

Assessment of sustainability competencies in primary education: a systematic review

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ABSTRACT

The development of learners' sustainability competencies is critical in fostering more sustainable, socially just and equitable societies. While a growing body of literature exists on sustainability competencies' assessment in higher education, to date, research that specifically studies sustainability competencies' assessment in other education levels is scarce. Following the PRISMA guidelines, a systematic review was conducted, where 28 original studies related to sustainability competencies' assessment in primary education were analysed. An overview of the main characteristics, strengths and weaknesses of the assessment approaches and tools used is provided. The reported articles showcase a diverse range of assessment tools such as questionnaires, interviews, performance observation and drawings. To date, questionnaires are the most widely used assessment tools and summative assessment the most frequently used assessment type. This review sheds light on the current assessment landscape and offers valuable implications for educators, practitioners and researchers about the assessment of sustainability competencies in primary education.

Keywords: sustainability competence, formative and summative assessment, primary education, competence measurement

Introduction

Transitioning towards more sustainable societies requires technical solutions in conjunction with a profound reorientation of social practices and livelihoods (Sterling, 2001; Wals, 2010). Achieving such a reorientation entails rethinking the content, competencies and purposes of education and developing significant sustainability learning and 'unlearning' amongst individuals and communities to promote sustainable lifestyles, democracy, active participation in socio-political issues and human well-being (Cebrián *et al.*, 2020; Lozano & Barreiro-Gen, 2019; Sterling *et al.*, 2017). Education for Sustainable Development (ESD), as an essential component of quality education involves all educational institutions, including those in formal, non-formal,

and informal settings, from early childhood to higher education, where sustainability competencies should be developed (Leicht, Heiss, & Byun, 2018; UNESCO, 2017). Thus, fostering sustainability competencies across all levels of education is crucial to achieve sustainability literacy and enabling individuals to act as positive change agents both in their personal and professional lives (Sipos, Battisti & Grimm, 2008).

In this respect, one of the main challenges outlined by ESD experts in relation to sustainability competencies is the operationalisation of these competencies in practice through the definition and implementation of appropriate pedagogical and assessment tools in different education levels (Bianchi, 2020; Brundiers et al., 2021; Mulà et al., 2022). While examples and best practices of ESD teaching and learning processes have been well-documented and studied in early childhood education, primary education, secondary education and higher education, there is scarce research evidence about sustainability competency assessment and development in primary education (Van Poeck, Læssøe & Block, 2017; Wals, Mochizuki & Leicht, 2017). In the last decade, a significant rise in the number of studies on sustainability competencies in higher education has taken place, with less attention being paid to other education levels such as early childhood, primary or secondary education (Brundiers et al., 2021; Sterling et al., 2017; Vesterinen & Ratinen, 2023).

Defining clear sustainability competencies' assessment approaches and tools is critical for educators, scholars, programme leaders, curriculum designers and policy makers to plan, design and test the effectiveness of ESD pedagogies and education programmes for fostering sustainability learning amongst students (Annelin & Boström, 2023; Redman et al., 2021). Assessment in education is the collection of evidence using different tools to observe student behaviour, make

judgments and determine student knowledge, performance and achievements (Curtis, 2010). In primary education it ranges from classroom level assessment to institutional or curriculum level through external standardised tests and examinations, where classroom-based assessment allows monitoring progress involving teachers and students and thus improving the quality of teaching and student learning (Mogboh & Okoye, 2019).

In competence-based education, assessment has two purposes or functions: formative assessment, which is conducted during the learning process to provide ongoing feedback to learners and instructors; and summative assessment, which occurs at the end of a learning period or unit to make a judgement about learners' achievements usually resulting in a grade or score (Black & Wiliam, 1998; Terzieva et al., 2015). Summative assessment tools often include tests, exams, portfolios, essays, projects, presentations, or reports that focus on overall learning after a period of instruction, allowing standardisation and its application to a greater number of student cohorts and time periods enabling the collection of data at individual, group, programme, school and system level (Mogboh & Okoye, 2019). While it can potentially contribute to the improvement of teaching performance, normally there is no space or time for the revision of instructional design and strategies in this type of assessment (Terzieva et al., 2015). Formative assessment tools include observations, questioning, classroom discussions or dialogues, quizzes, written tasks and self-assessment and peer-assessment to regulate student learning and the teaching process (Harlen, 2010). Formative assessment guides the learning process and leads to students taking ownership and enables them to become actively involved in learning and assessing themselves and others (Looney, 2011; Terzieva et al., 2015). While evidence shows that the use of

formative assessment strategies by teachers significantly influences student achievement, a challenge persists in designing and implementing effective competence assessment tools including both formative and summative assessment (Hattie, 2009; Leutner et al. 2017; Redman et al., 2021).

Moreover, ESD scholars and practitioners have widely advocated for student-centred approaches such as problem- and project-based learning, service-learning and action-based learning as the most effective pedagogical approaches to develop sustainability competencies amongst students (Cebrián et al., 2020; Lozano et al., 2017; Tejedor et al., 2019; Tilbury, 2011; UNESCO, 2017). In this context, existing assessment approaches and tools used for sustainability competencies in primary education, their synergy with pedagogical strategies and practices, and the strengths and weaknesses found in previous studies need to be examined to help practitioners, scholars, curriculum and programme designers to identify appropriate formative and summative assessment tools and monitor the effectiveness of teaching and learning in sustainability competency development.

To date, two systematic reviews addressing the state of sustainability competencies' assessment in higher education have been conducted (Cebrián et al., 2019; Redman et al., 2021), with no reviews specifically focusing on sustainability competency assessment in primary education. To address this gap identified in the academic literature, we conducted a systematic review to examine and analyse the use of sustainability competency assessment in primary education to identify the assessment approaches, tools and techniques used. The following research questions were posed:

- **RQ1:** What type of pedagogical strategies and approaches are used when assessing sustainability competencies in primary education?

- **RQ2:** What types of tools are used to assess the development of sustainability competencies in primary education?
- **RQ3:** How can existing literature inform improved assessment of sustainability competencies in primary education?

This paper provides an overview of the literature in this field, which is based on PRISMA methodology (Moher et al., 2009; Page et al., 2021). The main findings of the systematic literature review are outlined in the results and discussion section, which also addresses several challenges, opportunities and implications for further research and practice identified in the analysis. These findings can provide valuable insights for informing the design and effective implementation of sustainability competency assessment in primary education.

Sustainability competencies: theoretical background

In recent decades, student learning in sustainability has emerged as a field of research within ESD. This research focuses on the conceptualisation of sustainability competencies, learning outcomes, capabilities, attributes, and skills to be developed through education of students. As a result, in most cases, these terms have been used interchangeably causing a conceptual confusion (Mulà et al., 2022; Sipos et al., 2008; Sterling et al., 2017; Weik et al., 2011). Different regions use different terms, in Australia or New Zealand the term capability or learning outcome is mainly used, whereas in the UK the term skills and in Europe and the US the term competence is more predominant (Bianchi et al., 2022; Brundiers et al., 2021; Mulà et al., 2022; Shephard et al., 2015). In this paper, we conceive the term sustainability competencies as a holistic concept that encompasses a combination of knowledge, skills, ethical values and attitudes required to proficiently execute tasks, and to enable individuals and

communities to make a positive contribution in their everyday lives and tackle current sustainability challenges through reflecting on their own actions, making informed decisions and making responsible choices and actions (Bianchi et al., 2022; Brundiers et al., 2021; de Haan, 2006). In recent years, scholars in the field of ESD have focused on conceptualising and exploring the competencies that are needed for a positive transformation of people towards having more sustainable mindsets, such as the development of problem-solving, interpersonal competence, systems-thinking, future-thinking skills, as well as strategic and value-driven competencies (Brundiers et al., 2021; Lambrechts & Van Petegem, 2016; Shephard et al., 2015; Wiek et al., 2011). Proposed frameworks for sustainability competencies encompass generic competence frameworks (Rieckmann, 2012; UNESCO, 2017), as well as specific frameworks tailored for schoolchildren (de Haan, 2006), higher education students (Brundiers et al., 2021; Lozano et al., 2017; Wiek et al., 2016; Wiek et al., 2011), sustainability entrepreneurs (Mindt and Rieckmann, 2017) or educators (UNECE, 2012; Bertschy, Künzli and Lehmann, 2013; Rauch and Steiner, 2013; Cebrián and Junyent, 2015; Vare *et al.*, 2019).

Therefore, embedding sustainability competencies in the school curriculum is essential to enable learners to develop the necessary competencies to address the multifaceted sustainability challenges confronting contemporary societies (Wals and Lenglet, 2016). These competencies are acquired through meaningful and deep learning experiences that engage students in cognitive, psychomotor, and affective spheres of sustainability learning, using collaborative, critical reflection, active and participatory learning methodologies and processes (Kadji-Beltran, Zachariou & Stevenson, 2013; UNESCO, 2017).

However, the absence of a comprehensive and agreed-upon framework of sustainability competencies has resulted in the emergence of multiple frameworks and definitions of what constitutes the knowledge, skills, attitudes, and values needed for sustainability competent citizens (Cebrián et al., 2020). A major challenge remains to develop agreed-upon conceptual frameworks and comprehensive descriptions of these competencies to implement them effectively at different education levels and socio-cultural and institutional settings (Bianchi, 2020; Glasser & Hirsh, 2016; Sterling et al., 2017). This challenge has led to the lack of a clear and unified direction towards nurturing sustainability competent citizens through education (Brundiens et al., 2021; Mulà et al., 2022). In response to this challenge, the Joint Research Center (JRC) of the European Commission (EC) released the GreenComp framework in 2022 (Bianchi et al., 2022), which is a European Competence Framework for lifelong learning about sustainability and key green competencies. GreenComp provides a common ground for learners and guidance for educators, proposing a conceptual framework of what sustainability entails in terms of individual competencies. GreenComp comprises four interrelated competence areas: ‘embodying sustainability values’, ‘embracing complexity in sustainability’, ‘envisioning sustainable futures’ and ‘acting for sustainability’. Each area comprises three competences that are interlinked and equally important. This framework is intended to promote and facilitate the integration of sustainability competencies across European education systems (European Commission, 2022). This framework emerged from a review of existing sustainability competence frameworks and a comprehensive expert validation process (Bianchi, 2020; Brundiens et al., 2021; Wiek et al., 2011). However, the main sustainability competency discourses that underpin this framework came from European and North American perspectives

leading to a potential cultural bias in its conceptualisation and further operationalisation (Mulà et al., 2022).

To date, there has been little research into the development, results, and impact of courses and educational programmes that seek to promote sustainability competencies amongst students (Barth & Rieckmann, 2016; Lozano et al., 2017). The creation, implementation and validation of suitable assessment tools and strategies to evaluate students' sustainability competencies persists as a significant challenge (Mulà et al., 2022). The number of publications addressing the assessment of sustainability competencies has increased in recent years. However, most publications have explored the impact of different assessment tools mainly in the areas of higher education and educators, with insufficient exploration of other educational contexts such as primary or secondary education (Cebrián et al., 2020; Redman et al., 2021; Vesterinen & Ratinen, 2023). In higher education, questionnaires have been frequently used to evaluate or investigate students' sustainability-related knowledge, attitudes, and behaviors (Biasutti & Frate, 2017; Kagawa, 2017). Also, qualitative tools such as reflexive diaries, interviews, conceptual maps, rubrics, and scenario/vignette visioning have all been highlighted as effective qualitative approaches for evaluating sustainability competencies in higher education contexts (Sandri, Holdsworth & Thomas, 2018; García, Junyent & Fonolleda, 2017).

In relation to primary education, a recently published study has examined sustainability competencies in schools through a systematic review, exploring the extent to which existing research has studied these competencies, and the pedagogical approaches used (Vesterinen & Ratinen, 2023). Also, two literature reviews on sustainability competency assessment in higher education (Cebrián et al., 2019; Redman

et al., 2021) and one on survey assessment tools have been previously conducted (Annelin & Boström, 2023). The evidence from these literature reviews indicates that summative assessment tools such as tests or questionnaires are the most used tools in higher education contexts, with an underrepresentation of self-evaluation or formative assessment tools in scientific papers published (Redman et al., 2021). As previous studies in the field have pointed out, self-evaluation is particularly appropriate regarding competencies' assessment, and a variety of assessment tools should be designed and used in combination to evaluate and track students' sustainability performance effectively (Barth and Rieckmann, 2016; Mulà, Cebrián & Junyent, 2022). Therefore, this study aims to analyse the existing literature on sustainability competency assessment in primary education, to examine current practices in this education level and to identify the main assessment approaches and tools used, to inform further research and practice in the field.

Methodology

Systematic literature reviews are commonly used in social and educational sciences to map the state of the art of specific fields of study. We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to perform the review through a systematic search protocol to describe and determine eligibility criteria, sources of information, search strategy, data extraction and analysis, and to ensure transparent, replicable and rigorous screening and selection criteria (Moher et al., 2009; Page et al., 2021). PRISMA guidelines have also been used in recent review studies in the area of Education for Sustainability and sustainability competencies to conduct systematic searches of peer-reviewed literature, informing our review as well (Ardoin et al., 2022; Redman et al., 2021; Vesterinen & Ratinen, 2023).

The review took place from January to April 2023 by searching on different databases: SCOPUS, Web of Science and Google Scholar. There was no restriction on the publication year of the studies found. The following keywords were used:

TITLE-ABS-KEY ("*primary education*" OR "*primary school*" OR "*elementary school*" OR "*elementary education*" OR "*schoolchildren*") AND

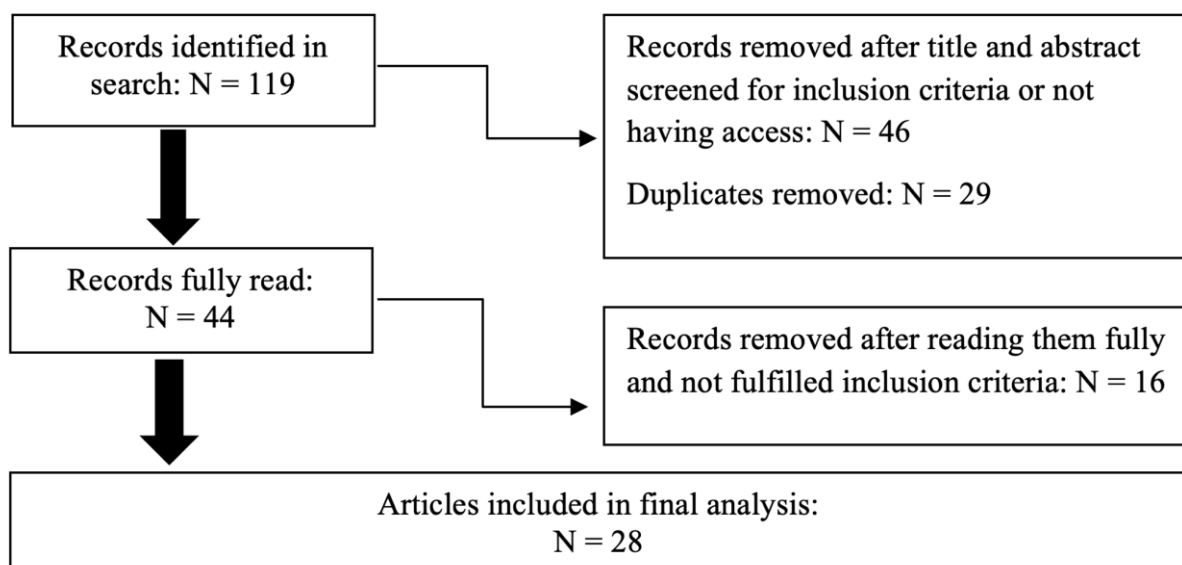
TITLE-ABS-KEY ("*education for sustainability*" OR "*education for sustainable development*" OR "*sustainability education*") AND

TITLE-ABS-KEY ("*competenc**" OR "*sustainability competenc**" OR "*green competenc**" OR "*values thinking*" OR "*normative*" OR "*systems thinking*" OR "*action competence*" OR "*action oriented*" OR "*futures thinking*" OR "*anticipatory*" OR "*strategic thinking*" OR "*interpersonal*" OR "*collaboration*" OR "*problem solving*") AND TITLE-ABS-KEY ("*assessment*" OR "*evaluation*" OR "*learning*")

As described in Figure 1, we got an initial sample of 119 studies. After removing duplicates and screening the abstracts, we read 44 full articles. Once we carefully read them, we removed those that did not meet inclusion criteria, resulting in a final sample of 28 articles to be analysed. The inclusion criteria were: a) articles published in English; b) describing competencies in sustainability (understood as an overarching term that refers to knowledge, attitudes, values, skills and other elements that are part of the definition of the term competence); and c) describing the instrument/s used to assess these competencies in primary school students. The literature search was limited to scientific articles published in peer-reviewed journals. Although we are aware of the benefits of including grey literature such providing diverse perspectives and up-to-date information not found in peer-reviewed sources

(Mahood et al., 2014), we excluded it due to existing challenges and difficulties such as a variable quality of the research and the difficulty on accessing these non-traditional works (Alexander, 2020). Moreover, we decided to exclude grey literature following Adams et al.'s (2017) guidelines, as our review is bounded to the academic field of sustainability competency assessment in primary education.

Figure 1. The preferred reporting of items for systematic reviews (PRISMA) flow diagram for article extraction with the final number of articles included (N = 28).



Main findings

In this section, the main findings are presented and discussed in relation to each of the three research questions. A total of 28 articles were found through the systematic literature review conducted. Most of the analysed studies originated from Europe (N=14; 50 %), Asia (N=6; 21,4 %) and North America (N=4; 14,3 %), followed by Oceania (N=2; 7,1 %), Latin-America (N=1; 3,6 %) and Africa (N=1; 3,6 %) with less geographical representation. As Figure 2 shows most of the articles were published after 2015 (N=24; 85,71 %).

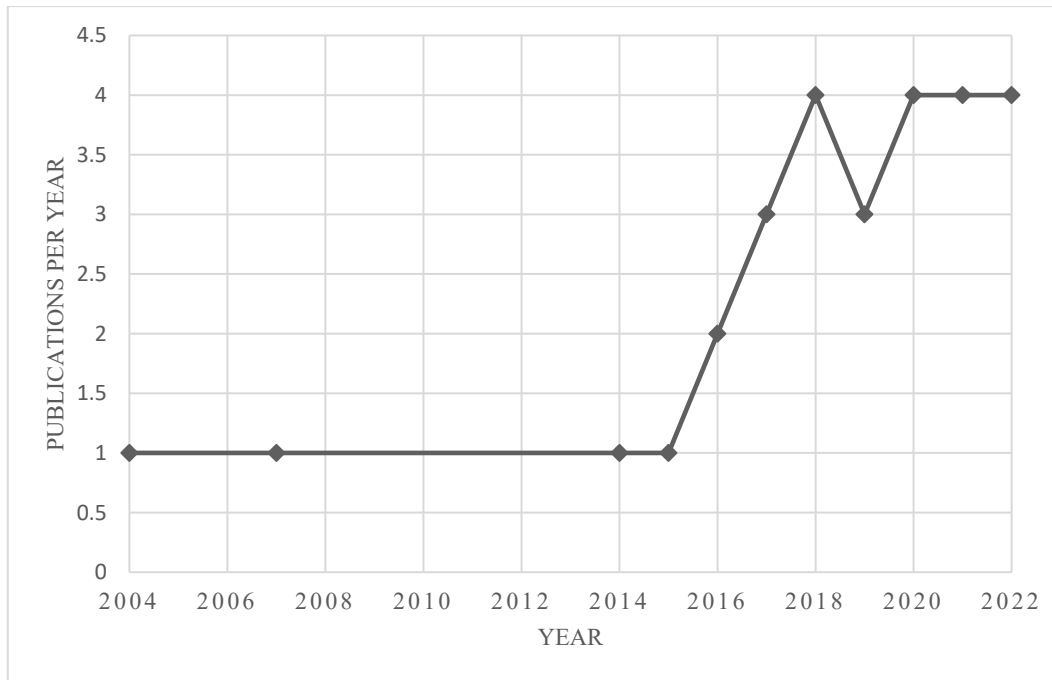


Figure 2. Final sample of the studies analysed per year of publication.

RQ1: What type of pedagogical strategies and approaches are used when assessing sustainability competencies in primary education?

Responding to our first research question, Table 1 shows in chronological order the selected articles, including the authors and publication year, the type of instructional activity, the pedagogical strategies and approaches used, the region of the study, the educational level/grade, and number of participants. Instructional activities are structured teaching and learning episodes with specific learning goals and outcomes, content, pedagogical and teaching practices, that can take place in formal and non-formal settings.

Table 1. Main characteristics and pedagogical strategies and approaches of the articles analysed.

SOURCE	TYPE OF INSTRUCTIONAL ACTIVITY	PEDAGOGICAL STRATEGY AND APPROACH USED	REGION	EDUCATIONAL LEVEL	N° PARTICIPANTS
McNaughton (2004)	Single discipline In-class	Experiential learning and imagination in learning drama-based	Europe	Upper primary	Not specified
Farmer et al. (2007)	Single discipline; Outdoor (field trip)	Hand-on learning and group discussions	North-America	4 th grade	15
Ito & Nakayama (2014)	Interdisciplinary; In-class;	Embodied Knowledge	Asia	6 th grade	38
Pauw et al. (2015)	Interdisciplinary; In-class	Not specified	Europe	6 th , 9 th , 12 th grades	2412
Phan Hoang & Kato (2016)	Interdisciplinary; In-class	Game based	Asia	4 th , 5 th grades	247
Hestness et al. (2016)	Single discipline; In-class	Not specified	North-America	6 th grades	39
Clark et al. (2017)	Single discipline; In-class	Not specified	North-America	4 th , 5 th grades	Not specified
Jackson & Pang (2017)	No instructional activity	Not specified	Asia	7 th -12 th grades	1405
Silo (2017)	Single discipline; In-class	Not specified	Africa	Not specified only age and the broadly mentioned primary level	8
Alwi et al. (2018)	Not specified	Not specified	Asia	5 th grades	62
Julien et al. (2018)	Interdisciplinary; In-class	Not specified	Europe	Not specified only age and the broadly mentioned primary level	81
Arruda et al. (2018)	Interdisciplinary; In-class	Learning units; Project-based; Problem solving	Latin-America	6 th -9 th grades	160
Eames et al. (2018)	Interdisciplinary; In-class and outdoor	Whole-school approach; Holistic and depth education	Oceania	9 th , 10 th grades	20

Krepelková et al. (2019)	Interdisciplinary; In-class	Thematically focused educational drama	Europe	Not specified only age and the broadly mentioned primary level	52
Waltner et al. (2019)	No instructional activity	Not specified	Europe	Not specified only age and the broadly mentioned primary level	1622
Yilmaz (2019)	No instructional activity	Not specified	Asia	3 rd , 4 th grades	332
Bassachs et al. (2020a)	Interdisciplinary; In-class	Reflective and cooperative learning	Europe	1 st , 3 rd , 5 th grades	90
Bassachs et al. (2020b)	Interdisciplinary; In-class	Cooperative learning	Europe	1 st , 3 rd , 5 th grades	90
Rudd et al. (2020)	Interdisciplinary; In-class	Social and moral education; Art-based education	Europe	8 th , 9 th , 10 th grades	180
Trott & Weinberg (2020)	Interdisciplinary; extracurricular	Place-based, Participatory and action-oriented pedagogies; Photovoice (use of photography); Head, hands and heart model for SD	Nort-America	Not specified only age and the broadly mentioned primary level	55
Hsiao & Su (2021)	Interdisciplinary; In-class	Experiential learning with VR applications; Problem-oriented	Asia	Not specified only age and the broadly mentioned primary level	303
Murphy et al. (2021)	Single discipline; In-class	Whole-school sustainability projects	Europe	2 nd , 5 th grades	145
Sass et al. (2021)	No instructional activity	Not specified	Europe	Not specified only age and the broadly mentioned primary level	2274
Scharenberg et al. (2021)	No instructional activity	Not specified	Europe	5 th , 6 th , 7 th , 8 th grades	1622
Baldwin et al. (2022)	No instructional activity	Not specified	Oceania	7 th , 8 th , 9 th , 10 th , 11 th , 12 th grades	425
Häggström (2022)	Interdisciplinary; In-class	Problem-based	Europe	Not specified only age and the broadly mentioned primary level	49
Verhelst et al. (2022)	No instructional activity	Not specified	Europe	1 st , 2 nd , 5 th , 6 th grades	629
Sass et al. (2023)	No instructional activity	Not specified	Europe	5 th , 6 th , 8 th grades	1398

From the twenty-eight articles analysed, nineteen (67,9 %) reported an instructional activity associated with sustainability competency assessment and nine (32,1 %) do not indicate any instructional activity. Of those reporting an instructional activity, eighteen included details regarding its main characteristics. Firstly, we identified if the instructional activity associated to the assessment of sustainability competencies was implemented in a single discipline or as an interdisciplinary activity. Six articles adopted a single-discipline approach, such as drama (McNaughton, 2004) and science (Hestness, 2016) and thirteen articles used interdisciplinary approaches linking subjects such as music, arts, science, maths, language, history, geography and chemistry (i.e. Arruda, 2018; Eames, 2018; Ito & Nakayama, 2014). We also classified the type of instructional activity according to: in-class, outdoor or extracurricular. Seventeen articles described in-class implementation (Hsiao & Su, 2021; Julien et al., 2018; Pauw et al., 2015); two reported outdoor education experiences such as field trips and an action-based programme connecting students and schools with neighbourhoods and the community, and one an extracurricular after-school programme focused on sustainability (Eames et al., 2018; Farmer et al., 2007; Trott & Weinberg, 2020). Thus, we observe that most of the articles analysed reported a specific instructional activity adopting interdisciplinary approaches (68,42%) and mainly implemented and developed in-class (89,47%). Other articles also studied the development of sustainability competencies or action competence for sustainability in a school year as the result of a classroom programme without reporting a specific educational activity or project (Scharenberg et al., 2021; Sass et al., 2023).

Furthermore, we found explicit reporting of a variety of pedagogical strategies and approaches described in the studies analysed: two reported experiential learning (Hsiao & Su, 2021; McNaughton, 2004), one hands-on learning (Farmer et al., 2007),

one embodied knowledge (Ito & Nakayama, 2014), one aesthetic appreciation and artistic methods (Arruda et al., 2018), and one used a participatory and action-oriented approach (Trott & Weinberg, 2020).

RQ2: What types of tools are used to assess the development of sustainability competencies in primary education?

The assessment approach, the sustainability competencies assessed, and the type of assessment tools used in each of the studies analysed are presented in Table 2. First, we analysed whether the assessment was formative or summative using Guo and Yan's (2019) definitions. Formative assessment refers to studies where sustainability competencies are assessed during the process and course of an instructional activity or educational project, and as an ongoing process, and summative assessment in studies where sustainability competencies are assessed at the end of a learning process or instructional activity, or without linking it to a specific learning process. In relation to this, summative assessment was used solely in almost three quarters of the studies analysed (N=20) and formative assessment was described in three studies (N=3). The combination of both, summative and formative assessment, was described in five studies (N=5). For example, Julien et al. (2018) used several tools during an instructional activity such as drawings, performance observation and a questionnaire; and McNaughton (2004) combined formative and summative assessment by employing performance observation, regular course work and interviews.

The timing of assessment in relation to instructional activities was also analysed. The use of questionnaires before and after an instructional activity (pretest post-test) to determine the development sustainability competencies or learning outcomes related to

ESD was described in sixteen studies (see Alwi, 2018; Ito & Nakayama, 2014; Pauw et al., 2015). Assessing student learning after a specific educational project or instructional activity was reported in five studies using tools such as interviews, focus groups and questionnaires (see Eames et al., 2018; Hsiao & Su, 2021). There were also studies assessing student learning during an instructional activity and after it (formative and summative assessment) (see Clark et al., 2017; McNoughton, 2004), only during the instructional activity (formative assessment) (see Arruda et al., 2018), and finally others that assessed sustainability competency development without an instructional activity associated (see Walter et al., 2019; Verhelst et al., 2022). For example, Scharenberg et al. (2021) studied students' sustainability competencies and Sass et al. (2023) action competence in sustainability at the start and end of a school year and the influence that classroom and teachers' factors such as their attitudes, professional knowledge and instructional practices had in their development.

We also examined the sustainability competencies that were assessed, whether specific 'sustainability competencies' were studied, or a combination or component of the competence term such as knowledge, skills or attitudes related to sustainability. Sustainability competencies were explicitly assessed in eleven studies. Sustainability competencies reported were action competence (Sass et al., 2023; Sass et al., 2021; Silo, 2017; Verhelst et al., 2022), future thinking (Jensen, 2000; Murphy et al., 2021), stakeholder engagement thinking, strategic action (Murphy et al., 2021), systems thinking (Murphy et al., 2021), interdisciplinary work, anticipatory thinking, empathy, responsibility, critical thinking, collaboration, (Bassachs et al., 2020a; 2020b). To illustrate this, Sass et al. (2023) describe assessing action competence in sustainability education based on a previous framework of the same author (Sass et al., 2020), and Murphy et al. (2021) assessed sustainability competencies such as systems thinking,

stakeholder engagement thinking, futures thinking and strategic action, that came from the key sustainability competencies identified by Frisk and Larson (2011), Wiek et al. (2011) and UNESCO's ESD competence framework (UNESCO, 2017).

Table 2. Main characteristics of reported assessment approaches and tools.

SOURCE	ASSESSMENT APPROACH	SUSTAINABILITY COMPETENCIES OR COMPONENT ASSESSED	ASSESSMENT TOOLS
McNaughton (2004)	Formative and Summative	Communication and decision-making skills, appreciation of and sensitivity to others	Performance observation; Regular course work; Interviews
Farmer et al. (2007)	Summative	Student actions, general content knowledge, ecological and environmental knowledge and perceived pro-environment attitude	Interviews
Ito & Nakayama (2014)	Summative	Subject-specific knowledge and skills and generic knowledge and skills for sensibility and creativity	Questionnaire
Pauw et al. (2015)	Summative	Perceptions of ESD at school related to holism (Sandell et al., 2005) and pluralism (Öhman, 2008), the effect of ESD on student's knowingness, attitudes and behaviour.	Questionnaire
Phan Hoang & Kato (2016)	Summative	Knowledge about solid management and waste education	Questionnaire
Hestness et al. (2016)	Summative	Climate science knowledge (Hestness et al., 2016)	Questionnaire; Drawings; Interviews
Clark et al. (2017)	Formative and Summative	Knowledge acquisition and retention, and systems thinking skills (Thibodeau et al., 2015)	Questionnaire; Regular course work; Performance observation
Jackson & Pang (2017)	Summative	Understandings and attitudes towards climate change from the New Ecological Paradigm (Dunlap, 2008; Dunlap et al., 2000; Hawcroft & Milfont, 2010).	Questionnaire; Interviews
Silo (2017)	Summative, Formative	Action competence (Jensen, 1997; 2004; Jensen & Schnack, 1997)	Focus groups; Interviews; Performance observation
Alwi et al. (2018)	Summative	Green skills	Questionnaire
Julien et al. (2018)	Formative	Future thinking (Wiek et al., 2011)	Drawings; Performance observation; Questionnaire
Arruda et al. (2018)	Formative	Environmental Education knowledge and the way students expose and socialize contents (Arruda et al., 2018)	Performance observation; Regular course work; Questionnaire
Eames et al. (2018)	Summative	Environmental literacy (Roth, 1992), values (Callenbach, 2005), action competence (Jensen & Schnack, 1997), environmental identity (Wenger, 1998).	Interviews
Krepelková et al. (2019)	Summative	Global awareness, self-confidence, students' interpersonal competence, students' empowerment.	Focus groups
Waltner et al. (2019)	Summative	Sustainability related knowledge, affective-motivational beliefs towards sustainability, sustainability-related behaviour, and Intentional sustainability knowledge applied (Rieß et	Questionnaire

		al., 2018).	
Yilmaz (2019)	Summative	Environmental awareness (P21 Partnership for 21st Century Learning, 2007), basic process skills (Aslan et al., 2016).	Questionnaire
Bassachs et al. (2020a)	Formative and Summative	System thinking, interdisciplinary work, anticipatory thinking, justice, responsibility and ethics, critical thinking and analysis, interpersonal relations and collaboration, empathy and change of perspective, strategic action, personal involvement, and tolerance for ambiguity and uncertainty (Johnson & Johnson, 2009)	Focus group; Performance observation; Regular course work
Bassachs et al. (2020b)	Summative	Description, argumentation, reflection and critical reflection (Kember et al., 2008).	Focus group
Rudd et al. (2020)	Summative and Formative	Attitudes and reflection on their experiences.	Questionnaire; Interviews; Regular course work
Trott & Weinberg (2020)	Summative	Cognitive, affective and behavioural dimensions of science engagement (Sipos et al., 2008).	Questionnaire; Focus group
Hsiao & Su (2021)	Summative	Experiential learning (feelings, reflections, observation, thinking and implementation), self-efficacy (attitudes towards learning setbacks, achievement of learning goals, etc.), learning motivation (value, expectation, emotion), learning satisfaction and learning effectiveness (Bandura, 1977; Kiili, 2005; Lumsden, 1994.)	Questionnaire
Murphy et al. (2021)	Summative	Systems thinking, stakeholder engagement thinking, futures thinking and strategic action (Frisk & Larson, 2011; UNESCO, 2017; Wiek et al., 2011)	Questionnaire; Focus group; Interviews; Regular course work
Sass et al. (2021)	Summative	Action competence in sustainable development, relevant knowledge, willingness, capacity expectations, and outcome expectancy for contributing to sustainable development (Jensen, 2000; Sass et al., 2020)	Questionnaire
Scharenberg et al. (2021)	Summative	Sustainability-related knowledge (Waltner et al., 2021)	Questionnaire
Baldwin et al. (2022)	Summative	Belief in climate change/anthropogenic cause, contributors to climate change, impacts of climate change, personal experiences with climate change, climate change mitigation, sources of information, frequency of discussing climate change, worry and hope, self-efficacy and action (<i>See all authors in original document</i>).	Questionnaire
Häggström (2022)	Formative	Learning and acting in sustainability issues (communication, social skills, and problem solving, negotiation skills, creativity, and relational critical thinking, self-confidence, critical thinking, sense of agency)	Performance observation
Verhelst et al. (2022)	Summative	Action competence in sustainability education (knowledge, willingness, capacity expectations, outcome expectancy) (Sass et al, 2020)	Questionnaire
Sass et al. (2023)	Summative	Action competence in sustainability, relevant knowledge, willingness, capacity expectations, and outcome expectancy (Sass et al, 2020)	Questionnaire

As shown in the last column of Table 2, the tools used to assess sustainability competencies were classified as questionnaires, focus groups, interviews, regular course work, performance observation and drawings. In Table 3, a brief description of each of the assessment tools is presented, including the total number of studies using each.

Table 3. Assessment tools reported with brief description and studies' frequency.

ASSESSMENT TOOL	BRIEF DESCRIPTION	N
Questionnaires	Students answer a questionnaire to measure the knowledge, skills, and/or attitudes related to competencies in sustainability.	20
Focus group/interview	Students verbally respond to prompts in a group or individual situation regarding their knowledge, skills or attitudes related to competencies in sustainability.	12
Performance observation	Students are evaluated in terms of their knowledge, skills or attitudes related to competencies in sustainability based on activities done during an instructional situation.	7
Regular course work	Students do regular course work to be analysed regarding of their knowledge, skills or attitudes related to competencies in sustainability.	4
Drawings	Students draw their understanding of a topic related to sustainability which reflect their knowledge, skills or attitudes related to competencies in sustainability.	2

Note: The brief descriptions are adapted from Redman et al. (2021).

In relation to assessment tools, questionnaires are used in almost three quarters of the articles analysed (N=20; 71,4 %). As detailed in Table 2, twelve (60 %) employed questionnaires solely, and eight (40 %) used this tool in combination with

other tools such as performance observation, regular course work and interviews. For example, Sass et al. (2021) designed and validated a questionnaire to measure action competence in sustainable development with a 5-point Likert scale (agreement). These authors administered this tool as a diagnostic assessment (no instructional activity associated) to a sample of 2274 participants and analysed the construct reliability through Cronbach alpha's calculation. Murphy et al. (2021) conducted pre- and post-test with 145 participants, using a questionnaire in combination with other tools. They used Likert scale questions to assess sustainability competencies such as systems thinking and futures thinking, analysing the data through descriptive statistics with paired samples t-tests to identify statistical significance between pre and post-test, which was complemented with semi-structured focus groups, interviews and a collection of visual materials from the instructional activity.

After questionnaires, focus groups and interviews were prominently presented as assessment tools used (N=12). As an example, Eames et al. (2018) performed a post-test evaluation 2 years after an instructional activity by interviewing 20 participants to assess, from an interpretive approach, their environmental literacy, values, action competence and environmental identity.

Also, performance observation was used to assess competencies in seven studies. For instance, Julien et al. (2018) asked 81 students to participate in a role-playing activity in which pupils explored several roles and developed their viewpoints in dialogue with other partners, representing different stakeholders and reimagining the future, thus assessing their futures thinking competence. Pupils' oral classroom participation was counted and analysed according to whether they agreed or disagreed with the proposal and the arguments of the character they embodied.

The use of regular course work was described in only four studies. For example, in Arruda et al.'s (2018) instructional activity, students participated in five learning units in which class work evidence such as drawings, oral presentations and other tasks related to the specific subjects were analysed to determine students' level of knowledge acquired about environmental actions in relation to each learning unit proposed.

Finally, the use of drawings was rarely reported in the articles analysed (N=2). Hestness et al. (2016) used this type of assessment tool to measure climate science knowledge among 39 participants from the North-American region. In combination with other tools like questionnaire and individual interviews, these authors asked students to draw their understanding of climate change, and include their personal connection to it and its impact on themselves and their social circle.

RQ3: How can existing literature inform improved assessment of sustainability competencies in primary education?

This research question aimed to identify the strengths and limitations of the assessment tools used in the studies analysed to suggest improvements and inform further research and practice. The aim is to inform practitioners, scholars, curriculum and programme designers to define and implement appropriate formative and summative assessment tools that enable testing the effectiveness of instructional activities, educational projects or programmes in developing sustainability competencies amongst students, which remains as a challenge in the field of ESD (Redman et al. 2021).

Regarding the limitations of the assessment tools used, when referring to questionnaires, the most widely used tool to date, the studies analysed revealed unequal gender representation among participants (Hsiao & Su, 2021), the small size of the sample (Trott & Weinberg, 2020; Verhelst et al., 2022), and possible bias when

selecting participants who hold more favourable attitudes towards the environment (Baldwin et al., 2022; Trott & Weinberg, 2020). Sample size can provide biased statistical results (Verhelst et al., 2022), with participants possibly having pro-environmental attitudes prior to the test (Baldwin et al., 2022). Other weaknesses encountered when using questionnaires include the level of difficulty of the questionnaire items not being adapted to the participants' age (Clark et al., 2017), or its applicability and transferability to different contexts (Waltner et al., 2019). When used in pre- post-test studies, before and after an instructional activity, an extended time gap between tests can lead to unrealistic results (Clark et al., 2017; Verhelst et al., 2022). Additionally, some studies lacked sufficient detail to determine the impact of the response order effect to participants' answers (Phan Hoang & Kato, 2016). These limitations influence the validity of the questionnaires designed and implemented, and their replicability to other contexts, challenging the effectiveness and precision in the measurement of sustainability competencies among students (Ratinen et al., 2024).

While questionnaires as an assessment tool present some limitations, these are also considered suitable for allowing reaching a wider population (Pauw et al., 2015), for including sociodemographic variables enabling more comprehensive analyses (Yilmaz, 2019), and for reaching younger audiences by incorporating holistic and pluralistic approaches (Sass et al., 2021). Regarding potential improvements in the use of questionnaires, studies reported the need to: incorporate variables in the scale such as time perspective, risk perception, self-determination and self-efficacy to improve the analysis (Křepelková et al., 2019; Scharenberg et al., 2021; Waltner et al., 2019); specify the pedagogic approach as a dependent variable (Křepelková et al., 2019); add more specific and general items (Waltner et al., 2019); use larger samples (Verhelst et al., 2022); conduct comparative and longitudinal studies (Sass et al., 2022); complement

the study using qualitative tools (Scharenberg et al., 2021; Waltner et al., 2019); gender differentiation (Hsiao & Su, 2021) and eliminate possible biases such as response order effect (Phan Hoang & Kato, 2016).

Focus groups and interviews were described as effective assessment tools (Alwi, 2018; Farmer et al., 2007). However, some limitations with these assessment tools were also reported including: a linear relation between the competence developed in the assessment and the competence developed in the instructional activity (Bassachs et al., 2020b), the small sample size and participants' context (Farmer et al., 2007), unequal gender representation and participant selection processes (Křepelková et al., 2019). Additionally, some studies reported that evidence of transformative learning among students was not clearly captured, possibly due to the nature of the data gathered that did not allow an in-depth analysis of individual or collective change (Eames et al., 2018). Further improvements proposed when using focus groups and interviews include conducting longitudinal and deeper analyses (Eames et al., 2018; Farmer et al., 2007) and their integration into regular course work (Trott & Weinberg, 2020).

Authors who used performance observation to assess sustainability competencies, considered it enabled the observation and analysis of participants' behaviour to a greater extent (Häggström, 2022). However, some limitations were identified, including the difficulty of measuring each participant's competency development (Bassachs et al., 2020b), the small size of the sample that did not allow analyses of subgroups, a self-selected sample that might affect participants' positive environmental attitudes (Trott & Weinberg, 2020), possible power relationships between researchers and students influencing children's behaviours (Häggström, 2022) and the lack of a control group to determine the effects of the instructional activity implemented (Rudd et al., 2020). In relation to possible improvements,

recommendations included counting with more observers and teachers to triangulate the results to enhance the reliability of observations (McNaughton, 2004). In relation to the use of regular course work as an assessment tool, several improvements were identified such as counting with experimental and control groups and conducting larger and more controlled trials (Rudd et al., 2020).

Finally, researchers using drawings as an assessment tool noted that using drawings allows children to express their personal views, emotions and values (Hestness et al., 2016), as well as elements of futures thinking competence (Julien et al., 2018). These studies suggest that teachers should use drawings as a diagnostic tool to gather information about prior knowledge and conceptions, and student familiarity with environmental topics (Hestness et al., 2016), being a suitable tool to be included in longitudinal studies (Julien et al., 2018).

Discussion

Our first research question aimed to identify what type of pedagogical strategies and approaches were used when assessing competencies in primary education. Our findings showed that most competency assessment studies were associated with interdisciplinary and in-class implementation. This finding contradicts previous studies that have identified that curricular development and implementation of sustainability are mainly linked to specific subjects such as science education, geography and civics/citizenship subjects (Aikens et al., 2016; UNESCO, 2021). Interdisciplinary implementation could be more challenging in secondary education than in primary education due to subject requirements, existing teaching approaches and institutional challenges when using interdisciplinary approaches (Rousell & Cutter-Mackenzie-Knowles, 2019; Taylor et al., 2019). While the integration of ESD within the curriculum

is moving from stand-alone subjects to more holistic approaches, and evidence of best practices that introduce ESD in an interdisciplinary way exists in many countries (UNECE, 2016; UNESCO, 2014; 2020), the pedagogical and assessment tools used were not always clearly outlined (Mulà et al., 2022). Further research on ESD initiatives and projects that implement interdisciplinary approaches and where the development of sustainability competencies is explored is needed (Sund & Gericke, 2020). In this context, STEM (science, technology, engineering and mathematics) education, where several subjects are taught in an integrated way, offers an opportunity to achieve the interdisciplinary approach required for sustainability learning and sustainability competency development (Clark & Button, 2011; Rogers et al., 2015; Zoller, 2015).

Moreover, the findings of this study show the use of a diverse range of pedagogical approaches and strategies when assessing sustainability competencies. These approaches and strategies are aligned with widely advocated ESD learning processes and practices (Tilbury, 2011; UNESCO, 2017), and include experiential learning, art- and drama-based, hands-on learning, project-based and problem-based learning, cooperative learning and participatory and action-oriented pedagogies. However, reaching definitive conclusions regarding the most often used pedagogical approaches based on our findings is challenging due to a general and incomplete reporting of the instructional activities or educational initiatives developed in the articles analysed. In further research it is important to document and provide rich descriptions of the instructional activities, pedagogical approaches and strategies used for developing sustainability competencies that provide evidence of effective pedagogical and assessment pathways that can be then replicated and transferred to other contexts (Mulà et al., 2022).

Nonetheless, it is worth noting that only one of the studies made explicit

reference to the use of participatory approaches such as participative inquiry, action learning or action research, which have been advocated as critical for the acquisition of sustainability competencies (Brundiers et al., 2021; Tilbury, 2011). Hence, our findings suggest the need to further promote, implement and document the use of participatory approaches aimed at developing sustainability competencies that focus on collective research and learning, and where students are empowered to solve real sustainability challenges, thus enabling them to act and experience working on sustainability issues in real-life contexts such as their own school, neighbourhood or town as part of their learning experiences.

The results indicate a notable prevalence of studies presenting ESD initiatives and projects originating from Europe, which is in line with previous reviews on sustainability competencies (Corres et al., 2020; Mulà et al., 2022). This finding could be due to the way that several sustainability competency frameworks and programmes have emerged from European Union organisations or with its economic support (Bianchi et al., 2022; European Commission, 2022; UNECE, 2012; Vare et al., 2019). While ESD has gained support from international organisations such as UNESCO or the United Nations (UNESCO, 2005, 2017, 2020; United Nations, 2012, 2015), the sustainability competency discourse is primarily dominated by European and North American perspectives (Mulà et al., 2022). Furthermore, there are inequalities in terms of research budgets between the Global South and North (Demeter, 2020). These differences can lead to a sociocultural bias in the sustainability competency assessment tools and frameworks that are developed and used. Thus, it is important that these tools and approaches are adapted and contextualised to suit different cultural, social and educational contexts.

Moreover, the results indicated that most of the articles on the assessment of

sustainability competencies were published after 2015, which could be attributed to the efforts made during the UNDESD and implementing the 2030 Agenda and the SDGs, and specifically Target 4.7 that refers to the need to ensure that all learners acquire sustainability knowledge and skills through ESD (United Nations, 2015). Additionally, there is a growing political and academic interest in relation to developing sustainability competency frameworks (Bianchi et al., 2022; Brundiers et al., 2021).

Our second research question focused on exploring what type of tools have been used to date to assess the development of sustainability competencies in primary education. The findings show that most of the instructional activities or educational programmes reported the use of summative assessment approaches, relying primarily on questionnaires as the most widely chosen assessment tool. In most cases the studies reported are led by scholars conducting specific research projects or piloting innovative ESD pedagogical strategies and approaches in collaboration with teachers and schools, and, in some cases, doctoral students who are teachers themselves and led the instructional activity presented. This finding could represent a challenge in terms of achieving one of the key purposes of assessment in education, that being to reflect on one's own teaching practice, on its instructional design and on the strategies to regulate student learning processes (Harlen, 2010; Terzieva et al., 2015).

We identified the predominant use of questionnaires to assess sustainability competencies in primary education, which is in line with previous literature reviews conducted in higher education (Cebrián et al., 2019; Redman et al., 2021). As suggested previously, it is necessary to incorporate a variety of assessment approaches, both formative and summative types in a complementary manner, and a range of assessment tools in combination to gain a more comprehensive understanding of sustainability competency development (Barth and Rieckmann, 2016; Redman et al., 2021).

Qualitative tools, such as scenario/vignette or drawings, could be developed and used to assess sustainability competency development in primary education, since these have been described as powerful instruments to explore children's sustainability-related competencies, knowledge, values, and attitudes (Alerby, 2000; McGinnis & Hestness, 2017; Shepardson et al., 2009). According to previous literature, qualitative tools such as interviews, focus groups, scenario vignettes and drawings are effective instruments to assess sustainability competencies (Sandri, Holdsworth & Thomas, 2018; García, Junyent & Fonolleda, 2017). Thus, further research could combine different assessment tools and approaches, including self-evaluation, for capturing the process and outcomes of ESD pedagogical strategies and approaches focused on the development of sustainability competencies (Cebrián et al., 2020).

We also identified that sustainability competencies based on clear theoretical frameworks were only explicitly assessed in eleven studies. Previous research has also described a lack of theoretical clarity and unity around what is assessed in terms of sustainability competencies (Brundiers et al., 2021; Corres et al., 2020; Mulà et al., 2022). Thus, the findings of this study support the need for and relevance of using validated frameworks for assessing sustainability competencies, such as the GreenComp framework (Bianchi et al., 2022). Using sustainability competencies based on a theoretical framework is important because it provides clear conceptualisations of competence areas, individual competencies and competence descriptors to be assessed, which can lead to more effective design of assessment tools and operationalisation of these frameworks in educational settings.

Our third research question aimed to identify the strengths and limitations of the assessment tools used in the studies analysed to inform improved assessment of sustainability competencies in primary education. Each assessment tool presents unique

limitations and strengths that must be considered when designing sustainability competency assessment tools for primary education. The studies analysed provide insights into several limitations observed and shared when using different assessment tools for sustainability competencies including gender bias, sample size, selection bias, applicability and transferability to different contexts, and the need to combine different assessment tools such as questionnaires, focus groups, interviews and regular course work (Sass et al., 2021; Scharenberg et al., 2021; Waltner et al., 2019). This finding is in line with previous research that has highlighted the importance of using different types of assessment tools in combination when assessing sustainability competencies to provide a more comprehensive understanding of how sustainability competencies are developed (Mulà et al., 2022; Redman et al., 2021). In our review questionnaires were found to present numerous limitations when used as the only assessment tool, which is in line with previous studies that have highlighted the challenge of developing valid competency measures, due to the broad definition of sustainability competencies and discrimination variables (Ratinen et al., 2024).

Shared recommendations and improvements that emerged in the studies analysed include exploring gender differences (Hsiao & Su, 2021; Křepelková et al., 2019), expanding the sample size (Trott & Weinberg, 2020; Verhelst et al., 2022), incorporating other assessment tools and conducting longitudinal studies to track participants' sustainability learning (Scharenberg et al., 2021; Waltner et al., 2019). These findings are in line with previous research that has pointed out the importance of conducting longitudinal studies that allow tracking of student performance and learning progression in the development of sustainability competencies amongst individuals and at different levels of education (Cebrián et al., 2020; Sass et al., 2021).

Implications for research and practice

Our study provides valuable insights into the assessment of sustainability competencies in primary education, providing an overview of existing assessment approaches and tools used and their strengths and limitations. These findings have implications for educators, scholars, programme leaders, curriculum designers and policy makers in planning and framing ESD pedagogies and programmes, and in finding appropriate and effective assessment tools for measuring sustainability learning and competencies in primary education students.

The diversification of assessment tools and the integration of formative and summative approaches can provide a more comprehensive assessment framework for assessing the development of sustainability competencies in primary education. Formative assessment empowers learners in their own learning journey and also facilitates aligning sustainability competency frameworks with specific learning contexts and levels, where teachers and educators play a vital role. In this sense, the involvement of teachers and practitioners in the assessment process and in further research projects focused on sustainability competency assessment is essential for their pedagogical knowledge and their day-to-day interactions with students in classrooms, enhancing the relevance, applicability and transferability of the assessment tools designed. There is also a need to document sustainability competency assessment experiences from different regions, especially the Global South, that can contribute to the expansion of existing discourses that have to date been overlooked, and that can enrich different sociocultural perspectives, challenging the predominant European and North American perspectives.

Based on the review conducted, we suggest the following pathways for future

research and practice that could assist educators, scholars, practitioners, and policy makers to improve sustainability competency assessment methodology and tools in primary education:

- Design, test and validate quantitative, qualitative and self-assessment tools to capture student sustainability learning and competency development throughout the learning processes.
- Use a range of assessment tools to measure the development of sustainability competencies in combination, to determine the effectiveness of each tool and gain a more comprehensive overview and evidence of how students' sustainability competencies develop.
- Conduct longitudinal studies using summative, formative and self-assessment tools in schools and in the transition between education levels, which would provide evidence of the development of sustainability competencies and its learning progression, considering the evolution of sustainability competencies acquisition and performance over time, defining levels of competence according to different education stages or levels.

By incorporating different assessment approaches and tools a more comprehensive insight of competency development could be achieved, reducing the potential bias associated with the use of a single instrument. In addition, it is important to design and validate reliable assessment tools especially adapted for assessing younger children's learning that are linked to sustainability competency frameworks, to measure progress and to inform future educational programmes and initiatives that aim to develop sustainability conscious and competent citizens.

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