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RESEARCH ARTICLE

Adopting sustainability competence-based education in academic disciplines: Insights from 13 higher education institutions

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Abstract

Higher Education Institutions (HEIs) have been incorporating sustainability into education and curricula, where recent research has focussed on sustainability competences, pedagogical approaches, and how to connect them, generally on a single HEI. The process of integrating sustainability into education based on curricula assessment has been explained using adoption of innovations; and has the potential to explain the process of developing competences through pedagogical approaches. The aim of this paper is to investigate this process at academic discipline level. An online survey was developed to investigate teaching sustainability competences in

13 HEIs, from which 678 responses from educators were obtained. The competences and pedagogical approaches from the responses were ranked, and then the connections between the competences and pedagogical approaches per discipline were analysed using a correlations-based framework, from which three disciplines groups were created. The groups were categorised using diffusion of innovations theory, which indicated that some disciplines are more innovative than others in adopting sustainability competence-based teaching. The results are used to propose two frameworks to better understand the adoption of sustainability competence-based teaching: (a) the D-RAPID framework; and (b) the Disciplinary Multi-dimensional Sustainability Influence Change for Academia (D-MuSICA) memework. The adoption of sustainability competence-base education must expand from a single HEI perspective to a disciplinary collaborative one spanning many HEIs, where academic disciplines should learn from each other's insights and mistakes and provide students with more transdisciplinary skillsets to make societies more sustainable.

KEYWORDS

academic disciplines, competences, education for sustainable development, educators, pedagogical approaches, teaching

1 | INTRODUCTION

Higher Education Institutions (HEIs) have been the cradle for educating the future decision-makers, scholars, entrepreneurs, leaders, and professionals (Cortese, 2003; Elton, 2003; F. J. Lozano & Lozano, 2014). The focus of HEIs has been on individual learning and competition, encapsulated in the world of each academic discipline (Cortese, 2003).

During the last two decades, HEIs have been incorporating sustainability into their systems (Friman et al., 2018; Holm et al., 2015; Kapitulčinová et al., 2018; R. Lozano, Ceulemans, Alonso-Almeida, et al., 2014) through a holistic approach (Vare et al., 2019), with increasing efforts at integrating it into education, particularly on curricula (Bielefeldt, 2011; R. Lozano, 2010; Pappas et al., 2013; Segalàs et al., 2010), and into academic disciplines (Desha & Hargroves, 2013; Kamp, 2006; R. Lozano, 2006; McKeown, 2002).

Integrating sustainability into curricula is key in providing students with the skills and insights to help societies become more sustainable (R. Lozano, 2006; Ploum et al., 2018; Stough et al., 2018). Educators are instrumental in this process, since they are the ones who ultimately can integrate sustainability into their courses (Ceulemans & De Prins, 2010; Rieckmann, 2018), and thus ensure that students develop the complete set of sustainability competences in the context of their studies (Desha et al., 2019; Kalsoom & Khanam, 2017). The challenges of urgent and at-scale curriculum renewal are complex and complicated, with a variety of approaches observed in HEIs around the world (Desha & Hargroves, 2013; R. Lozano, Ceulemans, & Scarff Seatter, 2014).

Most research on sustainability education has been on a single HEI (see Ferrer-Balas et al., 2004; Lozano-García et al., 2009; R. Lozano, 2010), focussing at course level (e.g., Boks & Diehl, 2006; R. Lozano, Ceulemans, & Scarff Seatter, 2014; MacVaugh & Norton, 2012; Pappas et al., 2013), or programme level (Byrne et al., 2013; Kamp, 2006; F. J. Lozano & Lozano, 2014; Segalàs et al., 2009).

Developments in the incorporation of sustainability in HEIs' curricula (Capdevila et al., 2002; R. Lozano & Peattie, 2011; Martin et al., 2005; Velazquez et al., 2005) have spanned from research on sustainability competences (Barth et al., 2007; Lambrechts et al., 2013; Trencher et al., 2018), to pedagogical approaches (Cotton & Winter, 2010; Desha & Hargroves, 2014; Segalàs et al., 2010; Sipos et al., 2008), and how to connect them (R. Lozano et al., 2017, 2019; Sipos et al., 2008).

Competences for sustainability (including knowledge, skills, and attitudes) are a way of describing intended educational outcomes (Hager & Beckett, 1995; Segalàs et al., 2010; Sturmberg & Hinchy, 2010). Lists of competences relating to education for sustainability and their use have been proposed by several authors in recent years. Wiek et al. (2011) proposed five overall competence groups: Systems-thinking; Anticipatory; Normative; Strategic; and Interpersonal competences. Rieckmann (2012) suggested 12 competences: Systemic thinking and handling of complexity; Anticipatory thinking; Critical thinking; Acting fairly and ecologically; Cooperation in (heterogeneous) groups; Participation; Empathy and change of perspective; Interdisciplinary work; Communication and use of media; Planning and realising innovative projects; Evaluation; and Ambiguity and frustration tolerance. Lambrechts et al. (2013) identified six competences: Responsibility; Emotional intelligence; System orientation; Future orientation; Personal involvement; and Ability to take action. Brundiers et al. (2021) updated Wiek et al.'s (2011) groups through a Delphi approach to come up with Integrated problem-solving, Interpersonal, Intrapersonal, Implementation, Strategic thinking, Values thinking, Futures thinking, and Systems thinking. Lozano et al. (2017) carried out a synthesis to propose 12 competences: Systems thinking, Inter-disciplinary work; Anticipatory thinking; Justice, responsibility, and ethics; Critical thinking and analysis; Interpersonal relations and collaboration; Empathy and change of perspective; Communication and use of media; Strategic action; Personal involvement; Assessment and evaluation; and Tolerance for ambiguity and uncertainty. The last list has been used empirically in a European context (R. Lozano et al., 2019) and internationally (R. Lozano & Barreiro-Gen, 2021), where it has been connected explicitly to pedagogical approaches in a systemic and systematic way, and thus is used in this paper.

Pedagogy is defined as "the art or science of teaching" (OED, 2007). The use of different pedagogical approaches is necessary to address the diversity of students (e.g., gender, cultural background, or study discipline) (Ceulemans & De Prins, 2010; UNESCO, 2006, 2012), where the pedagogical approach choice depends on the educational goals and the educational context (students, teachers, and the learning environment) (de Freitas & Oliver, 2005). Lists of pedagogical approaches have been proposed by several authors. Ceulemans and De Prins (2010) proposed a range of student-activating methods (e.g., videos, brainstorming, case studies, team work, jigsaw, assignments, problem-oriented education, oral presentations, and project learning). Cotton and Winter (2010) suggested several pedagogical approaches (e.g., role-plays and simulations; group discussions; stimulus activities; debates; critical incidents; case studies; reflexive accounts; personal development planning; critical reading and writing; problem-based learning; fieldwork; and modelling good practice). Lozano et al. (2017) synthesised 12 pedagogical approaches divided in three groups: (a) Universal, that is, pedagogical approaches that have been used in many disciplines and contexts; (b) Community and social justice, that is, those developed specifically for use in addressing social justice and community-building; and (c) Environmental education, that is, those from environmental sciences and environmental education practices. The last one is used in this paper.

Some attempts have been carried out to link sustainability competences and pedagogical approaches (see Sipos et al., 2008; Sprain & Timpson, 2012). The "Framework for connecting sustainable development pedagogical approaches to competences" (see Figure 1) explicitly links 12 sustainability competences and 12 pedagogical approaches in a systemic and systematic way (see R. Lozano et al., 2017, 2019; R. Lozano & Barreiro-Gen, 2021). The framework is aimed at helping educators in creating and updating their courses to provide a more complete, holistic, and systemic sustainability education to future leaders, decision makers, educators, and change agents. Research using the framework has been carried out at a HEI level (R. Lozano & Barreiro-Gen, 2021) or at a regional level (i.e., in Europe) (R. Lozano et al., 2019).

The process of integrating sustainability into education, focussing on curricula assessment, has been explained using adoption of innovations (R. Lozano, 2010); and can be used to explain the process of developing competences through pedagogical approaches. The aim of this paper is to investigate this process at academic discipline level.

The rest of the paper is structured in the following way: Section 2 discusses the diffusion of sustainability in education; Section 3 explains the methods used; Section 4 presents the results; Section 5 discusses the results' contribution to the literature; and Section 6 provides the conclusions of this research.

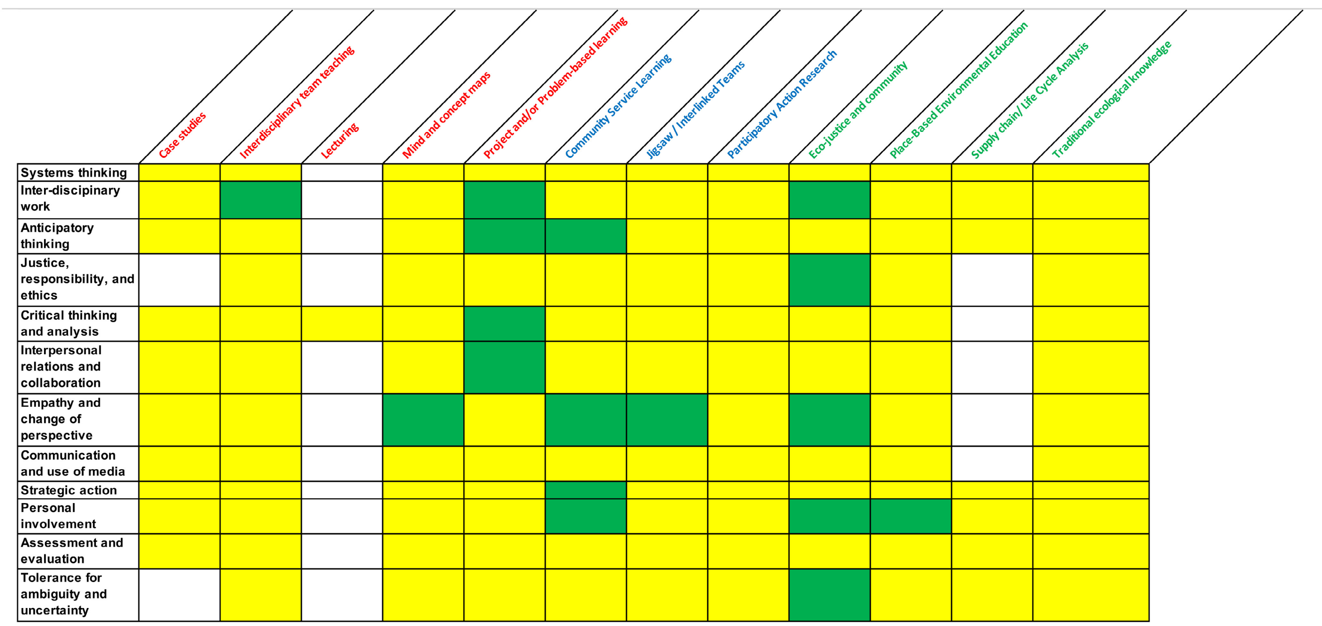

FIGURE 1 Framework for connecting sustainable development pedagogical approaches to competences. The green cells indicate a high likelihood of addressing the competence, the yellow cells indicate that the approach may address it, and the white cells indicate that the approach does not address the competence. *Source*: R. Lozano et al. (2019) [Colour figure can be viewed at wileyonlinelibrary.com]

2 | DIFFUSION OF SUSTAINABILITY IN EDUCATION

Diffusion of innovations provides a way to analyse the integration of competence-based sustainability education through pedagogical approaches (R. Lozano, 2010). Diffusion is when an innovation, such as competence-based sustainability education, is transferred through a social system over time (Rogers, 1962). Diffusion leads to the adoption, or rejection, of the innovation (Spence, 1994).

In diffusion of innovation, the adopters are categorised as "innovator", "early adopter", "early majority", "late majority", and "laggards" (Rogers, 1962). Within the curricula context, the label "laggards" has been changed to "conservatives" since this term is more representative of the level of engagement or contribution to sustainability (R. Lozano, 2010). According to Lozano (2006), the innovators have the satisfaction of being developers of the innovation, but have to bear the burden of early mistakes and issues with test-trials. The early adopters can, together with the innovators, serve as sustainability multipliers by convincing other adopter categories. The late majority and the conservatives tend to have the highest levels of change resistance, but may eventually adopt the innovation.

In general, the diffusion of innovation models have been based on the individual as unit of analysis (see Drury & Farhoomand, 1999; Kotler & Armstrong, 2001; Rogers, 1962; Spence, 1994). In the context of sustainability education, diffusion of innovations has been used to explain the adoption of sustainability using the RAPID model and the Multi-dimensional Sustainability Influence Change for Academia (MuSICA) memework. The RAPID model was developed from sustainability assessment in curricula of one HEI and has the following the following stages (see R. Lozano, 2010):

1. Recognition: Sustainability or some of its issues are explicitly stated in the course's aims and objectives;
2. Addition: Sustainability is explicit in the aims, and taught in one or more lectures within the course, whilst being addressed as an add-on;
3. Pedagogy: Sustainability is explicit in the course aims and its teaching forms a core component;
4. Intertwine: Sustainability is explicit in the aims, and it is integrated into the teaching and grading; and
5. Disciplinarity spanning: In addition to the activities of the Intertwine step, the course links with other disciplines, becoming more inter-disciplinary and trans-disciplinary.

The Multi-dimensional Sustainability Influence Change for Academia (MuSICA) memework (see Figure 2) was developed to explain in a more integrative way the diffusion of sustainability in curricula in one HEI as the unit of analysis. The MuSICA proposes on the *x*-axis the congruence of the SD aims, the delivery, and assessment; and on the *y*-axis the alignment of courses, degrees, schools (or faculties), and the university (see R. Lozano, Ceulemans, & Scarff Seatter, 2014). It should be noted that the RAPID model and the MuSICA memework do not take into consideration academic disciplines.

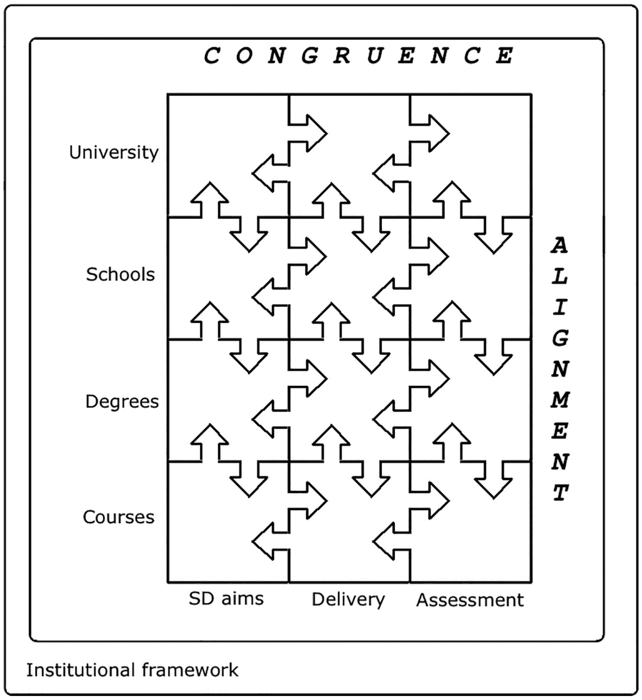

FIGURE 2 Multi-dimensional sustainability influence change for academia (MuSICA) memework to help to illustrate the transfer of the SD meme in curricula, and to and across the university (R. Lozano, Ceulemans, & Scarff Seatter, 2014)

3 | METHODS

A survey was developed to investigate teaching sustainability competences in 13 HEIs (see Table 1), which were selected upon their willingness to participate in the research (for more details on the results of each HEI refer to R. Lozano & Barreiro-Gen, 2021). The survey was sent to teachers of each HEI and consisted of six sections (this paper is focused on parts 1, 3 and 4):

1. Background questions about the respondents' characteristics, and their teaching;
2. Self-assessment of sustainability criteria taught;
3. Pedagogical approaches used, on a five-point scale;
4. Competences covered in the course, on a five-point scale;
5. Types of learning, on a five-point scale; and
6. Open ended questions about the incorporation of sustainability in courses.

The survey was translated to the local languages of each HEI (English, Finnish, Hungarian, Italian, Polish, Portuguese, Serbian, Spanish, Swedish, and Turkish) and double-checked by sustainability experts who are native speakers in respective languages, so that the meaning of the questions was not misconstrued, misinterpreted, or misunderstood.

The survey was applied using the online survey tool Qualtrics (2018) and opened between September 2019 to January 2020. Three

TABLE 1 Details of the case study HEIs

Name of HEI	Level	Faculties/Schools/Departments (in the original language)	Discipline	Country	Number of responses	Students FTE	Educators FTE
University of Gävle	Whole institution	Health and Occupational Studies	Health	Sweden	33	16,000	400
		Engineering and Sustainable Development	Natural and applied sciences				
		Education and Business Studies	Business				
University of Helsinki	Whole institution	Faculty of agriculture and forestry	Business and Natural and applied sciences	Finland	145	31,000	3900
		Faculty of arts	Humanities				
		Faculty of biological and environmental sciences	Natural and applied sciences				
		Faculty of educational sciences	Natural and applied sciences				
		Faculty of law	Natural and applied sciences				
		Faculty of science	Social sciences				
		Faculty of social sciences	Social sciences				
		Faculty of veterinary medicine	Social sciences				
		Swedish school of social science	Social sciences				
University of Parma	Whole institution	Dipartimento di Discipline Umanistiche, Sociali e delle Imprese Culturali	Humanities and Social sciences	Italy	75	27,000	1700
		Dipartimento di Giurisprudenza, Studî Politici e Internazionali	Social sciences				
		Dipartimento di Ingegneria e Architettura	Natural and applied sciences				
		Dipartimento di Medicina e Chirurgia	Health				
		Dipartimento di Scienze Chimiche, della Vita e della Sostenibilità Ambientale	Natural and applied sciences				
		Dipartimento di Scienze degli Alimenti e del Farmaco	Natural and applied sciences				
		Dipartimento di Scienze Economiche e Aziendali	Business				
		Dipartimento di Scienze Matematiche, Fisiche e Informatiche	Natural and applied sciences				
		Dipartimento di Scienze Medico-Veterinarie	Natural and applied sciences				
Universidade da Coruña (UDC)	Whole institution	Escola Politécnica Superior	Natural and applied sciences	Spain	132	17,000	1400
		Escola Técnica Superior de Arquitectura	Natural and applied sciences				
		Escola Técnica Superior de Enxeñeiros de Camiños, Canais e Portos	Natural and applied sciences				
		Escola Técnica Superior de Náutica e Máquinas	Natural and applied sciences				

TABLE 1 (Continued)

Name of HEI	Level	Faculties/Schools/Departments (in the original language)	Discipline	Country	Number of responses	Students FTE	Educators FTE
		Escola Universitaria de Arquitectura Técnica	Natural and applied sciences				
		Escola Universitaria de Deseño Industrial	Natural and applied sciences				
		Escola Universitaria de Relacións Laborais (adscrito)	Social sciences				
		Escola Universitaria Politécnica	Natural and applied sciences				
		Facultade de Ciencias	Natural and applied sciences				
		Facultade de Ciencias da Comunicación	Social sciences				
		Facultade de Ciencias da Educación	Social sciences				
		Facultade de Ciencias da Saúde	Health				
		Facultade de Ciencias do Deporte e a Educación Física	Health				
		Facultade de Ciencias do Traballo	Social sciences				
		Facultade de Dereito	Social sciences				
		Facultade de Economía e Empresa	Business				
		Facultade de Enfermaría e Podoloxía	Health				
		Facultade de Filoloxía	Humanities				
		Facultade de Fisioterapia	Health				
		Facultade de Humanidades e Documentación	Humanities				
		Facultade de Informática	Natural and applied sciences				
		Facultade de Socioloxía	Social sciences				
European University of Lefke	Whole institution	Faculty of Engineering	Natural and applied sciences	North Cyprus	32	12,000	120
		Faculty of Architecture	Humanities				
		Faculty of Law	Social sciences				
		Faculty of Agriculture Sciences and Technologies	Natural and applied sciences				
		Faculty of Health Sciences	Natural and applied sciences				
		Faculty of Economics and Administrative Sciences	Business				
Universidad de las Américas Puebla (UDLAP)	Whole institution	Schools of Arts and Humanities	Humanities	Mexico	69	9700	317
		School of Social Sciences	Social sciences				
		School of Sciences	Natural and applied sciences				
		School of Engineering	Natural and applied sciences				
		School of Economy and Business	Business				

(Continues)

TABLE 1 (Continued)

Name of HEI	Level	Faculties/Schools/Departments (in the original language)	Discipline	Country	Number of responses	Students FTE	Educators FTE
Universidad de Ciencias Aplicadas y Ambientales (U.D.C.A.)	Whole institution	Administración y Negocios	Business	Colombia	17	5000	175
		Ciencias	Natural and applied sciences				
		Ciencias Agropecuarias	Natural and applied sciences				
		Ciencias Ambientales e Ingenierías	Natural and applied sciences				
		Ciencias Jurídicas, de la Educación y Sociales	Social sciences				
		Ciencias de la Salud	Health				
Nyíregyháza University	Whole institution	Applied Human Science (includes psychology and pedagogy)	Social sciences	Hungary	64	4000	200
		Economy Science	Business				
		Environmental Science	Natural and applied sciences				
		Math and Informatics	Natural and applied sciences				
		Technical and Agricultural Science	Natural and applied sciences				
		Language and Literature	Humanities				
		Preschool and Primary School Teacher Training	Social sciences				
		Sport Science	Social sciences				
		History and Philosophy	Humanities				
		Tourism and Geography	Social sciences				
		Visual Culture (Visual arts)	humanities				
		Music Institute	Humanities				
Griffith university	Whole institution	Department of Accounting, Finance and Economics	Business	Australia	45	50,000	4000
		Department of Business Strategy and Innovation	Business				
		Department of Employment Relations and Human Resources	Business				
		Department of Tourism, Sport and Hotel Management	Business				
		Griffith Law School	Humanities				
		Queensland College of Art (including Griffith Film School)	Humanities				
		Queensland Conservatorium	Humanities				
		School of Applied Psychology	Health				
		School of Criminology and Criminal Justice	Social sciences				

TABLE 1 (Continued)

Name of HEI	Level	Faculties/Schools/Departments (in the original language)	Discipline	Country	Number of responses	Students FTE	Educators FTE
		School of Dentistry and Oral Health	Health				
		School of Education and Professional Studies	Social sciences				
		School of Engineering and Built Environment	Natural and applied sciences				
		School of Government and International Relations	Business				
		School of Human Services and Social Work	Health				
		School of Humanities, Languages and Social Science	Social sciences				
		School of Medicine	Health				
		School of Nursing and Midwifery	Health				
		School of Information and Communication Technology	Natural and applied sciences				
Central University of Technology (CUT)	Faculty	Faculty of Built Environment and Information Technology	Natural and applied sciences	South Africa	18[a]	6000[a]	123[a]
Warsaw University of Technology	Faculty	Faculty of Production Engineering	Business and Natural and applied sciences	Poland	11[a]	2400[a]	150[a]
University of Belgrade	Faculty	Faculty of Agriculture	Business and Natural and applied sciences	Serbia	17[a]	1000[a]	300[a]
University of Zaragoza	Faculty	Faculty of Economics and Business	Business	Spain	20[a]	4400[a]	300[a]

[a]Numbers are at faculty level.

reminders were sent out. The survey was sent via the gatekeepers to ensure anonymity and comply with ethical issues (including General Data Protection Regulation [GDPR] in the European HEIs). The gatekeeper sent the survey via mailing lists or emails.

The schools, departments, or faculties were set up according to their academic discipline (see Table 1) for the analysis, using the following categorisation:

1. Business (accounting, economics, finance, management, marketing);
2. Humanities (art, history, languages, literature, music, philosophy, religion, theatre);
3. Natural and applied sciences (biology, chemistry, computer science, engineering, geology, mathematics, physics, medicine);
4. Social sciences (anthropology, education, geography, law, political science, psychology, sociology);
5. Combined disciplines:
   1. Business and Natural and applied sciences; and
   2. Humanities and Social sciences.

The competences and pedagogical approaches questions included: (a) development of the 12 competences in their courses, with five possible answers (not at all; just mentioned during the course; discussed from time to time; complementary to the course, and integral to the course); and, (b) the use of the 12 pedagogical approaches, with six possible answers (not applicable/do not know it, never, seldom, from time to time, often, and all the time).

Two variables were used for comparison purposes: strength of the competences; and strength of the pedagogical approaches. These were calculated by dividing the sum of the all the items divided by the number of items that were considered to be "seldom", "from time to time", "often", and "all the time" for the pedagogical approaches used, or "mentioned", "discussed", "complementary to the course", and "integral to the course" for the competences.

The responses were analysed using, descriptive statistics, Kruskal–Wallis tests to test for differences between each academic discipline; Friedman test to rank the competences and pedagogical approaches, and Spearman correlations between the competences and the pedagogical approaches for each academic discipline (for the "Framework for connecting sustainable development pedagogical approaches to competences" (see R. Lozano et al., 2019)). The analyses were done using IBM SPSS 24 (IBM, 2015).

The correlation analysis results between the competences and pedagogical approaches were transformed to a three-level scale (see Figure 1): 0 to 0.2 (inclusive), labelled as "unlikely" (white cells in the figure); 0.2 to 0.4 (inclusive), labelled as "maybe" (yellow cells in the figure); and 0.4 to 0.66, labelled as "likely" (green cells in the figure).

3.1 | Limitations of the methods

The internal validity of this research might have been limited by the survey, which may not have offered a complete model of sustainability being taught at the case study HEIs. There might have been problems of interpretation of the survey items, reliability issues due to self-assessment, or problems of understanding the terms in another language. The number of respondents of each HEI may not allow a complete generalisation to sustainability teaching in each institution. A non-response bias may be caused by people who refused to answer or complete the survey. In two cases, the gatekeepers had to engage in face-to-face contact with the respondents, which may reduce the generalisability of the results due to non-random sampling. The survey was carried out in four different continents, where the academic years, may be different, and some teachers might have been overloaded with their normal academic activities and did not have the time to answer the survey.

4 | RESULTS

In total, 678 responses were obtained, from which 316 were female, 336 male, and 26 preferred not to say. Two-hundred fifty-five educators have teaching more than 20 years, 222 between 10 and 20 years, 80 between 50 and 10 years, 104 between 1 and 5 years, and 17 less than a year.

31% of all respondents (210) indicated that they teach sustainability explicitly in their courses. Of this, 27 educators have teaching more than 20 years, 44 between 10 and 20 years, 53 between 50 and 10 years, 82 between 1 and 5 years, and 7 less than a year.

Regarding the academic cycle, 211 educators taught solely at the bachelor level, 57 solely at the master level, 2 solely at PhD level,

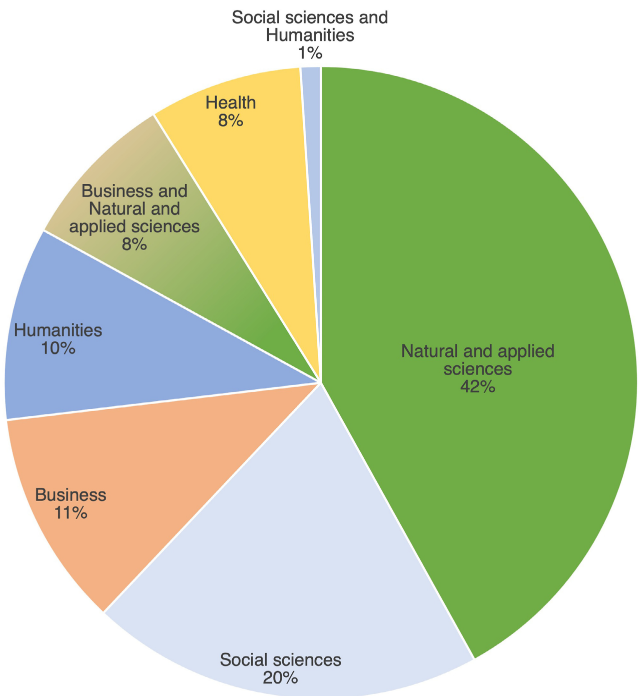

FIGURE 3 Survey responses according to the academic discipline [Colour figure can be viewed at wileyonlinelibrary.com]

248 at bachelor and master levels, 32 at bachelor and PhD levels, 18 at master and PhD levels, and 106 at bachelor, master, and PhD levels.

The number of respondents for the academic disciplines were (see Figure 3): 284 for Natural and applied sciences, 136 for Social sciences, 75 for Business, 67 for Humanities, 55 for Business and Natural and applied sciences, 53 for Health, and 7 for Social sciences and Humanities. The last one was not considered for further analysis given the very low number of responses.

A Kruskal-Wallis test was carried out between the six academic disciplines to check for differences in the competences (including the strength of competences), and pedagogical approaches (including the strength of pedagogical approaches). The strength of competences and strength pedagogical approaches showed significant differences. All the competences had statistically significant differences at $p < .05$, except strategic action. Three pedagogical approaches (lecturing, supply chain/life cycle analysis, and traditional ecological knowledge) has differences at $p < .05$; and five (case studies, inter-disciplinary team teaching, community service learning, jigsaw/interlinked teams, and place-based environmental education) had differences at $p < .1$. Four pedagogical approaches did not have any statistical differences (Mind and concept maps, Project- or Problem-based learning, Participatory action research, and Eco-justice and community).

Table 2 shows the ranking of the sustainability competences using a Friedman test for the disciplines. The disciplines show some similarities in their competence ranking patterns, with the exception of Business and Natural and applied sciences, where System thinking and Anticipatory thinking were ranked higher than in other disciplines. Critical thinking, Inter-disciplinary work, and Interpersonal relations and collaboration tend to be on the top three ranks, except for Health where Empathy and Change of perspective is ranked 1, Critical thinking as 4; Social sciences where Justice, responsibility and ethics is ranked 6 and Systems thinking 3, and Business and Natural and applied sciences where Systems thinking is ranked 3 and Interpersonal relations and collaboration 6. Communication and use of media tends to be ranked in the middle, except for Business and Natural and applied sciences, where it is ranked in place 10. Tolerance for ambiguity and uncertainty tends to be in the lower ranks, except for Humanities, where it is in the middle. Anticipatory thinking tends to be higher in the rank in Business, Business and Natural and applied sciences, and Natural and applied sciences than in the other disciplines.

Table 3 shows the ranking of the pedagogical using a Friedman test for the disciplines. Lecturing, Project- or Problem-based learning, Case studies, and Inter-disciplinary team, and Mind and concept maps tend to be on the 5 top ranks. Community service learning is on the 6 or 7 rank. Participatory action research is between the 6 and 9 rank, except for Health where it is 11. Jigsaw/Interlinked teams is higher in Business, Health, and Social sciences than on Humanities, Business and Natural and applied sciences, and Natural and applied sciences. Supply chain/Life cycle analysis is higher in Business and Natural and applied sciences than the other disciplines. Eco-justice and community is higher in Health and Humanities than the other disciplines.

There are more differences between the developed competences than the pedagogical approaches used. A similar pattern of pedagogical approaches have been used in different academic disciplines, but different competences have been developed.

The connections between the sustainability competences and pedagogical approaches were assessed using Spearman correlations for each academic discipline and illustrated with the help of the "Framework for connecting sustainable development pedagogical approaches to competences". From the correlations, three groups were created from the number of "unlikely", "maybe", and "likely" (respectively):

1. Natural and applied sciences (19, 83, and 42) and Health (35, 54, and 48) see Figure 4;

TABLE 2 Sustainability competences ranking using Friedman test for the academic disciplines (green shades show the highest values, yellow shades the mid-values, and red the lowest values) [Colour table can be viewed at wileyonlinelibrary.com]

	Business	Health	Humanities	Business and natural and applied sciences	Natural and applied sciences	Social sciences	All disciplines
Critical thinking and analysis	9.15	7.89	9.72	8.68	8.39	9.24	**8.77**
Inter-disciplinary work	6.90	8.13	8.52	8.87	8.24	7.38	**8.00**
Interpersonal relations and collaboration	7.28	8.11	7.74	6.42	7.12	7.83	**7.37**
Communication and use of media	6.75	6.70	7.61	5.42	6.25	6.80	**6.54**
Justice, responsibility, and ethics	6.15	7.58	6.65	5.76	6.05	7.50	**6.51**
Empathy and change of perspective	5.93	8.90	7.51	4.64	5.90	7.11	**6.45**
Systems thinking	6.11	4.80	4.99	7.76	6.92	5.49	**6.24**
Anticipatory thinking	6.54	4.90	4.67	7.20	6.62	5.67	**6.13**
Personal involvement	5.69	5.89	5.27	5.26	5.92	5.58	**5.70**
Assessment and evaluation	5.74	5.29	5.01	6.50	5.85	5.18	**5.61**
Strategic action	5.95	5.20	3.96	5.92	5.81	4.70	**5.36**
Tolerance for ambiguity and uncertainty	5.80	4.61	6.35	5.56	4.92	5.52	**5.32**

TABLE 3 Pedagogical approaches ranking using Friedman test for the academic disciplines [Colour table can be viewed at wileyonlinelibrary.com]

	Business	Health	Humanities	Business and natural and applied sciences	Natural and applied sciences	Social sciences	All disciplines
Lecturing	9.84	9.52	9.75	10.43	10.23	9.98	**10.04**
Project- or Problem-based learning	9.51	9.52	9.48	9.33	9.62	9.10	**9.42**
Case studies	9.72	9.65	9.23	8.85	9.04	9.39	**9.25**
Inter-disciplinary team teaching	7.03	7.44	7.24	7.83	6.86	7.55	**7.23**
Mind and concept maps	6.95	7.35	7.26	6.37	6.63	7.02	**6.89**
Community service learning	5.86	6.40	5.77	6.08	5.51	5.89	**5.77**
Participatory Action Research	6.33	4.58	6.27	4.88	5.85	5.28	**5.67**
Traditional ecological knowledge	4.31	4.81	4.98	5.37	5.39	5.03	**5.07**
Jigsaw/Interlinked Teams	5.17	5.42	4.53	4.47	4.53	5.47	**4.89**
Supply chain/Life cycle analysis	4.93	3.77	4.32	6.23	4.81	4.60	**4.76**
Place-based environmental education	4.19	4.73	4.55	4.25	5.20	4.47	**4.71**
Eco-justice and community	4.15	4.81	4.61	3.90	4.33	4.21	**4.31**

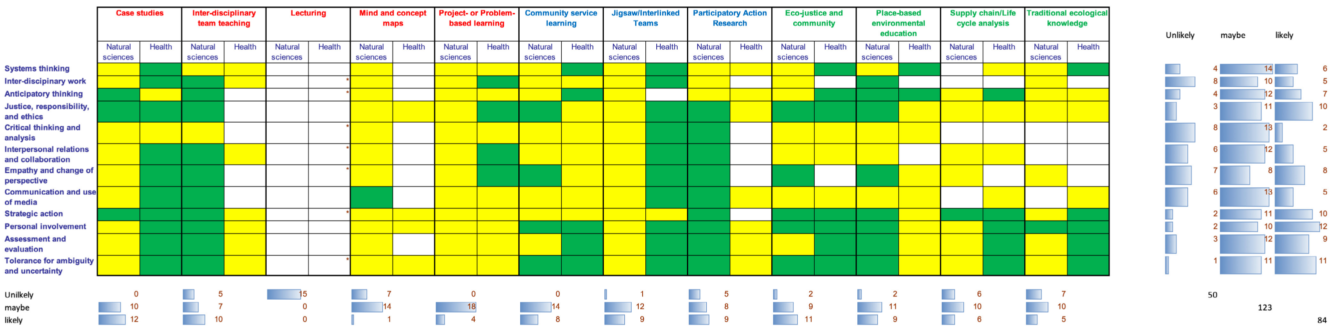

FIGURE 4 Connections between sustainability pedagogical approaches to competences for group 1 [Colour figure can be viewed at wileyonlinelibrary.com]

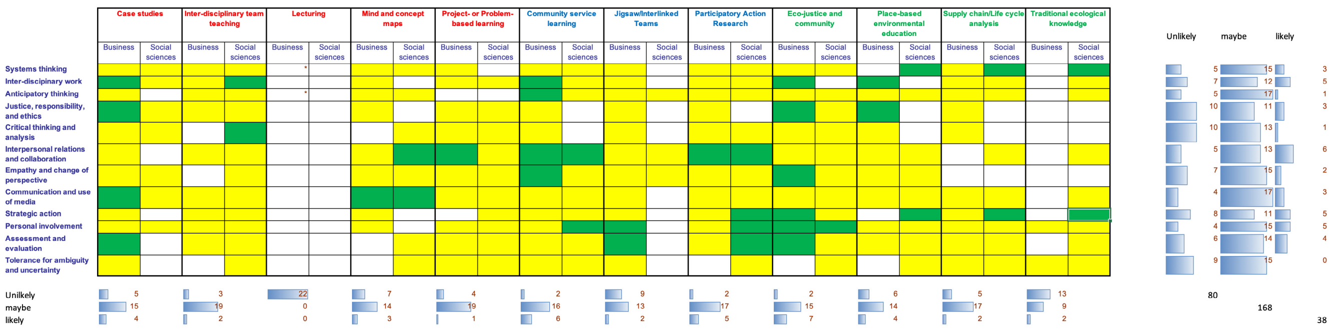

FIGURE 5 Connections between sustainability pedagogical approaches to competences for group 2 [Colour figure can be viewed at wileyonlinelibrary.com]

2. Business (35, 86, and 21) and Social sciences (45, 82, and 17) see Figure 5; and
3. Humanities (74, 47, and 21) and the combined Business and Natural and applied sciences (62, 62, and 19) see Figure 6.

Figure 4 shows the connections between the sustainability competences and pedagogical approaches of group 1 (Natural and applied sciences and Health). Case studies, Eco-justice and community, Inter-disciplinary team teaching, Jigsaw/Interlinked teams, Participatory action research, and Place-based education are the pedagogical approaches most likely to develop competences in this group. Case studies, Jigsaw/Interlinked teams, Traditional ecological knowledge, and Supply chain/Life cycle analysis develop more competences in Health, whereas Inter-disciplinary team teaching, Participatory action

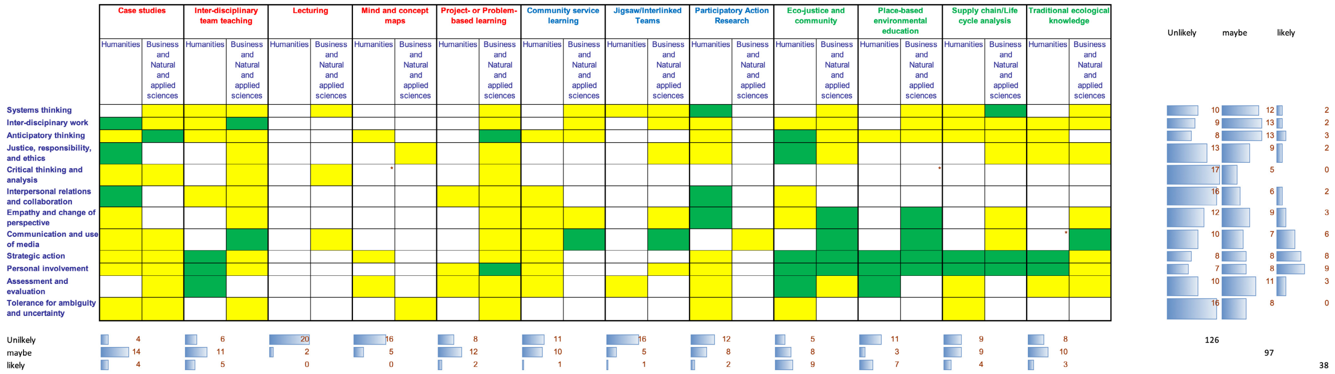

FIGURE 6 Connections between sustainability pedagogical approaches to competences for group 3 [Colour figure can be viewed at wileyonlinelibrary.com]

research, and Place-based environmental education more on Natural sciences. Community service learning and Eco-justice and community develop competences almost equally in both disciplines. Lecturing is considered to be unlikely to develop competences in both disciplines. The competences most likely to be developed are Tolerance for ambiguity, Personal involvement, Strategic action, and Justice, responsibility, and ethics, whereas the least developed are Critical thinking and analysis, Inter-disciplinary work, Empathy and change of perspective, and Communication and use of media.

Figure 5 shows the connections between the sustainability competences and pedagogical approaches of group 2 (Business and Social sciences). Eco-justice and community, Community service learning, and Participatory action research are the pedagogical approaches most likely to develop competences in this group. Eco-justice and community, Case studies, Community service learning and Jigsaw/Interlinked teams develop more competences in Business, whereas inter-disciplinary team teaching, Participatory action research, Supply chain/Life cycle analysis, and Traditional ecological knowledge more on Social sciences. Place-based environmental education and Mind and concept maps develop competences almost equally in both disciplines. Lecturing is considered to be unlikely to develop competences in both disciplines. The competences most likely to be developed are Interpersonal relations and collaboration, Inter-disciplinary work, Strategic action, and Personal involvement, whereas the least developed are Justice, responsibility, and ethics, Critical thinking and analysis, Tolerance for ambiguity and uncertainty, and Strategic action.

Figure 6 shows the connections between the sustainability competences and pedagogical approaches of group 3 (Humanities and Business and Natural and applied sciences). Place-based environmental education, Inter-disciplinary team teaching, Case studies, and Supply chain/Life cycle analysis are the pedagogical approaches most likely to develop competences in this group. Case studies and Participatory action research develop more competences in Humanities, whereas Project- or Problem-based learning, Community service learning, and Jigsaw/Interlinked teams more on Business and Natural and applied sciences. Eco-justice and community, Place-based environmental education, Supply chain/Life cycle analysis, Inter-disciplinary team teaching, and Traditional ecological knowledge develop competences almost equally in both disciplines. Lecturing is considered to be unlikely to develop competences in both disciplines, except for Business and Natural and applied sciences, which is the only discipline where lecturing may develop some competences. The competences most likely to be developed are Personal involvement, Strategic action, and Communication and use of media, whereas the least developed are Critical thinking and analysis, Interpersonal relations and collaboration, Tolerance for ambiguity and uncertainty, Justice, responsibility and ethics, and Empathy and change of perspective.

The results from the three groups show that the pedagogical approaches most likely to develop sustainability competences in all the disciplines are Eco-justice and community, Case studies, Place-based environmental education, and Inter-disciplinary team teaching, whereas the one least likely is Lecturing, followed by Mind and concept maps, Traditional ecological knowledge, and Jigsaw/Interlinked teams. The competences most likely being developed are Personal involvement, Strategic action, and Assessment and evaluation, whereas the ones least being developed are Critical thinking and analysis, Interpersonal relations and collaboration, Empathy and change of perspective, and Tolerance for ambiguity and uncertainty.

5 | DISCUSSION

The ranking of sustainability competences (Table 2) and pedagogical approaches (Table 3) provide insights of their importance of each academic discipline (including the combination of Business and Natural and applied sciences), this complements previous works (see R. Lozano et al., 2017, 2019).

The top three ranked competences (Critical thinking and analysis, Inter-disciplinary work, and Interpersonal relations and collaboration) and the bottom ranked one (Tolerance for ambiguity and uncertainty) are in line with previous research (see R. Lozano et al., 2019). Systems thinking, Assessment and evaluation, and Strategic action were in lower ranks, whereas Communication and use of media, Justice, responsibility, and ethics, Empathy and change of perspective were in higher ranks (differing from R. Lozano et al., 2019).

Most of the pedagogical approaches are roughly in the same rank as in previous research (see R. Lozano et al., 2019), with the exceptions of Supply chain/Life cycle analysis that went down in ranking, and Community service learning that went up.

One of the competences most highly ranked was Critical thinking; however, it is one of the least developed. Two potential causes for this could be: that the pedagogical approaches are not designed to develop it and therefore alternatives should be considered; or that the pedagogical approaches are designed to develop it, but they are not being used in the most effective way.

The connections between the competences and pedagogical approaches considering the academic disciplines revealed that the competences being developed are more individual (i.e., Personal involvement, Strategic action, and Assessment and evaluation) than collective ones (Critical thinking and analysis, Interpersonal relations and collaboration, Empathy and change of perspective, and Tolerance for ambiguity and uncertainty). These strengthen the arguments of Cortese (2003).

The three groups of disciplines obtained from the correlations-based frameworks show that there are differences in the diffusion of sustainability competence-based education, where it could be considered that the disciplines in group 1 (Natural and applied sciences and Health) are innovators or early adopters, those in group 2 (Business and Social sciences) could be considered either early or late majority, and those in group 3 (Humanities and Business combined with Natural and applied sciences) as either late majority or conservatives (see R. Lozano, 2006, 2010; Rogers, 1962). Some disciplines have adopted sustainability competence-based education better than others (group 1 better than group 2, and this in turn better than group 3). From these results, it is possible to propose a diffusion of innovation framework on academic disciplines (D-RAPID), based on the RAPID model (see R. Lozano, 2010), where the focus is on academic disciplines instead of courses, with the following stages:

1. Recognition: Sustainability principles are acknowledged in the discipline;
2. Addition: Sustainability is explicitly required in the courses and programmes of the discipline;
3. Pedagogy: A combination of pedagogical approaches are used to develop sustainability competences;
4. Institutional integration: Sustainability competence-based education is integrated into the teaching of the entire HEI; and
5. Disciplinarity spanning: Sustainability competence-based education is integrated into the teaching in more than one HEI, preferably all HEIs in the world.

The MuSICA memework, the D-RAPID framework, competence development, and a disciplinary perspective across different HEIs can be integrated to propose the Disciplinary Multi-dimensional Sustainability Influence Change for Academia (D-MuSICA) memework. The D-MuSICA is aimed at explaining the diffusion of sustainability in curricula; considering, on the *x*-axis, the congruence between sustainability aims, delivery, competence development, and assessment; on the *y*-axis, the alignment of courses, degrees, schools (department or faculties as used in different HEIs), and the HEI; and, the connection between HEIs (across their courses, degrees, and schools (or faculties)) through academic disciplines (Figure 7).

6 | CONCLUSIONS

HEIs have been incorporating sustainability into education and curricula. In this process, educators are key since they decide what is integrated into the courses. Although there have been calls to integrate sustainability into academic disciplines, most research on sustainability education has been on a single HEI, particularly on course and programme levesl. One of the most recent developments in the incorporation of sustainability in HEIs' curricula has been research on sustainability competences, pedagogical approaches, and how to connect them. The process of integrating sustainability into education based on curricula assessment has been explained using adoption of innovations; and can explain the process of developing competences through pedagogical approaches.

An online survey was developed to investigate teaching sustainability competences in 13 HEIs from 12 countries. The survey was applied

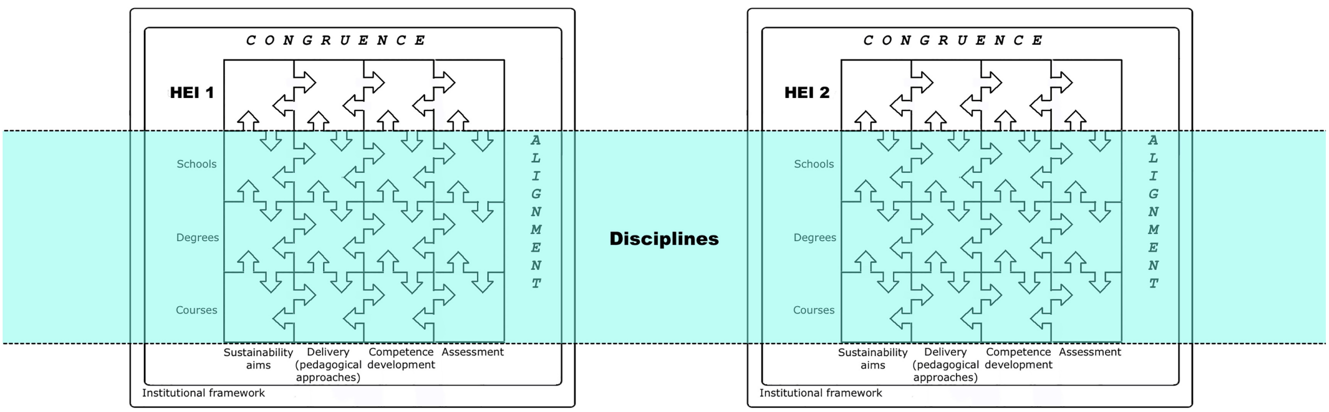

FIGURE 7 Disciplinary multi-dimensional sustainability influence change for academia (D-MuSICA) memework [Colour figure can be viewed at wileyonlinelibrary.com]

online, from which 678 responses from educators were obtained. This survey was significant internationally, in its broad coverage of universities spanning 13 HEIs and including 678 educator responses. The results highlight that some disciplines are more innovative than others in adopting sustainability competence-based teaching. The competences and pedagogical approaches from the responses were ranked, and then the connections between the competences and pedagogical approaches per discipline were analysed using the "Framework connecting sustainable development pedagogical approaches to competences". The number of "unlikely", "maybe", and "likely" (respectively) were calculated for the connections between the competences and pedagogical approaches in each discipline, which resulted in three groups. The groups were then categorised using diffusion of innovations theory, which highlights that some disciplines are more innovative than others in adopting sustainability competence-based teaching.

From the results, the paper proposes two frameworks to better understand the adoption of sustainability competence-based teaching incorporating academic disciplines: (a) the D-RAPID framework aimed at explaining the diffusion of sustainability in academic disciplines; and (b) the Disciplinary Multi-dimensional Sustainability Influence Change for Academia (D-MuSICA) memework aimed at elucidating the congruence between sustainability aims, delivery, competence development, and assessment; the alignment of courses, degrees, schools (or faculties), and the HEI; and, the connection between through academic disciplines.

The adoption of sustainability competence-base education must expand from a single HEI perspective (such as course and programme levels) to a disciplinary collaborative one spanning many HEIs. Academic disciplines should learn from each other's insights and mistakes and provide students with more transdisciplinary skillsets to make societies more sustainable. It should be noted that each discipline has its own nature and scope, and, thus, a different approach in contributing to sustainability, where there is art in science, and science in art.

Further research should be carried out on the factors that affect the adoption of sustainability competence-base teaching, the roles of gender in this process, and the ways to accelerate the adoption using the D-RAPID and D-MuSICA frameworks. The reasons of the differences in the competence ranking of combined disciplines (e.g., Business and Natural and applied sciences) should be studied further.

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