning experiences in preschools and long day care services across the NT of Australia. The games take a playful learning approach (Hirsh-Pasek et al., 2009; Ilgaz et al., 2018; Weisberg et al., 2013; Zosh et al., 2018) to early childhood science education, providing teachers with prompts to support integrated teaching and learning though a blend of child-directed play, guided play, and adult-led learning (Department of Education, 2018).

We focus on one key pedagogical practice within the implementation: assessment *for* learning. Highlighted in the Early Years Learning Framework (EYLF) for Australia (Department of Education, Employment and Workplace Relations [DEEWR], 2009), this practice is a key component of playful science education in early childhood settings. A large corpus of literature discusses the critical role of assessment in teaching and learning, starting from early childhood (Snow & Van Hemel, 2008) and extending across the full lifespan of education (Black & Wiliam, 2009, 2018; Griffin, 2019). In Australia, since the introduction of revised quality standards for Early Childhood Education and Care (ECEC) in 2018, Element 1.3.1 “assessment and planning cycle” has been consistently listed among the standards, with the largest proportion of early childhood services not meeting the National Quality Standard (NQS) in Australia (Australian Children's Education & Care Quality Authority, 2018, 2019, 2020, 2021). This emphasizes the need to strengthen teacher capabilities in assessment and planning. In addition, it signals an opportunity to investigate and understand the influences impacting teachers' assessment.

Proximal processes, or interactions between the developing child and people, objects, and symbols in their immediate environment, influence child learning (Bronfenbrenner & Morris, 2006). By extension, information gathered from assessment can be intentionally used by teachers to inform how they interact with children, thus influencing their learning. In this context, we seek to investigate the influences on teachers' assessment practices during the implementation of the NT Preschool Science Games. We aim to identify how teachers assess the development of children's science process skills while enacting the NT Preschool Science Games and factors that may influence their assessment practice in this context. This is achieved by addressing the following research questions:

1. How do teachers apply early childhood science assessment practices during the implementation of the NT Preschool Science Games?
2. What influences teachers' application of early childhood science assessment practices during the implementation of the NT Preschool Science Games?

## 2 | LITERATURE REVIEW

### 2.1 | Assessment practice

The role of assessment in education has been an ongoing area of educational research for more than 20 years (Bennett, 2011; Black & Wiliam, 1998, 2018; Davari-Torshizi, 2020; Griffin, 2007). Researchers have taken a discipline-specific approach to assessment in science education (Alonzo, 2018a; Cowie & Harrison, 2020; Pierson et al., 2019) and examined assessment practices during early childhood education (Keary et al., 2020; Lam & Wong, 2019; Snow & Van Hemel, 2008). However, combining early childhood science and assessment creates a new focal point, illuminating the opportunity for targeted research in this area (Greenfield, 2015).

To conceptualize early childhood science assessment, it is necessary to first understand the role and purpose of assessment in learning. Assessment is a process for making inferences about children's learning (Black & Wiliam, 2018). To engage in this practice, teachers require evidence of the child's learning in the form of what they do, say, make, write, or draw (Griffin, 2019). With this evidence, they conduct assessment, or make an inference, for the purposes of learning (Hayward, 2015). This process of making evidence-informed decisions for learning is widely discussed as assessment *of*, *as*, and *for* learning (Black et al., 2011; Black & Wiliam, 2018; Dann, 2014; Earl, 2003; Griffin, 2019; Penuel & Shepard, 2008). An assessment *of* learning is a summary of a child's thinking or achievement at one point in time (Black et al., 2011). Assessment *as* learning is an active learning process that occurs when children reflect and conduct a self-assessment on their own learning (Dann, 2014; Earl, 2003). Assessment *for* learning uses appropriate, adequate, accurate, and authentic evidence of what the children can do (Griffin, 2019) to inform decision-making and to adapt teaching to meet the children's learning needs (Black et al., 2004; Black & Wiliam, 2018; Penuel & Shepard, 2008).

Recently, learning progressions have received prominence in the research literature due to their ability to combine assessment *of* and *for* learning to drive forward learning (Alonzo, 2018b; Black et al., 2011; Gotwals, 2018; Shepard, 2018). For a piece of assessment evidence to be used in the assessment *of* and *for* learning, achieving both summative and formative purposes, a common assessment tool is required to make inferences from the evidence (Black et al., 2011). Learning progressions can provide the common link that underpins these two forms of assessment as they provide criteria for teachers to identify what a child can currently do (assessment *of* learning) and make decisions on what they are ready to learn next (assessment *for* learning) (Alonzo, 2011; Shepard, 2018; Wilson, 2018). In essence, this facilitates the identification of the child's ZPD so that the teacher, or more knowledgeable other, can target teaching and learning. In addition, this understanding of the child's future learning pathway identified through assessment *for* learning equips teachers with the knowledge required to make purposeful decisions in the moment when teaching (Wilson, 2018).

The research on science-specific learning progressions for the primary and secondary years is well established (Alonzo, 2018a). Recent studies have extended this research into early childhood, identifying children's misconceptions and the progression of children's thinking—for example, to taxonomic knowledge of animal species (Allen, 2015) and gears (Reuter & Leuchter, 2021). This merely scratches the surface of science content, highlighting the significant opportunity for further research into the progression of children's science conceptual understanding (Allen & Kambouri-Danos, 2017). Indeed, this call to action has been heard, with progress being made toward developing and refining evidenced-based learning trajectories in science, engineering, and technology to promote learning and inclusion in early childhood settings (Clements et al., 2021). Children's scientific thinking involves the development of not only scientific content, but also the process skills that underpin the procedures of scientific investigation such as observation, prediction, and communication (Guarrella, 2021). Research grounded in cognitive psychology demonstrates that children are capable of developing scientific thinking through asking questions, conducting experiments, and developing explanations for what they have observed (Zimmerman & Klahr, 2018). Yet an evidence-based learning progression of science process skills for use in assessment *for* learning remains elusive in early childhood science education. Mapping the development of science process skills would provide guidance for early childhood teachers to recognize and identify these skills in play and support intentional decision-making for children's future learning. In addition, equipping teachers with the knowledge of how to assess children's science process skills through the use of learning progressions may be one way to increase intentional teacher engagement in science experiences with children.

## 2.2 | Playful learning

The UN Convention on the Rights of the Child (United Nations Convention on the Rights of the Child, 1989) enshrines the right to play. While play holds this important and protected space in early childhood, it is a concept that is hard to define, leading to multiple, diverse definitions of play (Schlesinger et al., 2020). Many agree that play is largely an enjoyable and fun activity that is intrinsically motivated, voluntary, and flexible (Schlesinger et al., 2020; Weisberg et al., 2013;Yogman et al., 2018; Zosh et al., 2018). Typically, play does not focus on an end goal; rather, children play simply for the sake of playing (Yogman et al., 2018; Zosh et al., 2018). One of the many positive outcomes of play is learning, with research demonstrating the power of play for cognitive, social, and physical development (Fisher et al., 2010; Hirsh-Pasek et al., 2009; Schlesinger et al., 2020). The nature of children's play and the extent to which teachers engage with children to facilitate learning within play vary between cultures (Clarke-Stewart et al., 2006; Rao & Li, 2008). In many countries, play is the vehicle for teaching and learning, requiring early childhood teachers to recognize and assess children's demonstrations of knowledge and capabilities as they are displayed during play. Playful learning occurs when children develop new knowledge, skills, and understandings through their active engagement in enjoyable play experiences that foster learning and exploration (Fisher et al., 2010; Hirsh-Pasek et al., 2009; Ilgaz et al., 2018).

Playful pedagogies are central to early childhood education as they support both developmental and academic outcomes through playful learning (Fisher et al., 2010; Pyle et al., 2017). Breaking down the traditional dichotomy of free play and direct instruction as two competing pedagogies in early childhood education, Zosh et al. (2018) reconceptualized play as a spectrum of playful experiences. In between free play and direct instruction, sit guided play, games, co-opted play, and playful instruction, creating a continuum of playful experiences conducive to playful learning. These playful experiences differ in terms of the extent to which they are initiated or directed by the child or teacher and the presence (or absence) of an explicit learning objective (Zosh et al., 2018).

Playful learning involves teachers' intentional use of observations to understand children's learning priorities and interests within a selected area of learning, development and articulation of needs-aligned learning objectives, preparation of fun and meaningful learning environments favorable to play and learning, and purposeful interactions with children during play (Ilgaz et al., 2018). Guided play enhances learning opportunities in playful contexts by allowing the child to direct play while the teacher embeds the learning objectives, thus making guidance explicit in a context meaningful to the child (Weisberg et al., 2013; Zosh et al., 2018). This necessitates predetermined learning objectives (Ilgaz et al., 2018; Zosh et al., 2018) that can be transferred across contexts as the child directs the play. These transferrable learning objectives are identified through assessment *for* learning (Black et al., 2004).

By definition, the teacher takes an active role in guided play, preparing for and promoting learning in line with identified learning objectives (Weisberg et al., 2013; Zosh et al., 2018). However, the nature of a teacher's engagement with play and thus where they position themselves on the spectrum has been found to relate to their perspective on the role of play in learning (Pyle et al., 2017; Pyle & Danniels, 2017). For example, teachers who perceive the purpose of play to be for academic learning tend to engage in guided play, whereas those who view play from a developmental perspective are more likely to prefer free play (Pyle & Danniels, 2017). Pyle and Danniels (2017) also highlighted a critical tension and, indeed, potential misunderstanding among teachers, regarding the difference between child-centeredness and child-directedness. Child-directedness in play refers to the child directing the activity, whereas child-centeredness is when the child is at the heart of the curriculum, and decisions regarding playful learning opportunities are informed by the teacher's professional judgment of the child's learning (Pyle & Danniels, 2017). Playful learning experiences are child centered in that they create the playful context for teachers to enact their professional judgment in support of developing the children's knowledge, skills, and interests. This requires the teacher to step into play to support child learning at times when needed, rather than only following the child's direction without intervention.

## 3 | RESEARCH CONTEXT

### 3.1 | Science education in Australian early childhood settings

Curriculum development in Australian early childhood settings is guided by the EYLF for Australia (Department of Education Employment and Workplace Relations, 2009).

This national framework takes a child-centered approach and emphasizes eight pedagogical principles to support children's learning: holistic approaches, responsiveness to children, learning through play, intentional teaching, learning environments, cultural competence, continuity of learning, and transitions, and assessment for learning (Department of Education Employment and Workplace Relations, 2009). Designed to facilitate children's learning, the EYLF provides broad direction for educators' curriculum decision-making in relation to five outcomes associated with children's identity, relationships within communities, wellbeing, learning, and communication (Department of Education Employment and Workplace Relations, 2009). In this section, we discuss how the EYLF may be applied to support science education in Australian early childhood settings.

Locating science education within the EYLF requires a level of resourceful interpretation on behalf of the teacher. The word "science" is not used at all in the document. The development of science process skills can be inferred from Learning Outcome 4 that states "children develop a range of skills and processes such as problem solving, inquiry, experimentation, hypothesizing, researching and investigating" (Department of Education Employment and Workplace Relations, 2009, p. 35). With no reference to scientific content or understandings to support the development and use of these skills, it falls upon individual teachers to identify opportunities to plan for the inclusion of opportunities for children to rehearse scientific skills and processes and to acquire knowledge. While this provides teachers with significant scope to incorporate science learning, it also provides little guidance on what to include and how to implement science education. More recently, however, there has been recognition that the inclusion of children's development of conceptual thinking, including science, is warranted in future iterations of the EYLF (Hadley et al., 2021).

In Australia, the Early Years Planning Cycle (EYPC; Department of Education Employment and Workplace Relations, 2010) is used by teachers to assess and plan for children's science learning, along with all other social, cognitive, and physical learning included in the framework. The EYPC involves a cycle of collecting information, questioning/analyzing, planning, acting/doing, and reflecting (DEEWR, 2010). To support teachers to assess learning in this way, there is scope for additional resources that elaborate the progressive knowledge, skills, and abilities children are developing in all areas of learning, including science (Cloney et al., 2019). Indeed, Australian teachers are seeking support to further their understanding of science teaching and learning in early childhood (Barber et al., 2014). To this end, state and territory governments have begun to develop curriculum resources to support teachers to understand the what, why, and how of assessment and science education in early childhood (Cohrssen et al., 2020; Guarrella et al., 2018).

## 3.2 | Northern Territory, Australia

This research was conducted in the NT, Australia. The territory covers 17.5% of the mainland of Australia, making it the third largest state or territory after Western Australia and Queensland (Geoscience Australia, 2022). Despite its size, the population is estimated at 245,900 (Australian Bureau of Statistics, 2021) with just over 40% of residents living in remote and regional communities. There are 220 ECEC services in the NT, including 90 long day care services and 75 preschools (Australian Children's Education & Care Quality Authority, 2021).

The NT Department of Education identified that preschool teachers within their jurisdiction sought further assistance with the purposeful inclusion of STEM concepts within an informal, play-based curricula. In response to this need, they commissioned the development of a set of four curriculum resources: the NT Preschool Maths, Science, Engineering and Technology Games (Cohrssen & Cook, 2016; Guarrella et al., 2018; Hill et al., 2019; Stewart et al., 2020). In this research, we focus specifically on the NT Preschool Science Games (Guarrella et al., 2018). The games are culturally responsive, allowing for adaptations to suit the context in which they are used and are not designed to be followed step-by-step. Rather, they are intended to be flexible to support teachers to enact the integrated teaching and learning approach promoted by the NT Preschool Curriculum (Department of Education, 2018) that is informed by the EYLF (Department of Education Employment and Workplace Relations, 2009). An integrated teaching and learning approach is represented by a triple helix of child-directed play and learning, guided play and learning, and adult-led learning (Department of Education, 2018; Department of Education and Training [DET], 2017). Here, the triple helix represents the way in which teachers interweave playful learning (Ilgaz et al., 2018) into practice by taking on different roles within children's play. At times they will follow the children's lead, or they will guide learning by asking questions that prompt extended thinking. At other times, they may use strategies such as modeling to explicitly teach, for example, how to use a magnifying glass in play. Such an approach "involves educators being deliberate, purposeful and thoughtful in their decisions" (Department of Education Employment and Workplace Relations, 2009, p. 17) to extend children's learning in play. In practice, this empowers teachers to use the NT Preschool Science Games intentionally to develop children's science process skills in playful learning experiences that align with children's interest.

### 3.3 | Theoretical framework

Bioecological theory positions children as developing individuals who both influence and are influenced by proximal processes (Bronfenbrenner & Morris, 2006). These proximal processes are defined as the reciprocal interactions between a child and one or more of the people, objects, or symbols in their immediate environment (Bronfenbrenner & Morris, 2006). Child learning and development occurs as these interactions become progressively more complex over time, leading to the characterization of proximal processes as the "primary engines of development" within a child's immediate environment (Bronfenbrenner & Morris, 2006, p. 798). Teachers play an important role in promoting productive proximal processes (Navarro et al., 2020). As key actors within children's microsystems, teachers are involved directly in proximal processes themselves as they engage in interpersonal interactions with children. This research focuses on teachers situated within a child's microsystem and aims to understand the nature of science assessment practices during the implementation of the NT Preschool Science Games (Guarrella et al., 2018). In addition, it aims to identify factors influencing the teachers' science assessment practices to gain a fuller understanding of the interactions and influences impacting proximal processes in a child's microsystem (Bronfenbrenner & Morris, 2006).

## 4 | METHODOLOGY

This research adopts a multiple case study approach (Yin, 2009, 2018) with each teacher defined as a single unit of analysis or "case." In seeking to understand teacher assessment practices, this research provides insight on the nature of proximal processes within the microsystem (Bronfenbrenner & Morris, 2006).

## 4.1 | Participants

Purposive selection criteria were used to identify current teachers or lead educators teaching children aged 3–5 years in either a long day care or preschool setting in a capital city or regional town in the NT, Australia. To participate, participants were required to be responsible for curriculum planning and assessment. The NT Department of Education provided a list of preschools and long day care services in the capital city and regional town. The list was reviewed, and preschools and long day care services were excluded from the recruitment process if (1) they had participated in a trial of the NT Preschool Science Games (due to prior use of the games) or (2) they were a long day care service colocated with a school (due to the perceived influence of the school environment on teaching). As preschools are typically colocated with schools in the NT, this feature distinguishes them from long day care services that are typically "stand-alone" services. The remaining services were sorted by service type and location and randomized prior to introductory emails being sent to determine interest in participating in the study.

The study design provided for the recruitment of eight participants to allow for replication and systematic case comparisons across each type of setting: long day care in a capital city, long day care in a regional town, preschool in a capital city, and preschool in a regional town (Yin, 2009). These criteria were not met after the first round of recruitment, resulting in the distribution of a second email. Ultimately, the selection criteria were satisfied with the exception of a long day care service in a regional town: All long day care services that matched the purposive selection criteria were contacted, but only one service demonstrated interest in participating.

The research was conducted in line with university ethics approval (REF: 1853428.1) and permission to conduct research in preschool and long day care settings in the NT, Australia (REF: 14707). Seven teachers and lead educators (henceforth described collectively as "teachers") consented to participate in the study. In addition, the preschool principal or long day care service director and families provided informed consent to participate in the research. The teachers agreed to (1) include at least one NT Preschool Science Game in their curriculum per week and (2) after facilitating one NT Preschool Science Game, to use the SciDoc to assess children's learning during their enactment of the game. These implementation resources are explained in detail in the next section; however, of importance here is that the number of SciDoc entries was not stipulated. At the introductory seminar, consensus was reached that if one game was used per week, at least one SciDoc entry would need to be submitted to assess the learning of one child and to complete the EYPC.

Between May and September 2019, the implementation period, three participants withdrew from the study. Two participants cited illness, and one participant cited a 50% decrease in their allocated planning time, inhibiting their capacity to participate in the implementation. A fourth participant was promoted to a leadership position during the implementation and no longer met the curriculum planning and assessment inclusion criterion for the study. This resulted in a full dataset for three participants. With regard to the services at which participants were employed, the preschool and long day care service were both located in the regional town and situated in a high socioeconomic status (SES) area. The preschool in the capital city was in an area of middle rank SES (Australian Bureau of Statistics, 2018). Participating teachers are referred to by the pseudonyms Lola, Giulia, and Aisha and assigned Cases 1, 2, and 3, respectively. The characteristics for each are outlined in Table 1.

**TABLE 1** Case characteristics

| Variables | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| Pseudonym | Lola | Giulia | Aisha |
| Location | Regional town | Capital city | Regional town |
| SES | High | Middle | High |
| Service type | Long day care | Preschool | Preschool |
| NQS rating | Exceeding | Exceeding | Meeting |
| Highest qualification | Diploma | Bachelor's degree | Bachelor's degree |

Abbreviation: NQS, National Quality Standard.

## 4.2 | Implementation resources

### 4.2.1 | NT Preschool Science Games

The NT Preschool Science Games (Guarrella et al., 2018) were designed to support the development of scientific process skills through intentional interactions between teachers and children. The games were designed to be fun, familiar experiences that highlight embedded learning opportunities through the provision of specific science objectives. The structure of the games affords opportunities for child-centered and child-directed play, providing open-ended questions and words for teachers to model in play with children. Suggestions for consolidation and extension of learning are included to support ongoing assessment of children's science learning. The games are grouped according to the scientific disciplines (e.g., biological science, chemical science, and physical science) and promote the importance of young children's development of science process skills in line with the EYLF (Department of Education Employment and Workplace Relations, 2009) and the NT Preschool Curriculum (Department of Education, 2018). Five core science process skills that children can develop through guided play (observing, classifying, comparing, communicating and recording, and predicting and checking; Guarrella, 2021) are defined and integrated into the games, demonstrating how science can be found in multiple contexts and, at the same time, teaching can follow children's interests. Hard copies of the NT Preschool Science Games were distributed to long day care services and preschools across the NT in 2019, shortly before the commencement of this research, and remain freely available online (Guarrella et al., 2018).

### 4.2.2 | SciDoc

The first author developed a resource for teachers that aim to scaffold formative assessment of science process skills. Called Science Documentation ("SciDoc"), it was developed through a design, trial, and refine process in conjunction with early childhood teachers and educators in Melbourne, Australia. It is an online resource, offering a structured, step-by-step assessment process that follows the stages of the EYPC: observe, question/analyze, plan, act/do, reflect (Department of Education Employment and Workplace Relations, 2010). The SciDoc provides a series of prompts followed by opportunities for teachers to respond by selecting options or providing a written response. Examples of prompts and response options are shown in Table 2.

**TABLE 2** Examples of prompts and response options included in SciDoc

| Section | Prompt | Response options |
|---|---|---|
| Observation details | Date of observation | Calendar selection |
| | Child's name | Drop-down selection of de-identified child data |
| | NT Preschool Science Game used | Select from list of all NT Preschool Science Games |
| | The purpose of this observation is to observe this particular child's: | Select:<br>Observation skills<br>Classification skills<br>Comparison skills<br>Predicting and checking skills<br>Communication and recording skills |
| Observe and record | Describe below what the child did, said, wrote, drew or made in relation to this learning experience: | Free text entry |
| Analyze the observation evidence | Moving from left to right, identify the description that best matches the observation evidence you have collected<br>You may observe more than one science process skill being used at a time<br>If you have not observed a science process skill on this occasion, select not enough evidence | Theoretical progression of science process skills embedded into SciDoc<br>Participants select which criterion best matches observation evidence for each science process skill |
| Implications for planning | Identify which science process skill(s) you plan to consolidate or extend in future planning | Select:<br>Observation skills<br>Classification skills<br>Comparison skills<br>Predicting and checking skills<br>Communication and recording skills |
| | Identify which NT Preschool Science Game will support you to consolidate or extend development of this science process skill | Select from list of all NT Preschool Science Games |
| | Brainstorm additional ways you can use the information from your analysis to help you plan | Free text entry |

It was estimated that it would take 10–15 min to complete once teachers had observation evidence to enter into the SciDoc.

The SciDoc is underpinned by a series of theoretical learning progressions (Griffin, 2019) for science process skills that were piloted by teachers and educators in late 2018. These progressions enable assessment *for* learning of children's current science skills to facilitate future learning (Black et al., 2004; Black & Wiliam, 2018; Penuel & Shepard, 2008) and are presented here as a matrix of rubrics that demonstrates the development of science process skills using a criterion-referenced framework (Griffin, 2019; Figure 1). The development of the criteria within these rubrics was conducted in line with the 10 guidelines for developing quality criteria (Griffin, 2019). Prior to the pilot study, the learning progressions were reviewed by two academics with experience teaching in both early childhood and tertiary education settings. They provided feedback on language, clarity and alignment of the criteria with their knowledge of child learning. In addition, feedback from teachers and educators was used to refine the learning progressions during piloting. Finally, the authors discussed the revised theoretical progression and reviewed the progression of each science process skill individually before use in this study.

### 4.2.3 | Introductory seminar

A 1-day seminar was designed and delivered to introduce participants to the NT Preschool Science Games. Teachers were supported to rehearse the use of the SciDoc in conjunction with the NT Preschool Science Games to recognize the role of assessment in planning for children's science process skill development and to evaluate children's science process skill development using the SciDoc.

## 4.3 | Instruments

### 4.3.1 | Interview

A semistructured interview protocol was created specifically for this implementation study. The interview aimed to understand each teacher's lived experience during the implementation of the games. Each interview provides a cross-section of data, at a single point in time, for one case. When applied to case studies, cross-sectional design allows for across-case comparisons to illuminate the differences in the teachers' experiences (Fawcett & Pockett, 2015; Mills et al., 2010).

| | | | | |
|---|---|---|---|---|
| Explains and justifies how scientific tools helped observations | Explains and justifies own rule(s) used to group similar objects OR living things | Explains and justifies reasoning for identified similarities and differences between objects OR living things | Explains and justifies reasoning for what happened in the experiment | Explains and justifies recording of findings |
| | | | Conducts a simple experiment to check if the statement is true | |
| Uses scientific tools (e.g. magnifying glass) to extend the senses | Applies **own** rules to group objects OR living things based on their features and characteristics | | Refers to prior knowledge and/or observations to make a statement about what will happen | Records findings |
| Uses senses to notice **changes** in objects OR living things OR events in the learning environment | Applies **given** rules to group objects OR living things based on their features and characteristics | Distinguishes similarities and differences between properties of objects OR living things | Makes a statement about what will happen | Describes observable characteristics of objects OR living things or events |
| Uses senses to notice objects OR living things OR events in the learning environment | Identifies features and characteristics of objects OR living things | | Uses trial and error to explore what will happen | Responds verbally or non-verbally to the presence of objects OR living things OR events in the learning environment |
| Not enough evidence | Not enough evidence | Not enough evidence | Not enough evidence | Not enough evidence |
| **Observing** | **Classifying** | **Comparing** | **Predicting & Checking** | **Communicating & Recording** |

FIGURE 1 Theoretical progression of science process skills

Initial interview questions related to how participants used the NT Preschool Science Games and SciDoc, and follow-up questions related to factors influencing teachers' assessment of science learning and how assessment had been conducted without the SciDoc. Preplanned prompts were available to clarify answers if required to facilitate thematic coding at a later date (Kvale & Brinkmann, 2009). The interviews allowed for the characteristics of individual teachers' practice to be explored in detail, with particular attention paid to influences on the initiation and continuation of proximal processes (Bronfenbrenner & Morris, 2006). Interviews were conducted at the end of the implementation period, on site at each early learning service or preschool, and were approximately 45 min in duration.

### 4.3.2 | SciDoc

The SciDoc was intended to have a dual purpose: first as an implementation resource to support assessment, and second, as a data collection instrument. As teachers used the online instrument, their observations and subsequent analysis and planning were captured in an online repository. The observation and assessment data collected in the online repository were then available for analysis by researchers. In addition, participants received a PDF copy of their SciDoc entry to enable them to use this information in their business-as-usual teaching, thus limiting the burden of participating in this project.

## 4.4 | Procedure

Participants were invited to attend the introductory seminar conducted in May 2019 by the first author. The participants were introduced to the NT Preschool Science Games and supported to use the SciDoc. The implementation period immediately followed the seminar and continued for a period of 4 months. In September 2019, participants were invited to participate in semistructured interviews. Interviews were scheduled at participants' early childhood service or preschool and conducted by the first author.

## 4.5 | Data analysis

Days to first use, time between observation and documentation of analysis in SciDoc, and frequency counts of usage were identified. Descriptive text written by the teachers in the SciDoc was used to corroborate information provided in the semistructured interviews to create case summaries of enacted assessment practices during the implementation of the NT Preschool Science Games.

Transcripts of the semistructured interviews were analyzed thematically to identify factors influencing teachers' assessment practices when using the NT Preschool Science Games. Inductive descriptive coding was conducted across the entire dataset (Braun et al., 2019; Braun & Clarke, 2006) and used to create a summary of each case to facilitate a discussion between the authors on early patterns identified in the data. Subsequently, descriptive codes were revised and data clustered into groups containing similar patterns and/or characteristics (Miles & Huberman, 1994). Next, a matrix was used to map the evolving clusters of descriptive codes and to identify key events and processes occurring within and across cases. Again, the authors discussed patterns occurring across the dataset and agreed on the grouping of clusters to form themes and subthemes.

# 5 | RESULTS

## 5.1 | Teachers' early childhood science assessment practices during the implementation of the NT Preschool Science Games

The SciDoc was used to varying degrees by the three teachers (see Table 3). In Case 1, one attempt to use the SciDoc was recorded 10 days (six school days) after the introductory seminar; however, the observation was incomplete. Four observations during Term 2 and two observations in Term 3 were submitted for Case 2, totaling six observations during the implementation period. Three observations were recorded in the SciDoc for Case 3. All the observations submitted by the teachers in Cases 2 and 3 met the four characteristics of assessment *for* learning: appropriate, adequate, accurate, and authentic (Griffin, 2019).

### 5.1.1 | Assessment practices: Case 1 (Lola)

Lola made one attempt to use the SciDoc; however, the submitted observation was incomplete. No further attempts were made by this teacher to use the SciDoc to document and assess children's science process skills. However, during the interview, Lola identified that the children had an interest in "space," and this had been used to inform her science planning:

> My children were so interested in space recently, so we created this really great space station and made this really big rocket and we started to learn about the planets and all that sort of stuff. I was literally like googling how many planets are there, and what's the planet closest to the sun and how does it all work? (Case 1 Interview)

The children's interest in space influenced the teaching of facts and information rather than attending to science process skills. The absence of assessment *for* learning was evident as Lola acknowledged the children were not ready to learn content relating to space science:

**TABLE 3** SciDoc usage by case

| | Case 1 | Case 2 | Case 3 |
|---|---|---|---|
| Number of observations conducted | 1 (incomplete) | 6 | 3 |
| Days between professional learning seminar and first use of SciDoc | 10 days (6 school days) | 5 days (3 school days) | 7 days (5 school days) |
| Average time between observation and entry into SciDoc | | 4 days | Same day |

> [The children] weren't necessarily ready, I guess, to learn about the sort of stuff [content knowledge regarding planets]. Like, very interested in the planets and stuff like that but weren't ready to learn about you know the deeper stuff like the names of all of them and like the hottest planet and the coldest planet and all of that sort of stuff. (Case 1 Interview)

Rather than using the SciDoc and NT Preschool Science Games to assess and plan for future learning, Lola responded to the children's interest in a science area by providing activities and materials related to the topic. This demonstrates that assessment for learning was separate to other aspects of Lola's teaching practice as she based her planning solely on the children's play interests. This posed a challenge when the children's interest shifted away from the planets:

> I think I definitely tried [to support science process skills], but probably could have gone a little bit better. Like, you get a group of kids that are interested one day, love learning about the space and then the other kids that are just so hands on and all they wanted to do was just go on the rocket ship and they want to do that, and they are not necessarily as interested in that. So, it's really hard finding that line. (Case 1 Interview)

Responding to the children's interests without the use of assessment for learning had resulted in a focus on classroom productivity where the children were engaged and busy rather than a focus on analysis and reasoning, extending children's language and providing timely feedback through back-and-forth conversations. When the children's interest shifted, Lola was unable to achieve her implicit goal of teaching the children facts about planets as this was content directly tied to the children's interest rather than the development of science process skills that could be adapted to multiple contexts. Further, a tension existed between the child-directed play focused on space and the adult-led learning Lola attempted to introduce. When she was unsuccessful at introducing the facts about the planets to the children, the method of learning returned to child-directed play. Here, guided play supporting science process skills would allow for science learning to occur while adapting to the changing focus of play.

#### 5.1.2 | Assessment practices: Case 2 (Giulia)

Giulia used the SciDoc to conduct a total of six observations during the implementation period. On two occasions, the observation was recorded the same day it was taken. On the other four occasions, between 5 and 7 days lapsed before the observation was recorded in the instrument (Table 3). In three of the observations, in addition to identifying the individual child's learning, Giulia included commentary on what the whole class was learning.

Giulia conveyed a conflicting narrative in her interview. She discussed her positive response to the science learning progression used in the SciDoc: "I definitely did like that progression of learning laid out like that to see sort of where kids are developing and where they need to go in developing those process skills" (Case 2 Interview).

Yet, she also described how she did not use the information she collected via the SciDoc in practice:

> I filled it out … but I didn't really use it. I thought in the beginning, "I will post this information to the parents as a separate post on story park" but I think after the first two it didn't happen anymore … it didn't really get used. For overall, you know, for you know this is what the class needs, but not an individual level really. (Case 2 Interview)

Here, there is a discrepancy between what the teacher wanted and what occurred in practice. Giulia wanted resources to support her science teaching and saw the benefit in using the SciDoc for the assessment of science process skills. This, however, was not embedded into her practice over the course of the 4-month implementation period.

Review of her SciDoc entries revealed that each observation was linked. Giulia would identify which process skill she planned to support the child to extend or consolidate, and the purpose of the subsequent observation was to observe this process skill. While there was an ongoing connection between the science process skill being assessed, each observation was of a different child, and the learning of individual children was not revisited. This was supported by the teacher's reflection on her use of the SciDoc: "… because it wasn't just that one child, like with the language thing, like it was all of them and it was quite obvious, pretty much that most of them needed to work on that skill" (Case 2 Interview).

This teacher used the SciDoc more frequently than the other participants. However, it was not systematically used to identify individual children's science process skills and to plan for future learning. Giulia's use of the SciDoc did, however, provide her with insight into the children's learning at a group level:

> I was actually quite surprised because we have some kids who have some pretty decent vocabularies, but that descriptive language was actually really hard for them. And being able to articulate the differences between things, and things like that [comparing]. It was hard for them and I was like "Wow, ok" and that was a shock to me because when you just have conversations with them, you don't get that from them. It kind of made me go—no, actually we need to do a little bit of work on this to develop those skills of being able to describe things and being able to say why things are different from each other [comparing]. (Case 2 Interview).

Alongside her use of the SciDoc, Giulia continued with her established assessment practices for science education. This involved recording planned experiences, learning that had occurred in the room, and identifying areas of the curriculum that had been covered. Further, she identified the initiation point for this assessment practice as the children's interests: "But that all came from the children and their interests. So, we have kind of provided further opportunities to enhance what they were already naturally doing. But we are taking a lot of it directly from the children" (Case 2 Interview).

The EYPC outlines the key steps required to undertake assessment for learning (Department of Education Employment and Workplace Relations, 2010). Following from the analysis of learning that has occurred, planning is the next step of the cycle to enable teaching to be aligned with identified learning needs in the implementation phase. In this case, the teacher described her teaching as taking advantage of teachable moments:

> We are just taking advantage really of the teachable moments that happen in our day, more than going, "No I have to tick this box and plan this and do that." (Case 2 Interview)

> I kind of just trust the process that some science is going to come up and we will take advantage of that moment and do something with it at the time. (Case 2 Interview)

This suggests that rather than conducting assessment *for* learning of science process skills and identifying the children's learning needs and future goals ahead of time, Giulia was reactive to the children's scientific interests that emerged in play. This suggests an emphasis on child-directed play and learning in Giulia's informal curriculum. Combining assessment *for* learning with her approach of noticing and responding to the children's interests would allow the children to rehearse science process skills in line with their learning needs numerous times in areas of their own interest. Further, this would equip her with the learning objectives to engage in guided play and learning to create a more balanced application of the integrated teaching and learning strategies (Department of Education, 2018).

### 5.1.3 | Assessment practices: Case 3 (Aisha)

Aisha conducted three assessments using the SciDoc during the implementation period (Table 2). She explained that she had completed fewer observations and assessments via the SciDoc than she would have liked because the process took longer than her established practice (this involved using an iPad to take photos of what the children were doing throughout the day and recording notes of key events in her "day book"). Aisha's description of documenting this process aligns with the first three steps of the EYPC: collect information, question/analyze, and plan.

> I'd have a photo of Child A, description of how it came about, what's happening, what she's learning from it and where to next and then the learning outcomes for it. So, it might be like a little paragraph, so obviously I would try to make it short because the parents don't read them, but you know just trying to make a little snippet of what's happening, how it came about, where to next, learning outcomes and then just linking it to the EYLF. (Case 3 Interview)

This general overview suggests that Aisha conducted assessment *of* and *for* learning in her established processes. Aisha also described using assessment *as* learning, as she gathered the children's reflections on their engagement with learning experiences:

> I will write up big learning stories that go in their portfolios, so if we do something as a whole group or we do something if there is three or four of them working on something, snap a picture, you know well do a write up about it, link it to the outcomes, their voice, what they thought of it, that sort of thing. (Case 3 Interview)

Despite the use of assessment *of*, *as*, and *for* learning in her practice, Aisha highlighted the challenges of extending one child's science learning:

> One of the boys, like he is really into the science and stuff, we could work on something but then for example he's obsessed with bug hunting. It has gone on for months, but I'll say to him "Hey I'm going to work on this, do you want to do this?"

> and he will be like "No, I just want to do my bug hunting" and I'm like ok. Even though he is benefiting from it, you know, I can't see his progression because he is just fixated on this bug hunting. I've tried everything, I've introduced bug bingo, we've done other things to try and encourage him in, but all he wants to do is run around outside with a bug catcher and a magnifying glass. I think that's the, like with the early years like you know, because it is child led, if that's what he wants to do, that's what he's doing.

Here, Aisha identified the child's interest in bug hunting and linked this to science learning. Focusing on the theme of "bugs," she was unable to identify how the child's learning was progressing in play. Switching perspectives and analyzing this child's play in terms of science process skills would allow Aisha to identify where the child sat on the observation progression (see Figure 1, Observing: Uses scientific tools [e.g., magnifying glass] to extend senses). She would then be equipped to make decisions about consolidating or extending this skill while following the child's interest in bug hunting. In addition, further observation evidence would support her to assess and plan for future learning of classifying, comparing, predicting and checking, and communicating and recording in line with the child's evolving interests. In this way, the play can continue to be child led, but the teacher plays an important role in guiding the development of science process skills.

## 5.2 | Influences on teachers' early childhood science assessment practices during the implementation of the NT Preschool Science Games

Thematic analysis of interview data led to the identification of three key themes influencing science assessment practices: contextual influences, affective responses, and teaching practices. Each of these themes is defined by various subthemes, as outlined in Figure 2.

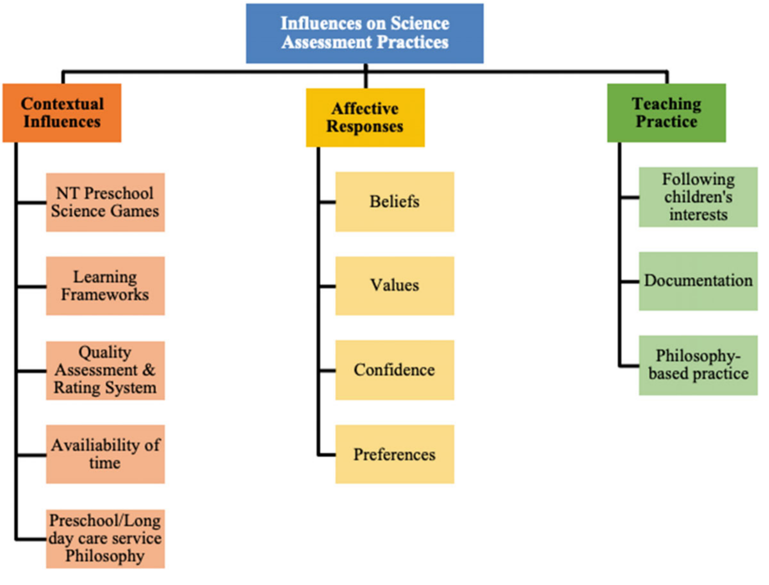


FIGURE 2 Thematic map of influences on science assessment practices

#### 5.2.1 | Contextual influences

The contextual influences are a set of external influences that shape the environment in which science is taught in early childhood. The NT Preschool Science Games, the National Quality and Assessment Rating System, the learning frameworks, time constraints, and preschool/long day care service philosophy are the five contextual influences identified in the interview data. While the influences are shared across the cases, the nature of each contextual influence varies for each case and is discussed here in turn.

For Lola (Case 1), compliance with the NQS 1.1 Program and 1.2 Practice were a high priority as she strived to teach "correctly" in line with her values. Lola was taught that a holistic approach meets these standards. In addition, the philosophy of the long day care service in this case promoted holistic teaching and learning in line with children's interests. This approach to teaching and learning is further reinforced in the EYLF that includes holistic approaches as one of the eight key pedagogical practices in the national framework (Department of Education Employment and Workplace Relations, 2009). This combination of external influences observed in Case 1, in conjunction with Lola's personal values, created a strong structure with limited flexibility for her to work within: "It was so easy to use but trying to fit it in because our observations need to be different to, like, our observations of the children are meant to be looking holistically at the children" (Case 1, Interview).

When a new approach to assessing science learning using a theoretical progression for science process skills was introduced, these external influences constrained Lola's ability to be flexible and to adapt her teaching practice to incorporate assessment for learning via the SciDoc. Ultimately, the contextual influences in this case resulted in Lola persisting with established assessment practices and only once attempting to assess children's science process skills with the SciDoc and failing to complete a full assessment.

Regardless of whether Lola used the SciDoc or not, a statement made by her during the interview is particularly significant: "Everything refers back to the EYLF, everything!" (Case 1 Interview).

Science is not explicitly referred to in the EYLF (Department of Education Employment and Workplace Relations, 2009). Therefore, if "everything refers back to the EYLF," teachers may have difficulty identifying how and when to analyze specific science process skills. This further supports the case for future iterations of the EYLF to be more specific about science education to give teachers the information that they need to assess, monitor, and support this learning (Hadley et al., 2021). Incorporating learning progressions for science process skills is one way to provide teachers with a road map for teaching, while still allowing for the flexibility of a child-centered approach to teaching.

In Case 2, Giulia discussed the introduction of a new teaching philosophy at the preschool prior to the commencement of this project:

> So, you know it has been a process over the year and ongoing for all of us to think about what teaching and learning actually looks like and that is all down to the journey that we are on with the Reggio Emilia approach. (Case 2 Interview)

Giulia allowed the children's interests to guide her teaching practice; this is closely aligned with the Reggio Emilia philosophy. Being attuned to children's developing knowledge and capabilities, and noticing what and how the children are learning, are elements of teaching practice strongly influenced by the Reggio Emilia philosophy in this case:

> And that's a big part of the Reggio approach as well you know, not going in there and going "No, your answer's wrong, this is the real answer" but actually stepping back and listening to how children's views of the world are and what they are actually thinking and what's informed them and then giving them opportunities to change their thinking without saying "No, here's the information, I'm going to teach you the right answer." That's sort of where we are at. (Case 2, Interview)

However, the act of noticing aligns with the use of the SciDoc that facilitates systematic identification, assessment, and planning for children's science process skill development. Indeed, it was Giulia who most frequently applied the theoretical progression for science process skills to children's learning. Nonetheless, her use of the SciDoc was not without its challenges, with availability of time influencing her capacity to assess children's science process skills.

Aisha, the teacher in Case 3, described the Quality Assessment and Rating System as an ever-present external influence as the preschool was undergoing assessment and rating during the implementation period. In an already busy preschool day, the teacher's available time to observe children's science process skills was limited, and she sought advice from school leaders on program priorities. Preparing for the external assessment and rating of the preschool was a more immediate priority than assessing the children's science process skills, and the teacher directed her time and focus accordingly. In addition, shortly after the introductory seminar, there was a school-wide shift to an inquiry learning approach. The NT Preschool Science Games became a useful tool, providing language for her to use with the children to integrate science into everyday experiences and further reinforcing her emerging belief that science was present in these experiences:

> When I first saw them [NT Preschool Science Games] I was like "Oh, these are probably like a lot of things we do anyway." So, it's probably, it's the language around it is all that has changed for me. Which was something that, not that I wouldn't have thought of it before, but with the planting yesterday we talked about the life cycle of the plant while we were planting them. Whereas [now] it was the language that went with it more so, like "What do you think might happen?" and the predicting and "We are going to have to watch this, how many days?" check it on the calendar. (Case 3, Interview)

### 5.2.2 | Affective responses

The theme *affective responses* incorporate the teachers' personal thoughts and feelings that influence science assessment practices. These affective responses are categorized into four subthemes: confidence, preferences, beliefs, and values. For the purposes of this research, beliefs encompass what the teachers considered as the truth or fact, and values reflect what was personally important to the teachers (Seah, 2019). The four subthemes appeared across all cases, each influencing teacher assessment practices differently and to differing degrees.

Research suggests that teachers have positive beliefs toward the importance of science in early childhood yet continue to lack confidence in their own science knowledge and feel uncomfortable planning science learning experiences (Oon et al., 2019; Pendergast et al., 2017). This was evident in our data as the teachers first highlighted the importance of including science teaching and learning in early childhood:

> These experiences in the early years really do help them build their knowledge, vocabulary, just interest in science in the later years. (Case 1 Interview)

> I feel strongly about children having those [science process] skills and the opportunities [for science education]. (Case 2 Interview).

> I do believe that it [early childhood science education] is really important or even just to be exposed to it, because I find normally at this age they're just taking so much in. (Case 3 Interview)

Over the course of the implementation, the three teachers reported differing levels of confidence in teaching science to young children. Lola described science not being her "thing" at school and held the perception that to teach science you required specific discipline knowledge, as she described: "When you think of science you think of all like, I guess technical stuff and like it goes so deep" (Case 1 Interview).

Further, limited engagement with early childhood science content and pedagogy in her initial teacher education had left Lola underequipped to teach science:

> When you do your diploma and stuff like that you don't realize how important it is because it [science] is never really just one subject to do so you just, you know you try and put it in your program every now and then and you are like oh, a volcano, or something like that, but not much thought goes into it and the children could actually be learning so much. (Case 1 Interview)

This combination of past experience, a perception of science being "technical" and content driven, and limited initial teacher education—perhaps due to the absence of science within the EYLF (Department of Education Employment and Workplace Relations, 2009)—had led to Lola having low confidence to teach science in early childhood. Promisingly, while participating in this study, her confidence in teaching science in early childhood increased, although Lola still required the NT Preschool Science Games to scaffold her science content knowledge:

> Probably a little bit more confident, but I would still have to look at the right things probably before actually implementing the lessons, like you know just to make sure I am saying the right things or teaching the right things as well, like I don't want to be using words I don't know. Even just magnetic versus nonmagnetic, instead of just saying that's a magnet, that's not a magnet, like you know, the magnetic force and all of that sort of stuff, it's just things you probably don't think to say beforehand. (Case 1 Interview)

Lola discussed her pleasure in participating in gardening experiences with the children, demonstrating a preference for child-directed activities. Yet, it appears she would likely feel underequipped to turn a fun, everyday experience such as an insect hunt into learning through guided play:

> It just depends on what it is. Like again, if it is the sensory stuff, I love getting down and getting dirty, I think it's so much fun, love getting involved with the kids. Even things like the gardening, I love doing that sort of stuff. And I love learning about

> the insects and that sort of stuff but again probably nervous about the different types of insects and what qualifies each as what and all that sort of stuff. So, it really just depends on what it is and how much googling I have done. (Case 1 Interview)

Turning to Case 2, Giulia described feeling confident to teach science in early childhood and reflected that knowing that science information was readily accessible provided her with confidence to teach and seek answers to unknown questions with the children: "I think it's fine to say, 'Hey look, I don't really know, let's look it up together.' We've all got the internet at our fingers these days" (Case 2 Interview).

This suggests that Giulia may focus on answers and the products of research rather than children's science process skills being developed through play. Indeed, Giulia did have access to vast amounts of information via the internet. However, without a level of conceptual knowledge, using this information directly in teaching could lead to the transmission of rote facts and demonstrates a preference for teacher-directed learning.

Focusing on the process of science exploration rather than the outcome of a particular experience supported Aisha in Case 3 to navigate science experiences where she was unsure of what might happen:

> There is still some stuff that like, like when we do the slime and it doesn't work out and I'm like "Oh crap, hell, what's going to come of this?" But a lot of the time with the preschoolers, it's not about the outcome it's about the experience of doing it. Like a lot of the stuff we do, if I was to leave them to their own devices, like 90% of the stuff doesn't work out but you're kind of trying to encourage them, "Oh hey why don't you try and add this?" or "Why don't you try that?" It's about the experience of doing it more so than the outcomes. So, like that's what I do find exciting about it too. Whereas some of the stuff where I probably could do it myself first but it wouldn't be as exciting … it is more about the process than the outcome. (Case 3 Interview)

Such an approach to exploring science *with* the children allowed Aisha to continuously develop her confidence in teaching science in early childhood while focusing on supporting the children's science process skills and following their interests at the same time. In addition, Aisha's conceptualization of science in early childhood evolved, leading to an emerging belief that science was present in everyday experiences. Participating in the implementation of the games allowed her to identify science in experiences that she would not have previously associated with science learning:

> There was a lot of things in it [NT Preschool Science Games] that I wouldn't have actually classed that as science, like slime. Slime is just really popular at the minute as well, which obviously, like these guys are like "I want to make rainbow slime and I want …" and we will be like "Yeah cool" but it is an experiment, putting everything together … I would have never classed that as a science thing in the classroom but yeah, I've kind of in that way, it has changed. (Case 3 Interview)

Across cases, the teachers placed high value in following the children's interests. Lola demonstrated this value by discussing the importance of extending on the children's interests in everything she did: "Everything that we have to do, or we do, is extended on the children's interests or community input, so everything is there for like a reason" (Case 1 Interview).

For Giulia, this value was seen in the way she embedded following the children's interests into her teaching practice:

> I think we've been learning to value children's voice in all areas of our program really and we capture that. ... As in, you know letting the children know that their voices are important, that we hear them. We record them, we use them, and you know they inform our planning, and they help us you know, learn what they know basically and what their understandings of the world are. (Case 2 Interview)

When discussing her science program, Aisha identified that she was more likely to teach science if it was aligned with the children's interests: "I do like doing it [teaching science in early childhood], I, but more so if it's part of their interest and that's what we are working with, then we will go with it" (Case 3 Interview).

These examples demonstrate the high level of importance each teacher placed on following the children's interests in their teaching and how this value influenced whether or not they embedded science within their preschool programs. Valuing children's interests is an important aspect of early childhood philosophy and practice. This value was of such significance to the teachers that programming was based on the children's interests rather than evidenced-based programming informed by assessment of learning, in this case science process skills.

### 5.2.3 | Teaching practices

The theme *teaching practices* encompasses strategies and pedagogies influencing teachers' science assessment practices in early childhood settings. Philosophy-based practice, documenting, and following children's interests were identified as subthemes of teaching practices and are discussed in turn.

Although philosophy-based teaching practices were evident across cases, there was a difference in the emphasis of the underpinning philosophy for each case. In Case 1, where the service philosophy was based on holistic teaching approaches, this was also evident in Lola's teaching practices. For example, Lola had a strong focus on holistic observations that included the analysis of learning across multiple learning areas. She identified that using the SciDoc to focus specifically on the assessment *for* children's science learning did not align with the philosophy-based practice of taking holistic observations:

> Yeah, so like even if it was like ... "They are learning about gravity" ... but also if in there you also just had a section to write you know they're building their negotiation and their turn taking skills and they're building their balance and spatial awareness and all of that sort of stuff. So, if there was a section to write all of that as well, so that we weren't doubling up. So that if we got checked ...! (Case 1 Interview)

This quotation demonstrates that in this case, an instrument such as the SciDoc that focused only on science process skills did not align with current teaching practice. In addition, due to the high value placed on following procedure for assessment and rating compliance, Lola reported being less likely to adapt a strategy that did not support a holistic approach. Constrained by her philosophy-based practice, Lola did not adopt a new approach to assessment for science learning. Not surprisingly, Lola's description of how she documented children's learning aligned with her holistic philosophy-based practice:

> … in the holistic view, so like when it comes to writing down the observation and then analyzing it, including that in your … teaching or analysis, that you can see that they are beginning to use science vocabulary or they are really interested in learning about reactions and like all of that sort of stuff and then still adding their turn taking and their negotiating … I tend to just write it out in a paragraph format. (Case 1 Interview)

This snapshot of Lola's documentation process demonstrates her attempt to conduct assessment *of* learning across multiple learning areas occurring in Case 1. On the other hand, in Case 2, where the preschool philosophy stemmed from the Reggio Emilia approach, Giulia's philosophy-based practice centered on taking advantage of the teachable moments in children's play:

> A lot of the science that has come up for us this term, other than the science games, has come straight from the children. They have done something, and we have gone "Wow, we can go somewhere with that" rather than me going "Oh, I'm going to sit down and plan some science this week and I am going to plan some maths this week." We are really taking advantage of those authentic moments that come up and you know less about "Let's sit down on the mat and learn something" … I don't spend this long planning because I don't really plan that much at all! It just happens!

The learning in these experiences was codocumented in a group reflection book with the children as they participated in assessment *as* learning, and Giulia recorded the experiences on the group planning posters to demonstrate learning areas had been "covered." This approach supported Giulia to enact integrated teaching and learning as she used the information from child-guided play to inform science curriculum. In contrast, Aisha discussed how she aimed to link multiple learning areas together in experiences in line with her philosophy-based practice:

> When we are working with slime like we've "Oh how many spoons do we need in that? Oh, that's five spoons, right, so drop five spoons in there. Ok count it out" So that's your numeracy in there as well. Then like your science because you're working on this and mixing it together, "What's going to happen?" So, it's just more about how you can tie everything into it … For me it's more just important to turn it into an inquiry than let's all sit down now and do science, that sort of thing.

The introduction of an inquiry philosophy was a recent change in Case 3, and this also led to the development of new documentation practices:

> We used to do it on a whole-group scale and now we have started … we have changed how we do things. We are focusing more on how we document each individual child and we kind of know from looking at their observations, you know exactly, ok well this is how they are achieving this. (Case 3 Interview)

This individualized approach set up the necessary conditions to enable both assessment *of* and *for* learning to occur.

The children's interests were often presented as a rationale for learning experiences to be implemented, meaning that planning was based on children's demonstrated prior interests or assumed future interests. The teachers often described responding to the children's interests in the moment and following where their ideas took them on the spot:

> So, like, Child B yesterday, she happened to just build that ramp and then that's how we talked about it [Cars & Ramps, NT Preschool Science Game] but yeah, that's where that came from, whereas before I did set this up and I did ask them to do it and I think like two kids came but it just wasn't their interest at that moment but it just didn't stick, whereas because Child B was doing that, that's why that came around this morning. (Case 3 Interview)

In Case 2, Giulia placed high value on capturing the children's voice and ensuring the children knew their understanding of the world was important, leading her to plan for science and other project-based learning based on the children's interests and ideas: "You know that's sort of where the project work comes from. By going 'Oh someone's got an idea. It may be right, it may be wrong, but where can we go with this? What can we offer?'" (Case 2 Interview).

As a result, when planning science with the NT Preschool Science Games, Giulia based her game choice on what the children would like or be interested in:

> Great if they [the NT Preschool Science Games] meet the needs of your kids at the time but you know to just pick one and do it for the sake of it, that didn't really sit with us. So, we sort of tried to build them in … so we tried to sort of go with what we thought our kids would like and what they would be interested in rather than trying to pull things out of nowhere and say "Hey, I'm going to do this for the fun of it!." (Case 2 Interview)

Aisha also described the importance of following the children's interests and using this principle to guide her planning:

> There is no point in me going "Let's all sit down and do this" if they are like, "I don't want to do this" … If I can adjust something to fit in I definitely will, but if not, if I can't tie it in, I won't use it. (Case 3 Interview)

She was cognisant of opportunities to adapt the games to incorporate them into the program in line with the children's interests, demonstrating a child-centered approach to teaching:

> But what I found with them was there was a lot of them that we did do that like I could alter a little bit to still fit in with our topic that we were working on at that moment, which is valuable. (Case 3 Interview)

Her understanding of the pedagogies underpinning the games and the learning objectives allowed her to extend playful learning beyond the game, both following the children's interests and supporting science process skills including predicting and checking, and communicating and recording:

> If it is something that they are super excited about that they have been asking me about, like slime, so when we tried to, we did the slime out of the book [NT Preschool Science Games] a few weeks ago. It didn't work out for us but as part of our inquiry then we went and we watched some YouTube videos. Their idea of slime was different to what I thought was going to happen. They love the slime that is like a pully slime, and it all sticks together and it goes in a little jar. I think that is what they thought was going to come from it, which obviously didn't … I was like "Right, let's make a list of ingredients that we could possibly try" and they were calling out the ingredients and we ended up just throwing a load of stuff together and it was not going to turn to slime but they just were like "Yeah, lets, more of that and more of this"… And then it's the questioning that comes from it as well, like why didn't it work out? What could we have done different? (Case 3 Interview)

Here, Aisha embraced the flexibility of the NT Preschool Science Games, applying the triple helix of child-directed play and learning, guided play and learning, and adult-led learning to extend the children's science process skills, and indeed many other areas of learning, in an engaging and enjoyable playful learning experience.

## 6 | DISCUSSION

In this study, teachers were provided with targeted tools to apply assessment *of* and *for* learning (Black et al., 2004; Black & Wiliam, 2018; Penuel & Shepard, 2008) of children's science process skills when implementing the NT Preschool Science Games. In this section, we address the two research questions in turn. First, we identify how teachers applied early childhood science assessment practices during the implementation of the NT Preschool Science Games. Thereafter, we discuss what influenced teachers' application of these practices during the implementation. Finally, we propose a model that may contribute to the purposeful inclusion of targeted learning in playful experiences across all learning areas, including early childhood science education.

We found that assessment practices varied between cases, with each leading to a different outcome. In Case 1, assessment of science interests led to planning to teach scientific facts, whereas in Case 2, assessment of individual children's science process skill development was used to inform group planning. In addition, this teacher used assessment as learning (Earl, 2003) to capture the children's perspectives on science learning experiences through codocumentation. In Case 3, opportunities to conduct assessment of and for learning (Black et al., 2004; Black & Wiliam, 2018; Penuel & Shepard, 2008) of science process skills were missed. In short, our findings demonstrate that despite having specific tools to support the assessment for learning of children's science process skills, these were inconsistently applied. This is not surprising considering assessment practice has been identified as a key area for improvement across childhood education and care services in Australia (Australian Children's Education & Care Quality Authority, 2019, 2020, 2021). It is surprising that while teachers in general want to extend their understanding of science teaching and learning, our participants demonstrated that they believed it was important to include science in their preschool programs, yet when provided with resources and support to do so, it was not taken up. This could be attributed to contextual influences in the exosystem, such as the availability of time, having a limiting effect on assessment practices. Alternatively, the low up take of these resources may be due to a discrepancy between the contextual influences and the teacher's affective responses within the microsystem. The observed misalignment between service philosophies, which impact on teachers' attitudes and beliefs, and the assessment for learning approach supported by these resources may have influenced the extent to which the teachers' applied the resources. Ultimately, the inconsistency in assessment practice demonstrated by the participants impacted the children's science learning by reducing efficacy of the proximal processes between the teacher and child that consolidate and extend learning because these interactions were not routinely informed by assessment evidence. Without assessment for learning, opportunities for playful science experiences that respond to children's increasing understanding are limited and thus constrain child learning.

Our research supports the use of learning progressions by applying an assessment tool designed specifically for the observation and development of science process skills—namely, the SciDoc. While the teachers identified the benefits of the instrument, regular use of the SciDoc was not adopted. The teachers continued with pre-established methods of documentation, including group reflection books, group planning documents, and individual observations (without science process skill progressions) to assess science learning. Again, when the teachers were provided with the support they sought, it was not applied in practice. We acknowledge that the documentation methods employed by the participants added to the teachers' assessment toolkit; however, the purpose of each differed from the SciDoc that was designed specifically to support assessment *for* learning (Black et al., 2004; Black & Wiliam, 2018; Penuel & Shepard, 2008) and thus support educators to meet the assessment and planning requirements of the NQS (Australian Children's Education & Care Quality Authority, 2018). For example, group reflection books were used for assessment *as* learning (Dann, 2014; Earl, 2003). Here, the process of reflection and codocumentation with teachers provides children with a learning opportunity by participating in assessment. The use of theoretical learning progressions via the SciDoc supports assessment *for* learning, leading to the identification of future learning opportunities. This equips teachers to seize the opportunities afforded by teachable moments stemming from the children's interests and respond with thoughtful, evidenced-informed learning prompts aligned with the children's learning trajectory. Importantly, this positions the teacher as a proactive influencer of learning in play rather than being reactive to child-directed play with limited influence on learning. We encourage continued efforts to support teachers to apply learning progressions in science, and indeed all areas of STEM, to support the learning of every child (Clements et al., 2021).

Turning to the influences on assessment practices during the implementation of the NT Preschool Science Games, our findings demonstrate that assessment was influenced by *contextual influences*, *affective responses*, and *teaching practice*. Application of the bioecological theory of human development supports our understanding of the multidirectional influences of these factors and the ways they present in reciprocal interactions between teachers and children (Bronfenbrenner & Morris, 2006). As pictured in Figure 3, the contextual influences are positioned within a child's exosystem, and affective responses and teaching practice of the teacher (who is a key actor within the microsystem) are situated within the microsystem. Thus, a bioecological perspective suggests that for the child to affect and be affected by events within the exosystem, a causal sequence incorporating a minimum of two steps is required to connect the contextual influences in the exosystem with the child in the microsystem. This is indeed evident in our data, with the teacher acting as the intermediary connecting the contextual influences in the exosystem (such as the learning frameworks, service philosophy, and the Quality Assessment and Rating System) to the microsystem, where they contribute to proximal processes with the developing child through their direct interactions. Our data demonstrate that

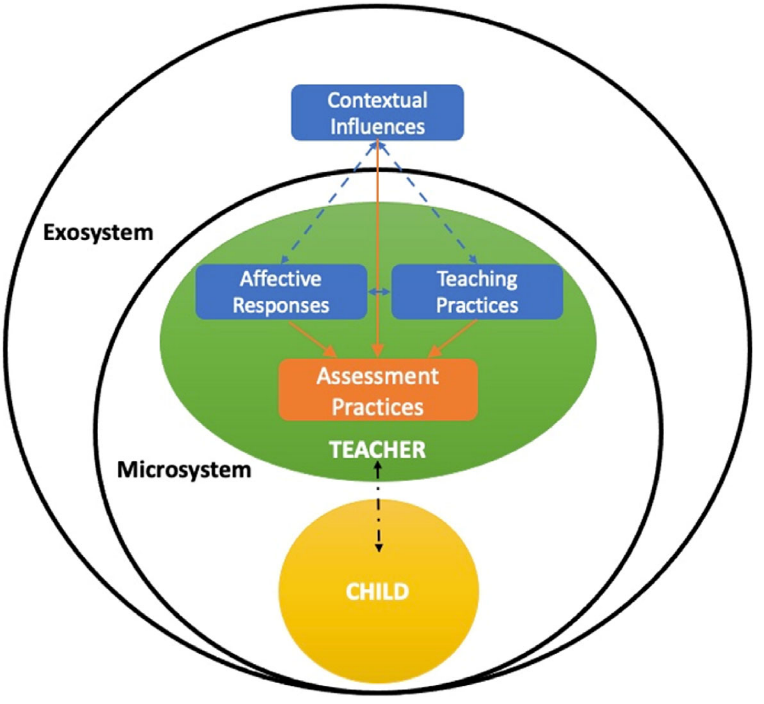


**FIGURE 3** Influences on science assessment practices positioned within bioecological theory (Bronfenbrenner & Morris, 2006)

contextual influences are internalized as affective responses in the teacher, in turn influencing their teaching and assessment practices prior to their interactions with the developing child. Here, the teachers are moderating changes in the exosystem and subsequently assimilating changes in the microsystem. In this way, the contextual influences, affective responses, and teaching practice exert influence on the assessment practices that guide the nature of the teacher–child interactions, ultimately impacting child outcomes.

Our findings suggest that assessment practices were not observed to be systematically integrated within science teaching practice during the implementation of the games. This is concerning because for playful learning to occur, teachers must gain an understanding of children's learning priorities through assessment *for* learning to implement needs-aligned learning objectives in play (Ilgaz et al., 2018; Zosh et al., 2018). If formative assessment is not undertaken, or if formative assessment does not inform planning for learning, then teachers are unsuccessful in promoting playful learning. This was observed across the three cases in this study, when the theme teaching practice was unpacked and viewed at the subtheme level. Focusing specifically on the subtheme following children's interests, we can see the complexity of influences on teachers' assessment practices in early childhood science education. Following children's interests was influenced by pedagogical practices listed in the learning frameworks (contextual influence) and the high value teachers placed on their pedagogy (affective response). Consequently, this had a compounding effect, leading to the subtheme following children's interests having great influence on assessment practice.

This influence presents in a number of ways. First, following children's interests can act as a gatekeeper to the inclusion or exclusion of science education in early childhood settings.

If a teacher determines children to be disinterested in science, not having observed this interest due to the absence of a science learning lens, planned opportunities for children to engage with science learning experiences may not be included in curriculum planning. In this circumstance, assessment of science process skills would not even be considered as an interest in science is not established. Further, as science is not explicitly articulated in the current version of the EYLF, teachers may be less inclined to introduce science into their planning. In the absence of opportunities for science-related exploration, minimal opportunities would present themselves for observation and assessment *as*, *of*, or *for* science learning. The absence of science learning opportunities would thus be self-perpetuating and restrict science-focused proximal processes, limiting the children's science learning. Second, if science learning is based solely on a child's interest in a science-related topic, this may lead to planning based on fact acquisition rather than learning experiences designed to facilitate informed assessment of children's observation, analysis, and reasoning skills. Both these scenarios demonstrate a preference for child-directed learning, precluding opportunities for playful learning that would enable a more child-centered approach (Pyle & Danniels, 2017). Indeed, it is critical to have a balance of integrated teaching and learning approaches alongside the assessment of children's capabilities and interests to allow for intentional playful learning opportunities to occur in science and, indeed, all learning contexts. This integrated approach is explicitly supported by the EYLF (Department of Education Employment and Workplace Relations, 2010) that highlights the importance of teachers drawing on a "rich repertoire of pedagogical practices to promote children's learning" (p. 16) including intentional teaching, learning through play, and assessment for learning. Our findings demonstrate a unique dynamic between assessment, teachers' affective responses and practice, and wider contextual influences. Teachers following children's interests was strongly associated with the absence of science assessment (with minor exceptions) to inform planning for learning within the informal curriculum. This highlights the importance of balancing the key early childhood teaching practice of following children's interests and assessment *for* learning to facilitate the full spectrum of playful learning opportunities (Ilgaz et al., 2018; Zosh et al., 2018).

Having identified that teachers often apply child-directed practices rather than child-centered practice when assessment for science learning is absent, we have established the need to support teachers to integrate play and assessment in early childhood science. To address this gap, we propose an assessment *for* playful learning model to make explicit the relationship between assessment for learning and playful learning (Figure 4, Table 4). Here, we describe the cycle of assessment for playful learning and demonstrate its applicability specifically to science learning in Table 4. In this model, four steps lead to playful learning, which in turn feed back into the cycle of assessment for playful learning. Each step involves intentional decision-making, and therefore the model is situated in a reflective context.

With a particular focus in mind (such as a child's science observation skills), the first step is to purposefully collect information about what children do, say, make, draw, or write. The emphasis here is on teachers gathering *meaningful* information from a range of sources (e.g., primary caregivers, other teachers or professionals, and the children themselves), specifically relating to what is to be assessed. Second, teachers assess the children's capabilities *and* identify their interests. Here, we place interests alongside capabilities to highlight the importance of both assessing children's learning and continuing to understand their interests to serve as the vehicle for learning. Next, the teacher identifies contingent learning objectives that respond to the child's assessed capabilities. This allows for future learning to be responsive to individual children and thus support differentiation within a group of learners. This also ensures the continuation of child-centered practice. The fourth step is to prepare the learning environment and to plan specific teaching strategies. This may involve setting up new play areas as provocations for learning in line with objectives, or creating lists of words to use to support skill development in play. Having planned learning objectives that are informed by assessments of both interests and capabilities, the teacher is well prepared to recognize and support learning that arises in play. From here, teachers take on various roles in play as they intentionally balance the triple helix of child-directed play, guided play, and adult-led play, all of which contribute to child-centered playful learning (Department of Education, 2018; Department of Education and Training [DET], 2017). Assessment for playful learning does not end at this point. The playful learning itself sets up the context for teachers to collect further information about children's learning and to continue through the steps of the cycle once again. We suggest that assessment *for* playful learning can be applied in early childhood science education (see Table 4), and further research may support its use across multiple learning areas.

## 6.1 | Limitations

Our findings should be considered in light of some limitations. The primary limitation to the generalization of these results is the small sample size. A larger sample size would have enabled inferences to be drawn regarding the challenges associated with using the SciDoc. In addition, future studies may consider the design of affective response documentation and continuous improvements that could be implemented with additional interviews over time. However, the in-depth analysis of three interviews and evidence from assessment practice provided rich data for analysis and revealed that the SciDoc was not applied systematically by participants.

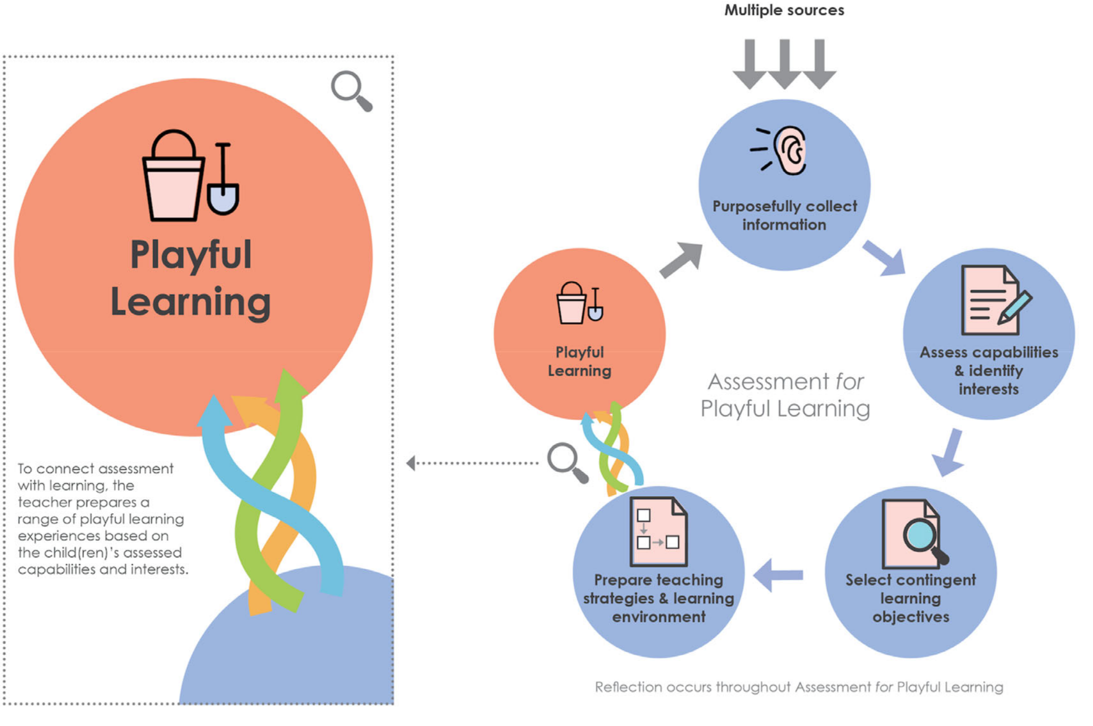


**FIGURE 4** Assessment for playful learning

**TABLE 4** Application of assessment for playful learning model to early childhood science education

| Assessment *for* playful learning | Examples of application in context of early childhood science education |
|---|---|
| Purposefully collect information | Purpose:<br>• To identify child's classification skills<br>Information collected:<br>• Child collecting stones outdoors and placing them in small piles. Picks up one stone and says, "This is a small baby one. Over there are big, big, bigs" and points to stones of different sizes<br>• At drop off, child mentioned collecting shells at the beach on the weekend |
| Assess capabilities and identify interests | Identified interest:<br>• Collecting objects<br>Identified science process skill capability:<br>• Classifying learning progression (see Figure 1)<br>(1) Identifies features and characteristics of objects or living things |
| Select contingent learning objectives | Learning objective:<br>• For the child to identify features and characteristics of objects or living things |
| Prepare teaching strategies and learning environment | Learning environment:<br>• Set up a sandbox with a range of shells, small rocks, and stones, sticks, and available natural materials that can be sorted into groups based on size, color, and shape<br>• Introduce "collection buckets" into the room and create a space for classifying collections<br>Teaching strategies:<br>• Words to use include classify, sort, group, same, different<br>• When prompting to classify objects focus on size, color, parts, and/or shape<br>• Ask open-ended questions like "What do you notice looks the same about these items?" and "How are these objects different? Why do you think that?" |
| Playful learning | • Monitor free play with objects in the sandbox<br>• Identify opportunities to introduce collection buckets in guided play if possible or make time for adult-led play in small group<br>• If interest in collecting wanes, continue to use teaching strategies to support classification skills as opportunities arise in all forms of play<br>• Purposefully observe if child is demonstrating next step in learning progression or continuing to consolidate learning |

This may be due to inaccuracies in the theoretical learning progressions underpinning the SciDoc, indicating further research on learning progressions of science process skills is required. In addition, the purpose and application of the instrument may not have been made clear enough to teachers during the introductory seminar. Finally, further research is required to test the generalizability of our model of assessment *for* playful learning and its usability in early childhood education settings.

## 7 | CONCLUSION

To advance science assessment within the context of an informal early childhood curriculum, it is necessary to support teachers to recognize and extend children's scientific learning as expertly as they follow children's interests in play. This will require increased resourcing of early childhood science teaching and learning that is systematic, sustained and tailored to meet teachers' needs. In this way, teachers will be better supported to embed new resources and approaches into their everyday teaching practice. Ultimately, this will allow teachers to understand what each child knows already, what they are ready to learn next, and the context within which they are interested in learning—that is, the child's interests. Getting the balance right between following interests and using assessment to extend learning would further strengthen pedagogical practice. When this balance is out, play may not result in scientific learning or there is a risk of rote teaching of scientific facts. We need to strive toward an equilibrium. When the balance is right, early childhood teachers integrate science teaching and learning into children's play through purposeful interactions that meet children at their level of capability and provide opportunities for learning within an area observed to be of interest to the child.

Assessment practice requires improvement in Australian ECEC services (Australian Children's Education & Care Quality Authority, 2019, 2020, 2021). In a step toward addressing this improvement need, we have proposed a cycle of assessment *for* playful learning to encourage teachers to make thoughtful and purposeful decisions regarding science education. When teachers collect information, assess children's current understanding, and identify children's interests, they are equipped to introduce new ideas to the children, create opportunities to assess new skills, observe children as they engage in free play and, importantly, engage in guided play drawing on learning objectives informed by, and informing, the assessment process. This clarity of purpose supports teachers to observe and assess what children know already and what they are ready to learn next. When teachers know what learning is possible within playful science experiences, they are better equipped to observe children demonstrating what they know already. It is at this point that authentic scaffolding—and planning for learning—can take place.

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