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Teachers' Capabilities in Sustainable Higher Education: A Systematic Review and Future Research Agenda Using TCCM Analysis

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Abstract: Amidst the global sustainability transition, higher education institutions face pressing demands to cultivate multifaceted teacher capabilities that address complex societal challenges. The paper reviews the recent teacher capability literature in sustainable higher education (SHE) following a Theory-Context-Characteristics-Methodology approach to map the state-of-the-art advancements in this field. A systematic review of 75 articles from Scopus and Web of Science databases was conducted through the Preferred Reporting Items for Systematic Reviews and Meta-Analyses procedure. The study reveals the dominant theories (learning theory, leadership theory, sustainable development theory, and stakeholder theory), contexts (Chinese and multinational studies), characteristics (teacher capabilities: technology integration capabilities, pedagogical design and implementation skills, key drivers: policy and resource support, and individual psychological factors, outputs: quality improvement of SHE), and methodologies (interviews, case studies, and structural equation modeling). It advances theoretical innovation and practical transformation of SHE at least in three pathways: (1) interdisciplinary theoretical integration to map driving factor-capability-outcome nexuses, (2) empirical expansion in developing economies with competency-policy linkage mechanisms, and (3) institutional synergies through system optimization and global partnerships. These insights provide actionable frameworks for SHE transformation, urging policymakers and educators to co-create capability ecosystems that align educational practices with sustainability imperatives.

Keywords: Sustainable Higher Education; Teacher Capability; Teacher Competence; TCCM Analysis; Digital Transformation

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1.Introduction

Amidst an accelerating global sustainability transition, sustainable higher education (SHE) is increasingly recognized as a catalyst for socially equitable, economically viable, and ecologically sound development[31]. Central to this mission is preparing future educators, researchers, and leaders with the expertise to address multifaceted sustainability challenges[51]. However, integrating sustainability into higher education faces a critical barrier: a disconnect between institutional sustainability goals and the capabilities of teachers to deliver transformative learning[51]. Although studies have examined

sustainability-orientated pedagogical innovations[45] and curriculum design[3][11], a systematic analysis of the specific capabilities teachers require for SHE remains underdeveloped[26].

Unlike "competence," a "capability" perspective better reflects the diverse values and complex contexts facing contemporary university educators[31]. To advance the development of SHE, teachers must evolve from traditional knowledge transmitters into facilitators of sustainability-oriented learning. This shift requires capabilities in integrating interdisciplinary knowledge, critical thinking, and digital literacy[24][47], as well as guiding students in sustainability practices[9]. Furthermore, the rapid advancement of AI and digital educational technologies is reshaping teacher-student relationships, necessitating the ability to effectively incorporate AI tools into pedagogy[30]. Unfortunately, current teacher training in higher education remains largely focused on subject-specific professional skills, with insufficient emphasis on SHE-related capabilities[33].

Previous research on SHE has primarily concentrated on student learning outcomes and institutional sustainability policies[21][30]. Regarding teacher capabilities, existing studies have centered on competencies, particularly digital ones[36]. However, systematic reviews of teacher competencies are confined to traditional higher education[17], and there is a dearth of research on teacher capabilities in SHE encompassing theories, scenarios, characteristics, and methodologies[40]. Moreover, the current literature shows several fragmented relationships: (1) a gap between sustainability literacy and pedagogical applications[26]; (2) limited theoretical and empirical research on teacher capabilities in SHE[21]; (3) substantial disparities in teacher capabilities across different educational scenarios[9].

Against this backdrop, this study comprehensively reviews 75 publications from Scopus and WOS databases on teacher capabilities in SHE, uncovering knowledge on research trends, main journals, authors, themes, theories, contexts, characteristics, and methodologies. Based on these findings, we propose a future research agenda to fill existing gaps. Our objective is to expedite the transformation of teachers' roles in SHE, support higher education institutions' teacher training programs, and contribute to the knowledge of SHE.

2.Research Methodology

Adopting the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework[17][32], this systematic review implemented a four-stage procedure (identification, screening, eligibility, and inclusion) to ensure methodological rigor in literature selection (see Figure 1).

(1) Identification

To capture relevant articles on teachers' capabilities in SHE, the query strings were designed based on Basilotta-Gómez-Pablo et al.[4] and Dervenis et al.[17]:

("Competence" OR "Ability" OR "Capability" OR "Capacity" OR "Literacy") AND ("Sustainability" OR "Sustainable") AND ("Teacher" OR "Academic Staff" OR "Professor") AND ("Higher Education" OR "University" OR "College")

We performed searches in the WoS Core Collection and Scopus databases on November 25, 2024, corresponding to the selection of AB and TITLE-ABS-KEY, both for the time period 2000-01-01 to 2024-11-25. The combined search results were 1379 articles.

(2) Screening

The literature screening process implemented three-tier exclusion criteria: (1) removal of 110 duplicate entries across databases, (2) exclusion of 73 non-anglophone publications, and (3) elimination of 517 papers related to conferences, book chapters, reviews, diaries, editorial, and datasets. In addition, considering the research objectives, the textual analysis (title/abstract/keywords) excluded 592 records related to pre-service teachers and student teachers.

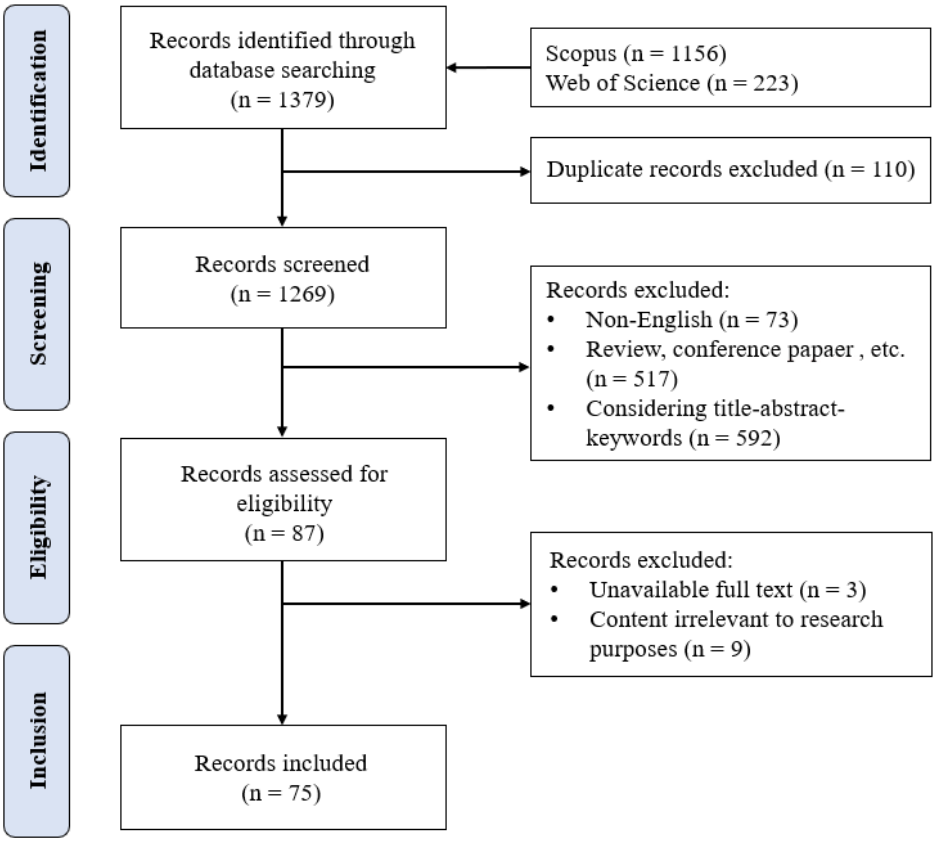
(3) Eligibility

After excluding 3 full-text unavailable records, the remaining 84 articles were carefully read to make sure that only the ones that were relevant to SHE and teacher competence (or competence, capability, ability) were chosen. After removing 9 studies due to insufficient thematic congruence, we obtained 75 eligible articles.

(4) Included

The 75 articles included would be analysed synthetically regarding the distribution of years, journals, authors, citations, and main themes, followed by a thorough content analysis focusing on theories, contexts, characteristics, and methodologies.

Figure 1. Article selection diagram based on the PRISMA procedure

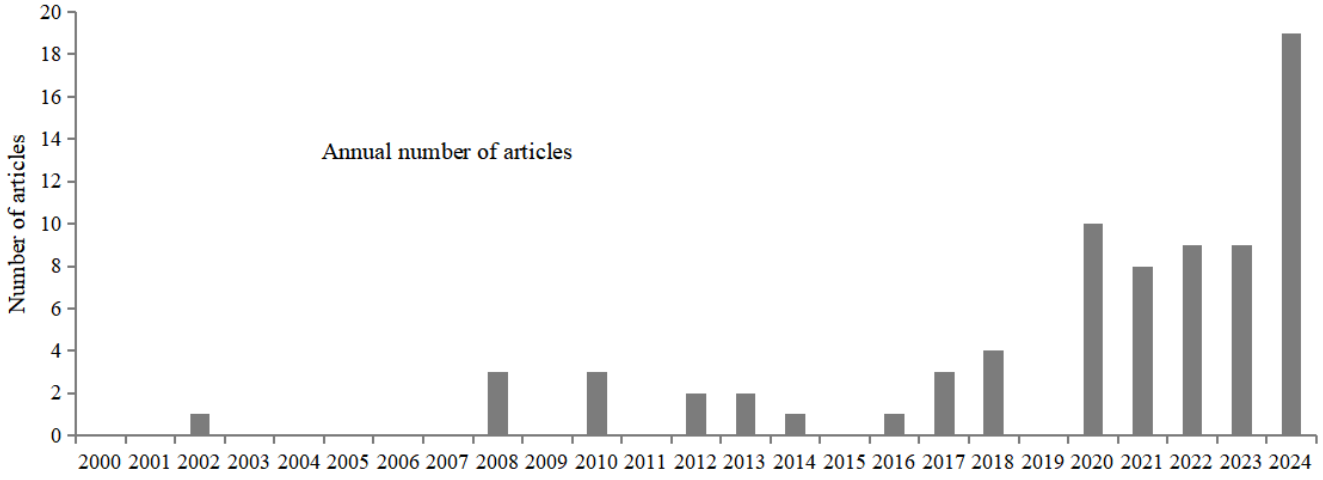


3.Performance Analysis

3.1 Annual Number of Articles

Figure 2 traces the 25-year trajectory of research on the target domain, with bar charts delineating annual publication trends. Although there was an increase in 2008 and 2010, the publications on teacher capabilities in SHE remained unstable for the first 15 years. Moving into 2016, the publications show a trend of rapid growth followed by a stable trend. Most strikingly, the year-on-year surge from 9 publications (2023) to 19 (2024) demonstrates intensified scholarly engagement with this topic.

Figure 2. Annual articles from 2000 to 2024



3.2 Top Journals

Table I shows the total publications (TP), total citations (TC), average citations (TC/TP), and impact factor (IF) of the top 10 journals. The highest TP is 12, i.e. the journal “Sustainability”, and the smallest is 1, which corresponds to the last 4 journals. The journal that stands out the most is the “Journal of Cleaner Production”, which has the highest IF (9.8) and the highest TC/TP of 109 out of the 10 journals. Although the “International Journal of Sustainability in Higher Education” has an impact

factor of only 3.0 compared to many other journals, it is still one of the outstanding journals in studying teacher capabilities in SHE, considering the highest TC (513) and the second highest TP (8). This is followed by journals with high IF and TC, "British Journal of Educational Technology" (IF = 6.7), "Higher Education" (IF = 3.6), "Environmental Education Research" (IF = 2.6), and "Entrepreneurship and Sustainability Issues" (IF = 1.2), whose corresponding TC are 52, 20, 73, and 29, respectively. Besides, "College Composition and Communication" has a TC of 89, which is the highest among the four journals with a TP of 1.

Table I Top 10 journals by TP and TC

Rank	Journals	TP	TC	TC/TP	Impact factor (2023)
1	Sustainability	12	297	24.75	3.3
2	International Journal of Sustainability in Higher Education	8	513	64.125	3.0
3	Journal of Cleaner Production	4	436	109	9.8
4	Higher Education	2	20	10	3.6
5	Cogent Education	2	2	1	1.5
6	Applied Mathematics and Nonlinear Sciences	2	0	0	3.1
7	College Composition and Communication	1	89	89	0.5
8	Environmental Education Research	1	73	73	2.6
9	British Journal of Educational Technology	1	52	52	6.7
10	Entrepreneurship and Sustainability Issues	1	29	29	1.2

Note: IF = Impact factor; TP = Total publications; TC = Total citations; Journals with the same TP were ranked by TCs.

3.3 Top Publications

Table II lists the 10 most influential articles, with TC values ranging from 43 to 258. The outcomes show that during the period 2000-2009, there were only two high-impact publications, presented in the journals of "International Journal of Sustainability in Higher Education" and "College Composition and Communication". There are five articles published between 2010 and 2014, including two each in the "Journal of Cleaner Production" and 2 each in the "International Journal of Sustainability in Higher Education", and 1 in the journal "Environmental Education Research". From 2015 to 2019, only 1 high-impact article, was published in the journal "British Journal of Educational Technology". Between 2020 and 2024, there were 3 other high-impact articles, published in the journals "Sustainability" and "Journal of Cleaner Production". Their research focus indicates that recently academics have begun to concern the use of AI in SHE and the development of teacher capabilities in different cultural contexts. Furthermore, it shows that of the 10 papers, all but three were co-authored.

Table II Top 10 cited articles

Rank	TC	Authors	Journals
1	258	Barth & Rieckmann	Journal of Cleaner Production
2	238	Svanström et al.	International Journal of Sustainability in Higher Education
3	151	Wals	International Journal of Sustainability in Higher Education
4	127	Ceulemans & De Prins	Journal of Cleaner Production
5	89	Cushman	College Composition and Communication
6	73	Sandri	Environmental Education Research
7	57	Bucea-Manea-ţoniş et al.	Sustainability
8	52	Bennett et al.	British Journal of Educational Technology
9	46	Hernández-Diaz et al.	Journal of Cleaner Production
	46	Asif et al.	Sustainability
10	43	Davison et al.	International Journal of Sustainability in Higher Education

Note: TC = Total citations.

3.4 Most Influential Authors

To identify the most influential authors in the field, we listed the top 20 based on TC (see Table III). Although only two authors, Rieckmann M. and Leal Filho W., have a TP of two, their TC, h-index, and m-index further reflect their academic impact. Rieckmann M. (Germany), Barth M. (Australia), and Svanström M. (Sweden) are among the most cited, with Rieckmann M. leading in TC (290), an h-index of 21, and an m-index of 1.105. In contrast, Polanco J. A. has relatively lower TC, h-index, and m-index. Notably, Leal Filho W. (Germany) ranks highest in h-index (56) and m-index (1.697), underscoring his influence. Table III also indicates the global distribution of authors across Europe, America, Asia, and Oceania.

Table III Top 20 authors with most citations

Rank	Authors	TC	TP	h-index	m-index	YFP	Organisations
1	Rieckmann M.	290	2	21	1.105	2006	University Vechta, Germany
2	Barth M.	258	1	24	1.600	2010	RMIT University, Australia
3	Svanström M.	238	1	30	0.938	1993	Chalmers University of Technology, Sweden
4	Wals A.E.J.	151	1	31	0.861	1989	Wageningen University & Research, Netherlands
5	Ceulemans K.	127	1	14	0.933	2010	Hogeschool-Universiteit Brussel, Belgium
6	Cushman E.	89	1	9	0.310	1996	Northeastern University, United States
7	Sandri O.J.	73	1	9	0.750	2013	RMIT University, Australia
8	Bucea-Manea-ţoniş R.	57	1	10	0.625	2009	National University of Physical Education and Sport, Romania
9	Kuleto V.	57	1	6	0.462	2012	University Business Academy in Novi Sad, Serbia
10	Ilić M.P.	57	1	10	1.000	2015	University Business Academy in Novi Sad, Serbia
11	Păun D.	57	1	5	1.250	2021	Spiru Haret University, Romania
12	Bennett S.	52	1	24	1.143	2004	University of Wollongong, Australia
13	Lockyer L.	52	1	18	0.750	2001	University of Technology Sydney, Australia
14	Agostinho S.	52	1	13	0.619	2004	University of Wollongong, Australia
15	Leal Filho W.	46	2	56	1.697	1992	Hamburg University of Applied Sciences, Germany
16	Colomer J.	46	1	27	0.844	1993	University of Girona, Spain
17	ul Amin N.	46	1	17	1.214	2011	Federal Urdu University of Arts, Science and Technology, Pakistan
18	Kayani S.	46	1	8	1.143	2018	Zhejiang University, China
19	Escobar-Sierra M.	46	1	7	1.000	2018	Universidad de Medellin, Colombia
20	Polanco J. A.	46	1	6	0.375	2009	Universidad de Medellin, Colombia

Note: TP = Total publications; TC = Total citations; YFP = Year of First Publication; The h-index and YFP are based on the Web of Science Core Collection metrics; Co-authors of the same TC were retained only if their h-index was higher than 3[41].

3.5 Most Productive Countries

Table IV presents the top 10 countries by TP, along with their TC, TC/TP, and publication distribution over time. China leads in TP with 24.07% (13), followed by Australia (14.81%, 8) and Portugal (11.11%, 6). In terms of TC, Australia (501),

Germany (336), and the United States (328) rank highest, while the United States (109.33), Germany (67.20), and Australia (62.63) are the most influential by TC/TP.

Regarding temporal distribution, all of China's 13 publications, along with those from India (4) and Colombia (2), are from 2020–2024. Australia has publications spanning all four time periods, whereas the United States has two publications from 2000–2009 and one from 2020–2024. Germany and South Africa have publications in 2010–2014 and 2020–2024, while Portugal, Spain, and Indonesia have contributions in 2015–2019 and 2020–2024.

Table IV also highlights a significant increase in TP during 2020–2024 compared to previous periods. Notably, beyond contributions from established research nations such as Germany, and Portugal, researchers from developing countries like China and India have increasingly engaged in this field.

Table IV Top 10 countries with total publications in different periods

Rank	Countries	TP	%	TC	TC/TP	2000-2009	2010-2014	2015-2019	2020-2024
1	China	13	24.53	112	8.62				13
2	Australia	8	15.09	501	62.63	1	3	1	3
3	Portugal	6	11.32	53	8.83			1	5
4	Germany	5	9.43	336	67.20		1		4
5	Spain	5	9.43	74	14.80			1	4
6	Indonesia	5	9.43	51	10.20			3	2
7	India	3	5.66	21	7.00				3
8	United States	3	5.66	328	109.33	2			1
9	South Africa	3	5.66	22	7.33		1		2
10	Colombia	2	3.77	47	23.50				2

Note: TP = Total publications; TC = Total citations.

3.6 Keyword Analysis

The clustering of keywords highlights key research themes[7]. Using VOSviewer, we conducted a co-occurrence analysis of keywords, identifying 16 out of 421 keywords that met the threshold (≥ 4 co-occurrences). The keyword network is categorised into three clusters (see Figure 3):

Red: Focuses on the role of teachers and higher education institutions in SHE, including higher education institutions, sustainable development, education for sustainable development, sustainability, teachers, competences, and teacher training.

Green: Represents higher education in specific periods, with keywords such as higher education, universities, students, COVID-19 pandemic, and literacy.

Blue: Encompasses educational behaviors and application contexts, including teaching, learning, education, and China.

According to node size and link strength in Figure 3[7], higher education has the strongest connections, particularly with sustainable development, teachers, competences, teaching, and learning, etc.

Table V lists keywords occurring at least four times in the 75 articles. To streamline analysis, we consolidated related terms: higher education, higher education institutions, education, and universities under higher education; sustainable development and sustainability under sustainable development; teacher, teaching, and competences as teacher competences; and student and learning as student learning. Thus, the most frequent keyword is higher education (51 occurrences), followed by teacher competences (35) and sustainable development (27), highlighting core themes in the literature. Other commonly used terms include student learning (14), education for sustainable development (12), and teacher training (10). Additionally, COVID-19 pandemic (7), literacy (4), and China (4) reflect relevant educational scenarios.

Figure 3. The keywords co-occurrence network

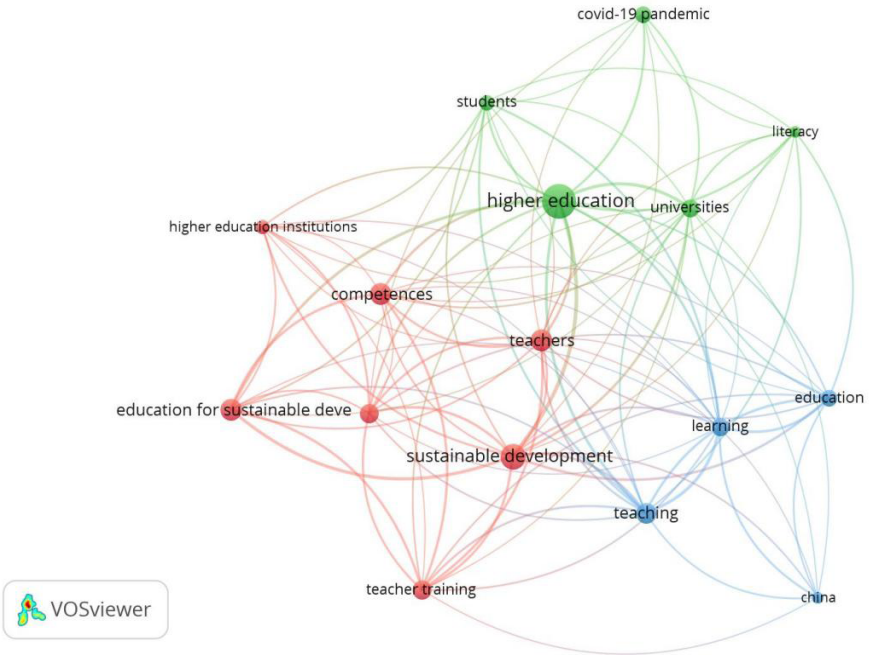


Table V Keywords occurrences with at least four times

Keywords	Occurrences
Higher education	30
Sustainable development	17
Education for sustainable development	12
Teachers	12
Competences	12
Teaching	11
Teacher training	10
Sustainability	10
Universities	9
Learning	8
Education	7
Covid-19 pandemic	7
Students	6
Higher education institutions	5
Literacy	4
China	4

4.TCCM Analysis

4.1 Theories

Among the 75 publications, 40 (53.33%) did not incorporate theoretical frameworks, while 30 (40%) applied a single dominant theory. Additionally, four studies integrated two theories, and one employed three. In total, 32 theories were identified (see Table VI). The most frequently used theories include learning theory (4 articles), leadership theory (4), sustainability theory (4), and stakeholder theory (3).

Learning theory underscores the ongoing need for teachers and students in SHE to acquire sustainability-related knowledge

and enhance competencies[38]. Meanwhile, leadership theory guides university administrators in enhancing teacher capabilities, including research and knowledge management[35] and teacher performance[46]. Sustainability theory explains the role of higher education in sustainability[22], whereas Stakeholder theory highlights the need for SHE to manage relationships among administrators, teachers, and students, as well as institutional systems[49].

Other single-theory applications, including motivation theory, human agency theory, social exchange theory, teacher identity theory, and well-being theory, are closely linked to the development of teacher competencies in SHE.

Table VI Theories employed

Theories	Related Articles	%	Theories	Related Articles	%
Learning theory	4	9.76%	Symbolic Interactionism	1	2.44%
Leadership theory	4	9.76%	Teacher identity theory	1	2.44%
Sustainable development theory	4	9.76%	Subjective educational theory	1	2.44%
Stakeholder theory	3	7.32%	Theory of Planned Behaviour	1	2.44%
Crisis management theory	1	2.44%	Institutional theory	1	2.44%
Social cognitive theory	1	2.44%	Resource-based view	1	2.44%
Self-efficacy theory	1	2.44%	The trait and factor theory	1	2.44%
Outcome-based education theory	1	2.44%	Dynamic capability theory	1	2.44%
Cybernetics	1	2.44%	Absorptive capacity theory	1	2.44%
Ability motivation opportunity theory	1	2.44%	Psychological capital theory	1	2.44%
Social exchange theory	1	2.44%	Cultural historical activity theory	1	2.44%
Human agency theory	1	2.44%	Unified theory of acceptance and use of technology	1	2.44%
Professional action competence model	1	2.44%	Practice theory	1	2.44%
Personalized human resource management theory	1	2.44%	Well-being theory	1	2.44%
Incentive theory	1	2.44%	Creativity theory	1	2.44%

4.2 Context

Table VII presents the country contexts of the included studies. The largest number of studies were conducted in China (13, 17.33%), likely due to the increasing emphasis on SHE and recent educational reforms[27]. Multi-national studies (10, 13.33%) also constitute a significant portion, highlighting SHE and teacher capability development as global issues requiring international collaboration. In contrast, Germany (2, 2.67%) and the United States (1, 1.33%) have relatively few studies, possibly because their mature education systems focus more on traditional disciplines or emerging technologies. Meanwhile, research in developing countries is expanding, with Indonesia (5, 6.67%), India (3, 4%), and Vietnam (3, 4%) reflecting growing interest in SHE as a means to enhance education quality and equity[25]. However, Africa, South America, and some Asian countries (e.g., Saudi Arabia, Iran) remain underrepresented, revealing a significant imbalance in regional research coverage.

Table VII Country context

Country context	Related Articles	%	Country context	Related Articles	%
China	13	17.33%	Korea	1	1.33%
Multi-country	10	13.33%	Portugal	1	1.33%
Indonesia	5	6.67%	Denmark	1	1.33%

Country context	Related Articles	%	Country context	Related Articles	%
Australia	4	5.33%	Italy	1	1.33%
Not specified	4	5.33%	Russia	1	1.33%
India	3	4.00%	Brazil	1	1.33%
Vietnam	3	4.00%	Saudi Arabia	1	1.33%
Germany	2	2.67%	Malaysia	1	1.33%
Iraq	2	2.67%	Mexico	1	1.33%
Spain	2	2.67%	Egypt	1	1.33%
South Africa	2	2.67%	Iran	1	1.33%
Switzerland	2	2.67%	Ghana	1	1.33%
Philippines	2	2.67%	Ecuador	1	1.33%
Columbia	2	2.67%	Kenya	1	1.33%
United States	1	1.33%	the Democratic Republic of the Congo	1	1.33%
Netherlands	1	1.33%	the Democratic Republic of Sao Tome and Principe	1	1.33%
Belgium	1	1.33%			

4.3 Characteristics

For the characteristics, we focused on the teacher capabilities, their antecedents, and outcomes in SHE.

Teacher capabilities are characterised by the following six core dimensions (see Table VIII):

(1) Technology integration – The ability to incorporate digital tools into teaching, encompassing digital literacy[37], data-driven pedagogy, and technology-enabled sustainable innovation[8].

(2) Pedagogical design and implementation – Skills for developing interdisciplinary curricula[12], fostering critical thinking[9], and facilitating inclusive, student-centered education[42].

(3) Academic research – Competence in academic media literacy[52], international research collaboration[23], and scholarly creativity[16].

(4) Sustainability literacy – Like systems thinking[1], SDG integration in education [21], and moral responsibility[2][27].

(5) Organizational and collaborative competences – Strengthening leadership[15][46], resource integration[49], and community engagement[14].

(6) Non-cognitive capabilities – Building psychological resilience[48], intercultural communication[55], and emotional literacy[57].

Regarding the key drivers of teacher capability enhancement (see Table IX), the first three can be regarded as external drivers, while the fourth are internal engines. One is technological infrastructure, such as digital teaching platforms and virtual laboratories[28], and technical support teams[50]. Second, training and professional development, including SHE knowledge training and practical application of online teaching tools[9]. Third, policy and resource support, such as sustainability-oriented policies, fair remuneration systems and teacher autonomy[43][49][54]. Fourth, social and cultural factors, which involve cross-cultural experiences[23] and societal recognition of SHE's value[34]. Fifth, individual psychological factors, including teacher self-efficacy[56], psychological capital[6] and learning motivation[19].

Teacher capabilities trigger multilevel effects of SHE (see Table X). The first is an improvement SHE quality in the form of improved teaching efficacy[24], strengthened interdisciplinary competence, heightened social responsibility awareness[25] [53], and behavioral shifts toward sustainability[1]. The second is breakthroughs in teacher professional development, such as increased international research output[23] and academic satisfaction[18]. The third is better teacher well-being, including professional identity[13] and burnout reduction[43]. The fourth is improved sustainable performance and competitive advantage[49].

Table VIII Dimensions of teacher capabilities in SHE

Dimensions	Sub-dimensions	Related Articles	%
Technology integration capabilities	Digital literacy; Information technology application skills; Online pedagogical adaptability (real-time interaction, technological trouble-shooting) Data-driven pedagogical decision-making; Technology-driven sustainable innovation; Digital self-learning	21	19.09%
Pedagogical design and implementation skills	Student-centered pedagogical philosophy; Interdisciplinary curriculum design (integrating SDGs); Critical thinking; Creative design; Innovative teaching; Reflective teaching skill; Inclusive teaching; Active lifelong learning; Internationalized teaching skill	23	20.91%
Academic research abilities	Academic media literacy; Professional (technical) competence; Creativity or pioneering research; Research ability; International research capacity; Academic affinity	17	15.45%
Sustainability literacy	Systems thinking, strategic thinking, value thinking, and future thinking Environmental awareness and social responsibility education Incorporation of SDGs into teaching and researching; Moral character	17	15.45%
Organizational and collaborative competences	Team spirit; Leadership and management skill; Resource integration capacity (leveraging policy and external funding); Community engagement and service; Entrepreneurial skills	17	15.45%
Non-cognitive capabilities	Psychological resilience (Emotional adjustment, crisis and stress coping); Intercultural communication (e.g. English language skill); Communication skill; Emotional literacy (e.g. inclusion, and psychological support)	15	13.64%

Note: One article may contain more than one sub-dimension capability.

Table IX Key drivers of teacher capabilities in SHE

Drivers	Description	Related Articles	%
Technological infrastructure	Digital teaching platforms and virtual laboratories, and stable network and technical support teams	3	9.68%
Training and professional development	Sustainability knowledge and preparedness, such as receiving regular training on the use of online teaching tools and SHE knowledge	4	12.90%
Policy and resource support	Such as sustainable development strategies, rational incentives (e.g. fair remuneration), connectivity and democratic governance (autonomy), and sound resource allocation	10	32.26%
Social and cultural factors	Cross-cultural experiences (e.g., study abroad experiences and participation in international faculty exchanges), and societal recognition of the value of SHE	4	12.90%
Individual psychological factors	Teacher self-efficacy, psychological capital, intentionality (e.g., motivation, interest, and beliefs), thoughtfulness, self-reactivity, self-reflectivity, and emotional intelligence	10	32.26%

Note: One article may contain more than one driving factors.

Table X Outputs of teacher capabilities in SHE

Drivers	Description	Related Articles	%
Quality improvement of SHE	Improved teaching efficacy (e.g., high student engagement and evaluation), increased interdisciplinary competence of students, heightened awareness of social responsibility, and behavioral changes towards sustainable development (e.g., participation in SDGs-related activities).	8	9.68%
Teacher professional development	Increased career satisfaction and retention, and internationalization of research output (e.g., high-level publications, international cooperation projects)	6	12.90%
Teacher well-being	Identity strengthening, professional well-being, and burnout reduction	4	32.26%
Sustainable performance and competitive advantage	Better brand reputation, improved resource utilization efficiency, practical community service projects (e.g., sustainable practices with NGOs), and policy advice outputs	5	12.90%

4.4 Methodologies

The research methodologies of teachers' capabilities in SHE is diversified (see Table XI). Qualitative research dominates the field with a 56.70% share. Among them, interviews (17, 17.53%) are the most used qualitative method, enabling direct insights into teachers' perceptions, challenges, and capacity-building needs[23]. In addition, case studies (15, 15.46%) can provide empirical insights into teacher capabilities and educational practices in SHE. Meanwhile, a variety of qualitative methods such as thematic analysis, literature analysis, and Delphi method are also widely employed, offering multi-perspective examinations of teacher capability development, conceptual evolution, and its alignment with SHE.

Although quantitative research accounts for a smaller proportion (35.05%) compared to qualitative studies, it remains a crucial approach. Among them, structural equation modeling was used most frequently (11, 11.34%), particularly for analyzing the correlations between multidimensional teacher capabilities and SHE outcomes[49]. Other statistical analysis methods have also been employed such as ANOVA, multiple regression analysis, logistic regression analysis, etc.

Besides, mixed methods were also applied in the research (6, 6.19%). For example, methods such as analytic hierarchical process and system dynamics[35] were utilised to synthesize the multifaceted aspects of teacher capabilities and the dynamic relationships between them.

Table XI Methods employed

Method		Related Articles	%
Quantitative		34	35.05%
	Structural equation modeling	11	11.34%
	Analysis of variance	2	2.06%
	Multiple regression analysis	1	1.03%
	Logistic regression analysis	1	1.03%
	Linear regression analysis	1	1.03%
	Confirmatory factor analysis	1	1.03%
	Exploratory factor analysis	1	1.03%
	Other statistical analysis	16	16.49%
Qualitative		55	56.70%
	Interview	17	17.53%
	Case study	15	15.46%
	Thematic analysis	5	5.15%
	Literature analysis	4	4.12%

Method		Related Articles	%
	Delphi method	3	3.09%
	Comparative analysis	2	2.06%
	Classroom observation	2	2.06%
	Conceptual work	2	2.06%
	Grounded theory	1	1.03%
	Netnography	1	1.03%
	An interactive model	1	1.03%
	Systematic text condensation	1	1.03%
	A focus group	1	1.03%
Mixed		6	6.19%
	Analytic hierarchical process	2	2.06%
	System dynamics	2	2.06%
	The fuzzy set qualitative comparative analysis	1	1.03%
	Q methodology	1	1.03%
Others		2	2.06%
	An evaluation method proposed by authors	1	1.03%
	Discussion by authors	1	1.03%

Note: One article may contain more than one method.

5.Directions for future research

5.1 New Research Directions of Theories

Current studies often rely on single theoretical frameworks with limited explanatory power for teachers' complex roles in SHE. For instance, learning theory[1] remains disconnected from Sustainable Development Goals, creating gaps between capability development and sustainability agendas, while leadership theory[35] emphasizes managerial efficacy but overlooks connections to psychological capital.

Future research should adopt multidisciplinary theoretical integration, combining education, psychology, and sociology to develop more comprehensive frameworks. Promising directions include merging dynamic capability with teacher identity theory to examine environmental adaptation; integrating institutional and psychological capital theories to explore policy-motivation interactions; and combining ecological with stakeholder theory for systematic capability modeling.

5.2 New Research Directions of Context

The lack of research on teachers' sustainable capabilities in Africa and South America may hinder SHE development. While some multi-country studies exist[1][19], they offer limited cross-country comparisons and collaboration, restricting a global perspective. Future studies should expand geographical coverage to include developing and underdeveloped regions, fostering cross-country collaboration to establish a global perspective.

5.3 New Research Directions of Characteristics

Current research prioritizes technical and pedagogical skills[29] over ethical and social considerations[10], lacks longitudinal and cross-cultural analysis[9], and treats sustainability literacy superficially without fostering value internalization[40]. Studies on non-cognitive skills neglect emotional literacy[39]. Additionally, teacher capability frameworks remain disconnected from policy implementation mechanisms[44], and the interplay between teacher motivation and institutional constraints is overlooked[5][20].

Future research should deepen sustainability literacy through context-based SDG learning and dynamic assessment to foster value internalization. It should also strengthen theoretical frameworks for non-cognitive competencies—integrating social-

emotional learning and cultural adaptation—to clarify how resilience and intercultural communication shape teaching. Further efforts should link teacher capabilities to policy implementation, demonstrating how competencies translate institutional goals into practice, while incorporating Global South perspectives in cross-cultural studies to improve model generalizability.

5.4 New Research Directions of Methodologies

Current qualitative research lacks methodological depth, with limited use of grounded theory and web ethnography. Quantitative studies have yet to incorporate big data analytics or econometric models, limiting insights into the dynamics and influencing factors of teacher capabilities. Additionally, mixed-methods research remains underutilized, restricting comprehensive analyses of multi-dimensional teacher capabilities.

Future research should expand qualitative approaches, integrating cross-cultural comparisons and longitudinal analysis to deepen understanding of teacher capability formation. Meanwhile, quantitative studies can leverage dynamic modeling, econometrics, and big data methods to explore complex relationships between teacher capabilities and sustainable educational outcomes. Strengthening standardized mixed-methods designs alongside emerging technologies (e.g., multimodal data fusion) will also enhance methodological rigor and provide more actionable insights.

6.Conclusions, Implications and Limitations

This study systematically analyzed 75 articles on teacher capabilities in SHE using the TCCM framework, identifying key themes (“higher education,” “teacher competences,” and “sustainable development”), dominant theories (learning, leadership, sustainable development, and stakeholder theories), primary contexts (mainly Chinese and multinational studies), core characteristics (teacher capabilities: technology integration and pedagogical skills, etc; key drivers: policy support and psychological factors; outcomes: SHE quality improvement), and prevalent methodologies (interviews, case studies, and structural equation modeling). Addressing existing research gaps, this study proposes new directions within the TCCM framework, laying a foundation for further exploration.

Theoretically, this study advances understanding of multidimensional teacher capabilities in higher education, bridging the gap between sustainability and capability development. Practically, it offers strategic recommendations for higher education institutions promoting sustainability. First, institutions should optimize policies by integrating sustainability metrics into performance evaluations and enhancing intrinsic motivation through tailored incentives. Second, resource integration is essential—establishing cross-institutional technology-sharing platforms, lowering digital tool adoption barriers, and collaborating with industries to develop AI-driven training modules. Third, fostering international collaboration through regional alliances can enhance cross-cultural competencies and support policy development via cross-national empirical databases. Lastly, institutions should strengthen community engagement by encouraging faculty participation in local sustainability initiatives and integrating practical experiences into curricula, forming a “teaching-practice-policy” feedback loop.

This study has limitations. The reliance on English-language literature from Scopus and WOS may exclude valuable non-English research. Additionally, regional representation is uneven, with an overrepresentation of studies from China, Australia, and Germany, potentially overlooking the distinct challenges faced by developing countries, such as the digital divide and policy fragmentation, limiting the broader applicability of findings.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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