Research in Science Education
https://doi.org/10.1007/s11165-026-10327-8

Uncovering Science Education in Australian Early Childhood Teacher Qualifications

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Received: 24 July 2024 / Revised: 2 September 2025 / Accepted: 6 March 2026

Abstract
Despite the existence of a national Science, Technology, Engineering and Mathematics (STEM) education agenda highlighting the importance of science education in the years before formal schooling, guiding documents for early childhood curricula and practice in Australia continue to lack systematic integration of science teaching and learning. Without clear guidance on how science (or science as an element of STEM) can be enacted in early childhood education, there is similarly limited guidance for the integration of science in initial teacher education (ITE). A social research audit of publicly accessible course handbooks was used to understand how science is positioned within Australian early childhood ITE programs. Findings suggest that preparation to teach science is highly variable, ranging along a continuum from none at all, through exposure to science within an integrated STEM or STEAM subject, to the development of discipline-specific science pedagogical content knowledge. This variability has implications for future research, policy and practice.

Keywords Higher education · Teacher preparation · Early childhood education · Science education

Introduction

Since the promulgation of the Childcare Act 1972 in Australia, state, territory and federal governments have played an active role in shaping early childhood education and care (ECEC) provision through implementing and monitoring policies (Irvine & Farrell, 2013). In turn, these policies influence the development of initial teacher education (ITE) programs at tertiary institutions nationwide. Here, universities play a key role in contributing to the quality of ECEC through their ITE delivery, ensuring that our future ECEC workforce is

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equipped with the knowledge, skills and abilities to support our youngest learners (Cohrssen et al., 2023).

The approved national framework for early childhood education and care, the Early Years Learning Framework for Australia Version 2.0 (EYLF, Australian Government Department of Education for the Ministerial Council (AGDE), 2022), includes the concept of "scientific thinking" (p. 53) for the first time. This inclusion comes without clear guidance on how science can be enacted in ECEC and consequently, there is similarly limited guidance for the integration of science in ITE courses. The Australian Children's Education and Care Quality Authority (ACECQA) requirements for early childhood teaching program assessment simply mention the inclusion of 'mathematics, science and technology' (ACECQA, 2024, p. 3) without elaboration. Yet, research continues to demonstrate the power of science education in early childhood for enhancing positive attitudes towards science (Eshach & Fried, 2005; Patrick et al., 2009), high levels of confidence, enjoyment, and overall interest in science later in school (Mantzicopoulos et al., 2008; Oppermann et al., 2018), school readiness (Morgan et al., 2016), and as a lever to increase the quality of instructional support in classrooms (Guarrella et al. 2022b; Cabell et al. 2013; Kook and Greenfield 2020).

We set out to explore how the limited reference to science in early childhood guiding documents may influence the inclusion of science in university-level early childhood ITE programs across Australia. It is envisioned that the findings will act as a point of international comparison for academics and higher education institutions reflecting on, and researching, the relationships between policy documents and ITE curricula. As an overarching research aim, we seek to understand how science is positioned within ITE programs by examining publicly available course information to determine what, when, how, and to whom this is delivered.

Specific research questions were:

1. Which initial teacher education qualifications included a focus on science education in early childhood?
2. What proportion of time was dedicated to science within ITE programs?

Background

Australian Early Childhood Initial Teacher Education

The National Quality Framework (NQF) is Australia's system for regulating early childhood education and care and comprises national law and legislation, the National Quality Standard (NQS), the assessment and quality rating process and approved learning frameworks such as the EYLF (ADGE, 2022). ACECQA is the independent national authority that assists state and territory governments in administering the NQF. It undertakes the assessment and approval of individual and organisation qualifications as set out by the NQF. These requirements are aligned with the Education and Care Services National Regulations, 2011 and stipulate that at least 50% of educators employed within an early childhood service must be diploma-level qualified or hold a higher qualification. In addition, each early childhood service is required to engage a specified number of early childhood teachers

(ECTs) relative to the number of children attending early childhood education and care at any given time.

Approved ECT qualifications include bachelor's degrees, master's degrees and graduate diplomas. Bachelor's degrees are typically four-year degrees that include 80 days of supervised professional experience (sometimes referred to as 'placement' or 'practicum'). For individuals with prior university qualifications, postgraduate pathways to becoming an ECT include both master's degrees and graduate diplomas in early childhood education. These range from one to two years in duration depending on study loads. Such qualifications include 60 days of supervised professional experience with a minimum of 10 days spent with children aged under three years and 20 days with children aged three to five years.

In approving ITE course accreditation applications, ACECQA takes four key requirements into consideration: (1) qualification level, (2) age focus, (3) duration of supervised professional experience and 3) curriculum content. Six curriculum content areas are taken into consideration. Pertinent to this research, is the content area of education and curriculum studies. This is where "numeracy, science and technology" are required for ECT qualifications (ACECQA, 2024, p 3).

Australian Policy Landscape

The introduction of the National Innovation and Science Agenda (NISA) in Australia (Department of the Prime Minister and Cabinet, 2015) led to the endorsement of a National STEM School Educational Strategy by Australian Education Ministers in 2015 (Education Council, 2015). This document highlights that "foundational STEM knowledge needs to start from early childhood" (p. 5) and includes early childhood science, technology, engineering and mathematics (STEM) as a jurisdictional priority action to build "early curiosity for science and technology, and the importance of foundational numeracy skills" (p. 8). The E of STEM (engineering) is notably missing from this statement, and difficult to find in curriculum documentation (Cohrssen et al., 2025). Further, whilst signalling the importance of science, technology and numeracy in early childhood, this national policy document leaves the implementation of foundational STEM teaching and learning, and what this means, to the states and territories. This national education policy has not been fully realised within the ACECQA early childhood ITE accreditation documents. There is no mention of STEM, only mathematics, science and technology in the ITE accreditation requirement documents (ACECQA, 2024). These conflicting messages create confusion as to how science or STEM should be included in ITE programs. In this study, we examine the inclusion of science in ITE as this is required by the accrediting body ACECQA, yet we acknowledge the potential presence of STEM in ITE programs due to conflicting policy messages.

In light of this contradiction, it is perhaps unsurprising that recent Australian education policy reviews have identified that early childhood STEM education is underdeveloped in strategy documents (Murphy et al., 2019). Indeed, science has also been identified as lacking, with the systematic integration of science teaching and learning absent across documents guiding curricula and practice in Australia (Guarrella 2022a). Both versions of the EYLF (AGDE, 2022; DEEWR, 2009), which have guided early childhood education and care in Australia since 2009, have focused on inquiry and experimentation lending themselves to supporting the development of children's science process skills (Guarrella 2022a). The first version of the EYLF suggested that educators could "model mathematical and scientific language and language associated with the arts" (DEEWR, 2009, p. 38). The second version has gone two small steps further by suggesting that educators "support all children to access science and technology experiences" (p. 35), includes the term "scientific thinking" in the context of children's learning (p. 53) and suggests that cooking experiences and sand and water play can be used to support children's scientific skills (p. 54). However, this document does not include science-specific conceptual or procedural knowledge (Havu-Nuutinen et al., 2021).

Similarly, the *indirect* inclusion of science through the teaching and learning of STEM varies across states and territories – despite the existence of a national strategy document (Education Council, 2015). Specific jurisdictional strategies in Victoria and South Australia acknowledge discrete subject areas, encouraging deep knowledge in science, mathematics and technology to encourage connections between learning areas being developed later (Department of Education and Training, 2016; Department for Education, 2024). Tasmania, on the other hand, takes an interdisciplinary approach to STEM from early learning through to secondary schooling (Department of Education, 2017). Again, due to this inconsistent messaging on the indirect inclusion of science through STEM, we take direction from the EYLF (AGDE, 2022) which refers to scientific thinking and science process skills to direct the focus of this study towards science education in early childhood ITE as opposed to STEM in ITE.

Importance of Science in Early Childhood

Young children's learning and development is influenced by a complex interplay of bi-directional interactions with people, objects and symbols in their environment, over time (Bronfenbrenner & Morris, 2006). Within the context of early childhood education, this necessitates intentionality by the teacher in the way they resource learning opportunities, construct learning environments, and purposefully interact with children within the early childhood setting. By extension, this has implications for the 'what' and 'how' of science education in early childhood, yet the corpus of literature in this field remains small (O'Connor et al., 2021). Whilst outcome measures used to assess children's science understanding are few, aligned with bioecological theory of development (Bronfenbrenner & Morris, 2006), research often uses measures of interaction quality to infer potential child outcomes (Greenfield et al., 2024; Authors, 2021). Research has demonstrated that when science teaching and learning starts in early childhood, it can enhance children's science achievement and understanding of science concepts when studied formally at school (Eshach & Fried, 2005; Saçkes, 2013). In addition, playful science experiences offer both an ideal context for children to develop executive function skills (Bustamante et al., 2018; Nayfeld et al., 2013) and support children's positive attitudes towards science (Patrick et al., 2009). When children start school with gaps in physical, biological and social sciences general knowledge, they experience persistent science achievement gaps throughout schooling (Morgan et al., 2016). Learning is a cumulative process as existing knowledge forms the basis on which new knowledge is built (Duncan et al., 2007) and so to bridge gaps in what children know, it is necessary to consolidate existing understanding as well as for children to acquire new knowledge and skills.

To support children's scientific learning in early childhood, teachers need to take an active role in identifying children's current interests and capabilities as well as what they are ready to learn next in play (Guarrella et al.,, 2023). Yet, research demonstrates teachers in the United States, Australia and Germany spend little time interacting with children in science-related experiences in early childhood settings (Early et al., 2010; Oppermann et al., 2019; Press et al., 2024). Whilst opportunities and resources are provided for children to explore, teachers seldom engage with children exploring the resources to promote science learning (Gelman & Brenneman, 2004; Nayfeld et al., 2011; Tu, 2006). As a result, in the absence of teacher engagement during children's play with the science resources, children are likely to use the materials as props within imaginary play – this play is important, but opportunities are missed to facilitate science learning (Fleer, 2009).

This so-called 'hands-off' approach to early childhood science education can be linked to teachers' attitudes, beliefs, and confidence in teaching science to young children. Research has demonstrated that while teachers may have positive attitudes towards science within the context of early childhood education, they demonstrate a lack of confidence in their own science knowledge and feel uncomfortable planning science experiences (Oon et al., 2019; Pendergast et al., 2017). Further, teachers' confidence in their scientific knowledge and ability to teach science directly relates to both the frequency with which they engage children in science experiences (Gerde et al., 2018) and how they implement their science curricula (O'Brien & Herbert, 2015). What is more, teachers' lack of confidence in turn influences children's motivation towards science (Oppermann et al., 2019), thus impacting their lifelong engagement with science and science learning. This is clearly of concern, given that teachers are among the most powerful influences on learning (Hattie, 2023).

In summary, based on this corpus of literature, ACECQA accreditation documents (ACECQA, 2024) and our understanding of the EYLF (ADGE, 2022), there is a compelling case for giving science a more prominent position in early childhood ITE qualifications. Informed by this perspective, this research seeks to identify the position of science education in Australian early childhood ITE courses. We seek to understand if science is presented as a discrete subject to preservice teachers, as one part of STEM, or whether in essence, preservice teachers are presented with an integrated STEM approach from the start. We are also interested in the emphasis placed on science education to infer the strength of students' science pedagogy as they enter the profession. This is a critical first step in understanding the development of workforce capabilities in relation to early childhood science teaching and learning.

The rationale for this investigation is informed by the Process-Person-Context-Time (PPCT) model (Bronfenbrenner & Morris, 2006). Operationalising Bronfenbrenner's bioecological theory, the PPCT model emphasises that everyday bidirectional interactions between the developing child and people, objects and symbols over time (Siraj & Huang, 2020) within children's most immediate (proximal) environments drive the "engines of development" (Bronfenbrenner, 2001, p. 6767). These proximal processes occur fairly regularly and become increasingly complex over "extended periods of time" (Bronfenbrenner & Morris, 1998, p. 996). In the application of the PPCT model, early childhood educators and children's peers constitute the people with whom most interactions take place. Indeed, educators play a crucial role as they shape the learning environment and thus influence interactions that occur within them. The immediate *context* of concern to us in this study is the early childhood setting itself. A science focus in ITE qualifications would contribute to the characteristics of educators as they would be equipped to encourage children's science skills and dispositions through back-and-forth interactions, the design of learning experiences that encourage scientific exploration and thinking, and the frequency with which scientific ideas are addressed.

This research, grounded in the Australian context, offers valuable insights with broad international applicability. By systematically investigating science subject offerings in early childhood ITE, this study serves as a crucial point of comparison for researchers worldwide examining the connections between policy documents and ITE curricula. The findings may inform the development of evidence-based curricula to equip teachers globally with the pedagogical content knowledge required for early childhood science teaching and learning. In the section that follows, we detail a framework for the audit process that guided our study, enabling future replication in international contexts.

Method

Recently, Australian research has begun to examine ITE course offerings and their alignment with guiding documents and educational philosophy (Davis & Davis, 2020; Jones & Tonge, 2025; McArdle et al., 2019). To varying degrees, these studies have conducted audits to examine the extent to which play (McArdle et al., 2019), physical education (Jones & Tonge, 2025) and "education for sustainability" (Davis & Davis, 2020) are embedded in early childhood ITE courses. Hughes (2005) highlights the common cyclical process shared by audit processes and social research; defining expectations, selecting methods for observation and analysis and finally, bringing about change. The current study adopted the following three-stage research process:

Stage 1: Expectations Defined by Setting Research Questions

Based on our appraisal of the background literature, the following research questions were established to guide the study:

1. Which types of ITE qualifications include a focus on science education in early childhood?
2. What proportion of time is dedicated to science within ITE programs?

Stage 2: Select and Apply Research Methods to Appraise ITE Courses and Rigorously Analyse Data

Data derived from publicly accessible course handbooks that provide course and subject overviews, learning objectives and requirements. For this research, a *course* was defined as a program of study consisting of multiple *subjects* needing completion to fulfil the requirements of a *qualification*. As the information we analysed is in the public domain, no specific university ethics approval was necessary.

The ACECQA website was reviewed in October 2023 to identify ITE courses named on the NQF Approved Qualifications list[1]. Bachelor's degrees, graduate diplomas in early childhood education and master's degrees in early childhood education that lead to an accredited early childhood teacher qualification were identified (see Appendix 1). This included dual qualifications (early childhood and/or early childhood and primary). Courses named on the

[1] https://www.acecqa.gov.au/qualifications/nqf-approved.

Table 1 Number of accredited early childhood initial teacher education courses by qualification level

Qualification level	No. of accredited courses
Bachelor's degrees	50
Graduate diplomas	8
Master's degrees	22
Total	80

NQF Approved Qualifications list that were not offered through Australian education institutions were excluded. A total of 80 courses were included in the final dataset (Table 1).

In a second step, a Microsoft Excel database was created (see Appendix 2 for an example of the database structure). Website hyperlinks within the ACECQA NQF Approved Qualifications list were followed to university websites on which course outlines were accessed. The name of the university, the name of the course, qualification type, total core credit points and the website hyperlink were recorded in the database. Next, course outlines were reviewed to determine whether science was taught as a discrete subject and/or taught as part of integrated STEM or integrated STEAM subjects. To address the first research question, the names of science, technology, engineering, mathematics, arts, integrated STEM and/or integrated STEAM subjects were recorded for each course and assigned a score of 1 if the subject area was included and a score of 0 if it was absent. Integrated STEM subjects were defined as subjects integrating two or more of the STEM disciplines and integrated STEAM subjects were defined as subjects that integrated one or more of the STEM disciplines with the arts. In a third step, it was noted whether each subject was compulsory or an elective and coded with a score of 1 (compulsory) or 0 (elective). To address the second research question, the relative weighting of each subject was calculated and recorded (e.g., 6 credit points out of a maximum total of 72 credit points = 8.33%). These data were then analysed using descriptive statistics.

Stage 3: Discussion of Findings and Implications to Bring About Change

Following the presentation of the results, this stage of the research process will be addressed within the discussion, limitations and conclusion.

Results

A total of 466 subjects were reviewed and categorised as Science ($n=59$), Integrated STEM ($n=65$), Integrated STEAM ($n=20$), Technology ($n=36$), Engineering ($n=0$), Mathematics ($n=146$) or Arts ($n=140$). Of these subjects, 396 were classified as a core subject and 70 were elective subjects. Figure 1 demonstrates the number of core and electives by subject category, including mathematics, technology, engineering and arts for comparison. Of interest, the elective subjects were all within the bachelor's qualifications (as opposed to master's degrees or graduate certificates), with the exception of two elective mathematics subjects and fourteen elective arts subjects across the master's programs.

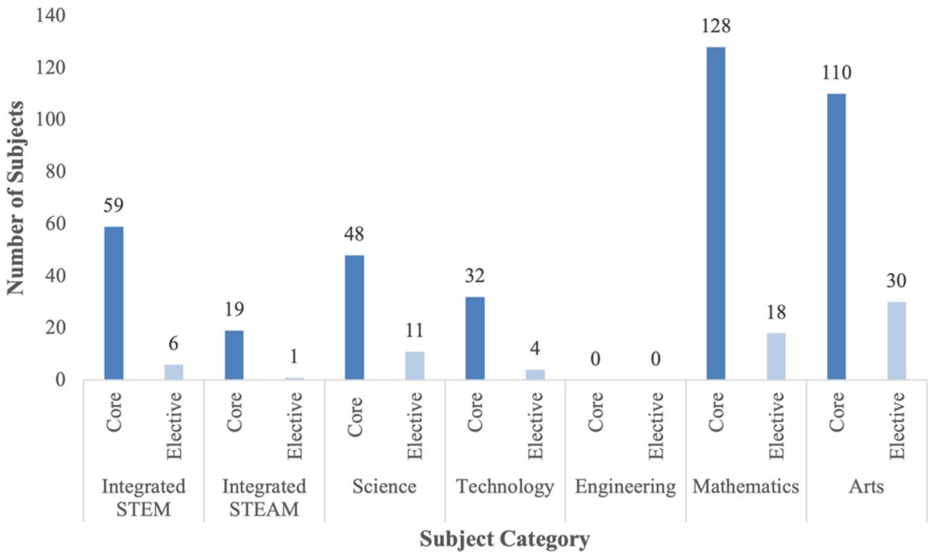

Fig. 1 Count of core and elective subjects by subject category

Inclusion of Science Content by Qualification Types

The analysis that follows focuses on core subjects and excludes elective subjects. This approach aimed to identify the typical experience of a student enrolling in courses, as opposed to a student who may prefer to undertake additional study in a discrete subject area.

The proportion of courses offering each subject category was tabulated to enable identification of the number of courses offering discrete science subjects across qualifications and the proportion of the courses within the qualification type subsample of the dataset (Table 2). Of note, 54% of bachelor's degree courses offer a discrete science subject, followed by 41% of master's degree courses. Critically, discrete science subjects are *absent* from graduate diploma courses (Table 2). In addition, four courses provided *no* science content at all, whether as a stand-alone subject or indirectly embedded in STEM or STEAM subjects (bachelor's courses $n=1$, graduate diploma courses $n=1$, master's courses $n=2$).

Proportion of Time Dedicated to Science

Of the courses that included science content, between 2.5% and 8.33% of the total course was dedicated to core science subjects. The average weighting relative to the overall degree

Table 2 Proportion of courses offering one or more subjects in science, integrated STEM or integrated STEAM by qualification level

	Science (%)	Integrated STEM (%)	Integrated STEAM (%)
Bachelor's degree	27(54)	30(60)	6(12)
Graduate Diploma	0 (0)	5 (63)	3(38)
Master's degrees	9 (41)	11 (50)	8 (36)
All qualifications	36 (45)	46 (58)	17 (21)

varied across qualifications, with bachelor's courses having a lower average science weighting (4.55%) relative to the overall degree, in comparison with master's degrees (6.16%) (see Fig. 2). However, longer ITE courses (i.e. a four-year bachelor's degree versus a two-year master's degree), allocated 'course time' to stand-alone science subjects *as well as* science accessed indirectly through integrated STEM and STEAM subjects.

As the graduate diploma courses included no discrete science subjects at all, we next examined the credit point weighting of the integrated STEM and STEAM subjects relative to the overall weighting of the degrees to estimate the proportion of time *indirectly* dedicated to science via STEM or STEAM. Graduate diploma courses allocated a higher credit point weighting to integrated STEM and STEAM subjects than the bachelor's and master's degrees (see Figs. 3 and 4). This difference is particularly pronounced in the integrated STEM subjects (Fig. 3).

Discussion

This study set out to understand how science was positioned within early childhood ITE programs given that it receives little attention in the revised EYLF (AGDE, 2022) despite the decade-old endorsement of a National STEM School Educational Strategy (Education Council, 2015) that includes an explicit priority to encourage curiosity in science in early childhood. This was motivated by our desire to determine the emphasis placed on science education in ITE courses to gain insight into the preparedness of new graduates to support science teaching and learning since teachers have great influence on teaching and learning (Hattie, 2023). In the past, early childhood educators have been reported to lack self-efficacy in science teaching and learning (Oon et al., 2019; Pendergast et al., 2017) which impacts the frequency with which they invite to children think scientifically (Gerde et al., 2018). Yet, early childhood teachers play a crucial role within the PPCT model (Bron-

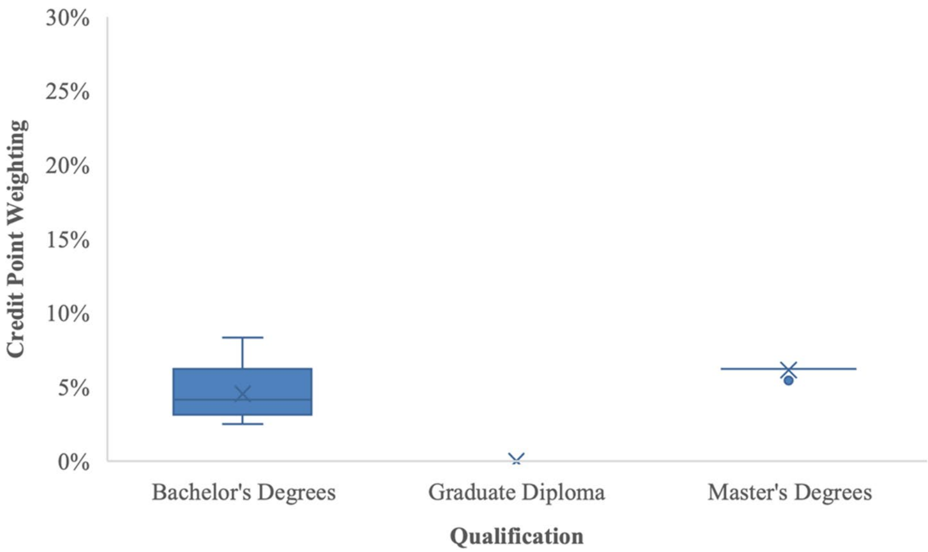

Fig. 2 Credit point weighting of discrete science subject relative to overall degree, by qualification type

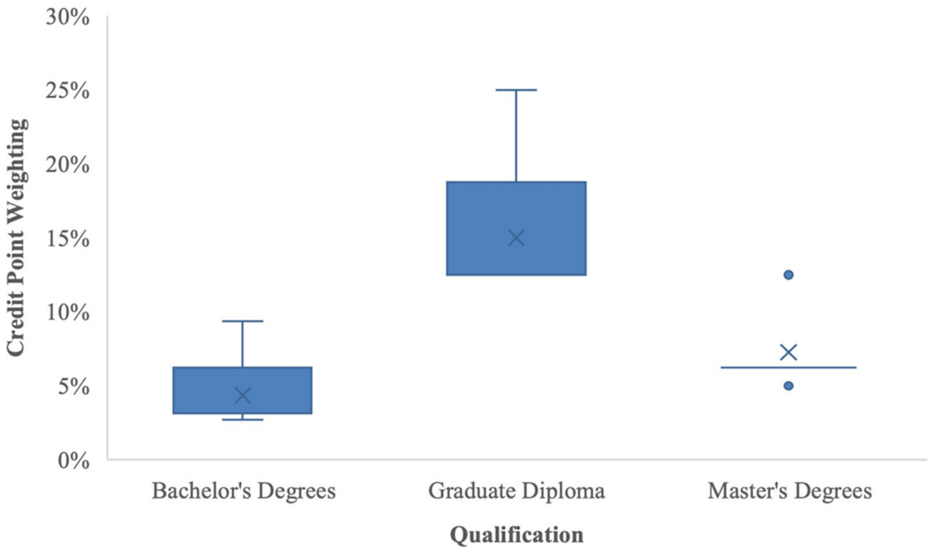

Fig. 3 Credit point weighting of integrated STEM subject relative to overall degree, by qualification type

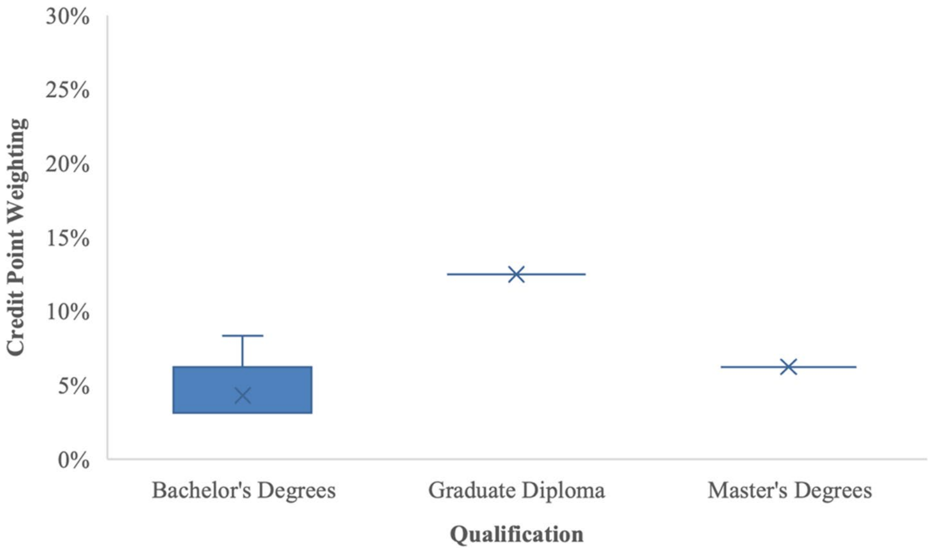

Fig. 4 Credit point weighting of integrated STEAM subject relative to overall degree, by qualification type

fenbrenner & Morris, 1998; Siraj & Huang, 2020) by shaping children's learning context through the provision of playful learning experiences that encourage proximal processes characterised by scientific thinking, exploration and language. To determine the extent to which recently graduates are equipped to engage in high quality science-related proximal processes, a social research audit was conducted of publicly available course outlines for

ACECQA-accredited early childhood teacher qualifications. We found the focus on science as a discrete subject to be highly variable in Australian early childhood ITE courses, despite ACECQA accreditation requirements outlining the mandatory inclusion of science content within these programs (ACECQA, 2024).

Whilst we aimed to investigate the position of science in early childhood ITE programs, when science was not present as a discrete subject within a course, we had to search for its implied presence in STEM or STEAM subjects. With the exception of three courses, the bachelor's and master's degrees we reviewed required students to complete either a discrete science subject, or an integrated STEM or STEAM subject. Consequently, Australian EC bachelor's and master's degree ITE courses occupy differing positions along the STEM spectrum, ranging from segregated content areas to integrated STEM (Nadelson & Seifert, 2017). This inevitably leads to inconsistency in early childhood teachers' preparation to support science learning in early childhood but reflects the conflicting messages embedded in guiding documents and policy statements concerning the inclusion of science and/or STEM education in early childhood (Guarrella et al., 2022a). This inconsistency of policy direction is visible in individual institutions' differing interpretations of the requirement to include "numeracy, science and technology" in ACECQA-accredited ITE courses (ACECQA, 2024) and highlights the need for further research in this regard.

The graduate diploma courses included in our dataset, on the other hand, offered only integrated STEM or STEAM subjects: no discrete science subjects were included in these ITE courses. All graduate diploma qualifications are thus positioned at the 'integrated' end of the STEM spectrum (Nadelson & Seifert, 2017). The degree of STEM integration within these subjects remains uncertain – whether this is multidisciplinary, interdisciplinary or transdisciplinary (Vasquez et al., 2013). Indeed, further research is necessary to identify whether preservice teachers are afforded the opportunity to develop discipline-specific pedagogical content knowledge (Shulman, 1986) in science to equip them to recognise, respond to, and plan for children's learning, or whether discrete content knowledge is overlooked in pursuit of STEM (or STEAM) as an integrated learning area.

Alarmingly, we identified one graduate diploma, one bachelor's degree and two master's degrees that did not require all students to complete either a discrete science subject, or science content as a component of an integrated STEM (or STEAM) subject. Research has consistently demonstrated teachers' lack of confidence in their science knowledge and their ability to plan for and teach science in early childhood (Oon et al., 2019; Pendergast et al., 2017). The absence of science in ITE programs is a missed opportunity to equip and support preservice teachers to gain this confidence early in their careers. Ultimately, this impacts the children in ECEC settings as teachers are less likely to encourage proximal processes characterised by scientific thinking, interact with children in playful science experiences that support the development of executive function skills (Bustamante et al., 2018), prepare children for formal science learning at school (Eshach & Fried, 2005; Morgan et al., 2016; Saçkes, 2013) and last but by no means least, respond to children's interests (Clements & Sarama, 2016).

The proportion of time dedicated to science within the ITE programs included in this research was interrogated to address the second research question. The three types of qualification vary in duration from one year to four years. The longer the qualification takes to complete (i.e. a four-year bachelor's degree versus a one-year graduate diploma), the lower the overall weighting of the science content, relative to the overall qualification. However, whilst the subject weighting for science may be low, longer courses can allocate ‘course time’ to multiple stand-alone science, STEM or STEAM subjects. This cumulative approach may allow students to gain knowledge and pedagogical skills in individual discipline areas to teach them as an integrated, cohesive whole – an approach that aligns with the integrated, informal curriculum enacted in Australian early childhood settings.

By comparison, the year-long graduate diploma qualifications we examined did not offer discrete science subjects, yet when they included STEM subjects, a higher proportion of time was allocated to STEM subjects than to discrete science, or integrated STEM or STEAM subjects, in bachelor’s and master’s degrees. This larger proportion of time may allow teacher-educators to focus on both the discipline-specific pedagogical content knowledge *and* the integrated nature of STEM or STEAM. However, it is unclear from handbook documents whether ITE curriculum design decisions in this regard are informed by course-level pedagogical positions about how preservice teachers’ learning is best supported, whether such decisions are intended to tap into the current STEM or STEAM zeitgeist (Clements & Sarama, 2021), or whether subjects are bundled together due to crowded ITE curricula. Knowledge of and confidence in recognising and teaching the big ideas of science are critical cornerstones that form strong, stable foundations for EC teachers to facilitate science learning. If these are not adequately addressed, the state of science education in Australia will continue to languish (Guarrella et al., 2022a).

Limitations

This study merely scratches the surface of science education in Australian early childhood ITE courses and consequently has several limitations.

First, whilst allowing us to answer the research questions, our method reduced the data to set categories (subjects) that were coded as present or absent within each ITE course. In addition, we defined integrated STEM subjects as subjects integrating two or more of the STEM disciplines, and one or more of the STEM disciplines with arts in STEAM subjects. This allowed us to identify courses that had multiple STEM subjects. The limitation here, however, was that this approach focused on individual subjects within a qualification, rather than looking at how subjects might ‘hang together’ to form a cohesive whole. By way of example, one of the bachelor’s degrees in this study includes two three-credit point subjects (Mathematics & Engineering, and Science & Technology) to be completed successfully as prerequisites to enrolling in a six-credit point subject (STEM in Early Childhood Education). The coding we employed thus classified all three subjects as integrated STEM subjects. In practice, the structure of this cluster of subjects allows for the discrete subjects to be addressed individually before students are supported to undertake an integrated STEM approach. Further analysis of subject outlines and content – a deeper dive into curriculum documentation – is needed to determine the extent to which the ‘big ideas’ are being taught to equip pre-service teachers with the ability to encourage and extend children’s science learning through the enactment of the Early Years Planning Cycle (Guarrella et al.,, 2023).

Second, the number of graduates per annum completing the courses included in this audit study is unknown. Consequently, the impact on children’s learning at a population level as a consequence of this highly variable teacher preparation is yet to be determined.

Third, this study was limited in scope investigating science education in early childhood ITE courses accredited in Australia. Early childhood policy, frameworks and curricula differ across the globe and the extent to which science education is embedded within these documents varies (Havu-Nuutinen et al., 2021). Further, the systems and processes for accrediting ITE qualifications are not standardized. Future research may need to adapt elements of the method to accommodate the education policies and context of the country in which it is conducted.

Finally, this study provides cross-sectional data, demonstrating a snapshot in time. Courses are refined and handbooks are updated by universities every year. Further, course reviews and the four-year course accreditation cycle result in significant changes being made to subjects and courses. These indicative findings should thus be cautiously interpreted.

Conclusion

In this study, we sought to understand how and where science was incorporated in initial teacher education courses. In bachelor's and master's degree courses, science was presented as a discrete subject and indirectly through integrated STEM or STEAM. On the other hand, science was always integrated with technology, engineering and mathematics (and at times, the arts) in graduate diplomas: from the start, preservice teachers enrolled in graduate diplomas were being taught STEM or STEAM without first learning about the disciplines as parts of the whole. We were also interested in the relative weighting of science courses within ITE courses to infer the extent to which graduates were equipped to teach science in early childhood settings when they enter the profession. Our findings suggest that preparation to teach science is highly variable, ranging along a continuum from none at all, through exposure to science within an integrated STEM or STEAM subject, to the development of discipline-specific science pedagogical content knowledge. This variability has implications for future research, policy and practice.

We advocate for more explicit guidelines in accreditation documents beyond the inclusion of "numeracy, science and technology" in early childhood ITE courses. A focus on science needs to be embedded in all early childhood ITE courses. In the absence of explicit guidance in the EYLF (AGDE, 2022) or other policy documents, decisions need to be made about what science content and process skills are appropriate in early childhood education to support teachers and provide children with more equitable access to learning. This gap is both reflected in and compounded by variability in the focus on science in early childhood ITE courses, thus setting up inequities in children's learning. Professional learning for in-service teachers would strengthen their science pedagogical content knowledge and confidence in facilitating children's science learning as well as the integration of science concepts and processes in STEM. Our analysis suggests that where STEM and STEAM are included in ITE courses, these differ in content and approach and again, explicit guidelines would contribute to more equitable access to learning (Clements & Sarama, 2021).

Future research that dives deeper than publicly accessible course outlines would enable researchers to investigate how science subjects are delivered in early childhood ITE programs and identify the specific science pedagogy and knowledge being taught to preservice teachers. For higher education institutions' curricula to be informed by evidence of what works best to equip teachers with the necessary knowledge to notice, assess and plan for science learning, it is necessary to systematically investigate the nature of subject offerings, as well as the decisions made regarding preparing pre-service teachers to facilitate science learning in early childhood education.

Appendix 1

Table 3 Approved qualifications retrieved from https://www.acecqa.gov.au/qualifications/nqf-approved in October 2023

Qualification Type	University	Course
Bachelor's Degree	Australian Catholic University	Bachelor of Early Childhood Education (Birth to Five Years)
Bachelor's Degree	Australian Catholic University	Bachelor of Education (Early Childhood & Primary)
Bachelor's Degree	Avondale University	Bachelor of Arts/Bachelor of Teaching (Birth to 12 years)
Bachelor's Degree	Box Hill Institute	Bachelor of Early Childhood Education
Bachelor's Degree	Charles Darwin University	Bachelor of Education in Early Childhood Teaching (Birth to Twelve Years)
Bachelor's Degree	Charles Sturt University	Bachelor of Education (Birth to Five Years)
Bachelor's Degree	Charles Sturt University	Bachelor of Education (Early Childhood & Primary)
Bachelor's Degree	CQ University	Bachelor of Education (Early Childhood)
Bachelor's Degree	Curtin University	Bachelor of Education (Early Childhood Education)
Bachelor's Degree	Deakin University	Bachelor of Early Childhood Education
Bachelor's Degree	Deakin University	Bachelor of Early Childhood & Primary Education
Bachelor's Degree	Edith Cowan University	Bachelor of Education (Early Childhood Studies)
Bachelor's Degree	Excelsia College	Bachelor of Early Childhood Education (Birth to Five)
Bachelor's Degree	Federation University	Bachelor of Education (Early Childhood Education)
Bachelor's Degree	Federation University	Bachelor of Education (Early Childhood & Primary)
Bachelor's Degree	Flinders University of South Australia	Bachelor of Inclusive & Specialised Education (Early Childhood)
Bachelor's Degree	Flinders University of South Australia	Bachelor of Early Childhood Education (Birth- 8)
Bachelor's Degree	Griffith University	Bachelor of Education (ECE Major)
Bachelor's Degree	Ikon Institute of Australia	Bachelor of early Childhood Education
Bachelor's Degree	James Cook University	Bachelor of Education (Early Childhood Education)
Bachelor's Degree	La Trobe University	Bachelor of Early Childhood Education
Bachelor's Degree	La Trobe University	Bachelor of Education (Early Childhood/Primary)
Bachelor's Degree	Macquarie University	Bachelor of Teaching (Early Childhood Education)
Bachelor's Degree	Macquarie University	Bachelor of Arts with the degree of Bachelor of Education (Primary) with a major in Early Childhood Teaching
Bachelor's Degree	Melbourne Polytechnic	Bachelor of Early Childhood Education
Bachelor's Degree	Melbourne Polytechnic	Bachelor of Education (Early Years & Primary)
Bachelor's Degree	Monash University	Bachelor of Education in Early Childhood & Primary Education
Bachelor's Degree	Murdoch University	Bachelor of Education (Early Childhood and Primary Teaching)
Bachelor's Degree	Queensland University of Technology	Bachelor of Education (Early Childhood)
Bachelor's Degree	Royal Melbourne Institute of Technology (RMIT)	Bachelor of Education (Primary & Early Childhood)
Bachelor's Degree	Southern Cross University	Bachelor of Early Childhood Education
Bachelor's Degree	Southern Cross University	Bachelor of Education (Early Childhood/Primary)
Bachelor's Degree	Swinburne University	Bachelor of Education (Early Childhood Teaching)
Bachelor's Degree	Swinburne University	Bachelor of Education (Early Childhood & Primary)

Table 3 (continued)

Qualification Type	University	Course
Bachelor's Degree	TAFE NSW	Bachelor of Early Childhood Education & Care (Birth-5)
Bachelor's Degree	University of Canberra	Bachelor of Early Childhood & Primary Education
Bachelor's Degree	University of New England	Bachelor of Education (Early Childhood Education and Care)
Bachelor's Degree	University of New England	Bachelor of Education (Early Childhood & Primary)
Bachelor's Degree	University of Newcastle	Bachelor of Education (Early Childhood & Primary)
Bachelor's Degree	University of Notre Dame	Bachelor of Primary Education (Early Childhood Specialisation)
Bachelor's Degree	University of Notre Dame	Bachelor of Education (Early Childhood & Care 0–8 Years)
Bachelor's Degree	University of South Australia	Bachelor of Early Childhood Education (Hons)
Bachelor's Degree	University of Southern Queensland	Bachelor of Early Childhood (BECH)
Bachelor's Degree	University of Southern Queensland	Bachelor of Education (Early Childhood)
Bachelor's Degree	University of Sunshine Coast	Bachelor of Education (Early Childhood)
Bachelor's Degree	University of Sydney	Bachelor of Education (Early Childhood)
Bachelor's Degree	University of Western Sydney	Bachelor of Education (Early Childhood)
Bachelor's Degree	University of Wollongong Australia	Bachelor of Education - The Early Years
Bachelor's Degree	Victoria University	Bachelor of Early Childhood Education
Bachelor's Degree	Victoria University	Bachelor of Early Childhood Education & Leadership
Graduate Diploma	Excelsia College	Graduate Diploma of Early Childhood Education (Birth to Five Years)
Graduate Diploma	Monash University	Graduate Diploma of Early Childhood Education
Graduate Diploma	Royal Melbourne Institute of Technology (RMIT)	Graduate Diploma in Early Childhood Education
Graduate Diploma	Southern Cross University	Graduate Diploma of Education (Early Childhood)
Graduate Diploma	Swinburne University	Graduate Diploma of Early Childhood Teaching
Graduate Diploma	University of Melbourne	Graduate Diploma in early Childhood Teaching
Graduate Diploma	University of Southern Queensland	Graduate Diploma of Early Childhood Education and Care
Graduate Diploma	Victoria University	Graduate Diploma in Early Childhood Education
Master's Degree	Australian Catholic University	Master of Teaching (Early Childhood and Primary)
Master's Degree	Charles Darwin University	Master of Teaching Early Childhood
Master's Degree	Charles Darwin University	Master of Teaching Birth to Five
Master's Degree	CQ University	Master of Teaching (Early Childhood)
Master's Degree	Curtin University	Master of Teaching (Early Childhood Education)
Master's Degree	Deakin University	Master of Teaching (Early Childhood)
Master's Degree	Deakin University	Master of Teaching (Primary & Early Childhood)
Master's Degree	Edith Cowan University	Master of Teaching (Early Childhood)
Master's Degree	Federation University	Master of Teaching (Early Childhood)
Master's Degree	Flinders University of South Australia	Master of Teaching (Early Childhood)
Master's Degree	Macquarie University	Master of Teaching (Birth to Five Years)
Master's Degree	Monash University	Master of Teaching Early Childhood Education
Master's Degree	Monash University	Master of Teaching Early Childhood & Primary Education

Table 3 (continued)

Qualification Type	University	Course
Master's Degree	Queensland University of Technology	Master of Teaching (Early Childhood)
Master's Degree	Southern Cross University	Master of Teaching (Early Childhood)
Master's Degree	University of Melbourne	Master of Teaching (Early Childhood & Primary)
Master's Degree	University of Melbourne	Master of Teaching (Early Childhood)
Master's Degree	University of South Australia	Master of Teaching Early Childhood
Master's Degree	University of Southern Queensland	Master of Teaching & Learning (Early Years)
Master's Degree	University of Sydney	Master of Teaching (Early Childhood)
Master's Degree	University of Western Sydney	Master of Teaching (Birth to Five Years)
Master's Degree	University of Western Sydney	Master of Teaching (Birth – 5 Years/Birth – 12 Years)

Appendix 2

Course Details				Subject Details														
University	Name of course	Hyperlink to course outline	Total Core Credit Points (Course)	Name of Integrated STEM Subject	Integrated STEM 1=Present; 0=Absent	Core or Elective 1= Core; 0=Elective	Credit Point Weighting	Credit Point Weighting Relative to the Overall Degree (%)	Name of Integrated STEAM Subject	Integrated STEAM 1=Present; 0=Absent	Core or Elective 1= Core; 0=Elective	Credit Point Weighting	Credit Point Weighting Relative to the Overall Degree (%)	Name of Science Subject	Science (stand-alone) 1=Present; 0=Absent	Core or Elective 1= Core; 0=Elective	Credit Point Weighting	Credit Point Weighting Relative to the Overall Degree (%)

Fig. 5 Example of database structure

Authors' Contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Cristina Guarrella, Caroline Cohrssen and Naomi Lilley. The first draft of the manuscript was written by Cristina Guarrella and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Funding Open Access funding enabled and organized by CAUL and its Member Institutions. This work was supported by a Seed Funding Grant from the Faculty of Education, The University of Melbourne.

Data Availability The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics and Consent to Participate Not applicable.

Conflict of Interest The authors have no competing interests to declare that are relevant to the content of this article.

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