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A Framework of Professional Transferable Competences for System Innovation: Enabling Leadership and Agency for Sustainable Development

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Abstract: System Innovation (SI) is a critical approach in driving individual and collective actions towards sustainable development (SD). This article presents the validation process of the Climate-KIC Professional Competence Framework (CF) for SI. This framework is based on principles of system thinking and the need for human capital to deal with challenges related to long-term sustainability. It comprises twenty competences grouped into five stages that describe contexts where professionals implement transformations: Exploring, Framing, Designing, Implementing and Strengthening. The stages are not linear or strictly sequential because overlapping and loops are frequent in transformational and disruptive changes. The CF fulfils several functions in the development of human and social capital: competences' assessment, their development and training, and their certification to make them more interpretable in the labour market. The methodology for assessing professionals' competences and the certification procedure are described. Overall, the CF aims to promote the development and visibility of human capital in a critical area for sustainability.

Keywords: system innovation; sustainable development; competence framework; system thinking; human capital; transformational; disruptive; leadership; professional transferable competences

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1. Introduction

Today's societies are subject to important changes that challenge their survival and long-term sustainability. Climate change is a prime example of this situation, e.g., [1], but other interconnected challenges—such as pandemics, poverty, conflicts, and inequalities—are also on the agenda, along with the goal of managing globalisation and digitalisation using inclusive criteria. We are still in an "interregnum" time [2] where the old order is dying but the new one has not yet been born, and the way we approach this period can lead to or hinder the achievement of a sustainable world. Given the complexity of these trends and the goals to be achieved, traditional change models are of limited use, and more complex views based on systems thinking are needed, with perspectives that accept non-linear patterns, interrelations among elements of systems and environments, and the participation of stakeholders in the co-creation of solutions to achieve a better life for all [3].

Promoting and managing SI requires adequate human capital. This is the motivation underlying this study. So far, much of the previous sustainability transition studies have focused on technological innovations and historical analysis [4,5], governance and policy issues [6], as well as the role of spaces and places [7]. As Farla et al. point out, a general feature of sustainability transition research is the systems perspective [8]. This resulted in a lack of more actor-oriented and agency-sensitive analysis. The role of individuals and their abilities has hardly been examined so far. Motivated by the belief that assessing

a certain set of key competences and making them visible are important steps towards professionalising change activities for sustainable development, this article aims to answer the following research questions: (1) What competences do change agents need to innovate socio-technical systems in a long-term sustainable manner? and (2) how can these competences be assessed and validated?

In this context, we define competence as a set of behaviours that are instrumental in the delivery of desired results [9]. In our understanding, a competence consists of three essential elements: Knowledge, skills, and attitudes-values [10]. In addition, they are socially (participation of stakeholders) and future (achieving a better and sustainable world) oriented, and they are intimately connected to a given context (although competences are transferable, instrumental behaviours depend on context characteristics where they are displayed). Theoretically, our work is grounded in the field of system innovation (SI) that has become a fruitful conceptual and methodological framework for managing transitions based on radical transformations towards long-term sustainability. This approach is congruent with complex systems thinking for different reasons. First, it describes a complex view of elements within the system, including technological and social (culture, political forces, etc.) facets, whose interconnectedness allows a richer portrait of transitions. Second, transformative changes require the consideration of interrelated levels. Initial disruptive ideas and initiatives start in protected spaces called niches within (and in co-existence with) the status quo and the current paradigm. Over time, developing, maturing, and extending the ideas and actions of niches facilitates change at a higher level—the regime, that is, the change in a paradigm, providing a new stable and structured combination of social and technological factors. Once the change of regime is established, it is possible to transform the landscape (more external factors). The more structured social (e.g., cultural values of a society) and material (organisation of cities) elements underlying the landscape can be transformed [11]. Third, as in systems thinking in general, an important topic in SI is setting boundaries, in other words, how to establish the limits of the change and how to extend them to achieve a more ambitious change (e.g., from niches to the change in both the regime and the landscape). Fourth, leverage points are used to accelerate transformations. Following a complex and non-linear scheme, it is assumed that small changes in these points help to produce more dramatic changes in the system as a whole. Finally, stakeholders' participation is required to achieve transformation. Radical and generalised changes are difficult if stakeholders are not considered [12].

Therefore, SI is the result of a transformation process in which actors (e.g., stakeholders and others) navigate transitions, develop visions, and adapt them through searching and learning, experimenting with different options and overcoming barriers and resistance by taking advantage of different levers [13,14]. This means that the appropriate skills have to be available. Professionals, policymakers, and other change leaders may play important roles and fulfil relevant functions in these processes. Thus, the contribution of this article is to identify the necessary competences for people to contribute meaningfully to this endeavour. With this in mind, the current study describes the validation process of the Climate-KIC Professional Competence Framework (CF) for SI. Climate-KIC is a European knowledge and innovation community, working towards a prosperous, inclusive, climate-resilient society based on a circular, zero-carbon economy (https://www.climate-kic.org). This framework is integrative. It considers the main strengths of extant competence models from both managerial and educational approaches, avoiding their limitations. To do so, the framework pays attention to (a) the context and time frame for implementing the competences; (b) a format of competences that can be assessed and evaluated; (c) the combination of dynamics and main psychosocial components of competences; (d) the articulation of both individual and collective competence levels, and (e) the involvement of professionals and leaders in co-creation processes and participatory dynamics.

By doing so, this article is closing a critical research gap and contributes to the growing literature on system innovation and professional transferal competences for sustainable development. First, we clarify our scientific approach. Second, we introduce our under-

standing of competences for SI, followed by a literature review of existing competence models for SI and SD. By integrating the different existing approaches as well as identifying their strengths and gaps we then propose the Professional Competence Framework for System Innovation (PCFSI) and describe methodologically its development, validation and assessment process. Finally, we conclude the implications of our findings both for research and practice and highlight limitations as well as future developments.

2. An Applied Research Approach

Before starting with our conceptual framework and the introduction of PCFSI, it is relevant to clarify the scientific approach underlying the process. Our effort is based on applied research, following some of the crucial principles of Action Research today [15,16]. First, the choice between social relevance and rigour is not a dilemma. Both aspects should be present to produce practical knowledge for a better life. The PCFSI is based on solid previous knowledge and systematic analysis but always to define and enhance competences that allow professionals to promote SD. Specifically, the PCFSI is based on research and development. That is, the investigation is oriented to design a new and integrative competence framework with practical functions. Second, the role of researchers changes, emphasising cooperation with other relevant participants in the process [17]. Researchers are not considered the only producers of knowledge, but rather become co-creators. In fact, in the validation process of the PCFSI, a number of experts participated. Finally, the research purpose is threefold: instrumental, theoretical, and emancipatory [18]. Accordingly, we want to improve professional competencies oriented to SD (instrumental); to contribute to knowledge by validating an integrative framework of competences (theoretical), and to promote a sustainable and better life for all (emancipatory).

3. Competences for System Innovation

Leading SI involves important changes in management because professionals are expected to promote the inclusive participation of the different stakeholders. In fact, professionals are experiencing profound changes and challenges due to digitalisation and globalisation [19]. In the new context, "professionals will need to have a global, systemic, multidisciplinary mindset . . . to rethink from first principles the means [they] use to conceive, produce, deliver and maintain [their] professional products/services using the capabilities enabled by the automation resulting from the Fourth Industrial Revolution. [They] will need clearly crystallised, authentic personal and professional identities, directed and guided by a well-founded Work Charter as a moral anchor and compass" [20] (p. 5). The challenge in the education of future generations of experts will be to prepare them to think and act in the longer term, make strategic changes, and interact and work with other stakeholders to promote change implementation in ways that move them towards transitions. These changes require new competences, not just technical but also transferable, and they involve a revision of the education and training goals and strategies for professional development. The OECD [21] establishes in its priority 4 that, beyond subject-specific expertise, tertiary education should also develop students' creativity, critical thinking, entrepreneurship, and communication skills (p. 14). In addition, the education of new leaders and professionals requires a shift in the normative and value systems, with new "virtues" that can inspire more sustainable strategies and decision making [22]. This is congruent with the evolution of human resource management from a view focused on employee performance to another one that also considers both employees' concerns [23,24] and the environment of an organisation, pursuing social legitimacy in the society [25]. Accordingly, professional's competences should not only be based on performance objectives but also on those changes which are necessary for a sustainable future of our world.

As stated previously, a competence has been defined as a set of behaviours that are instrumental in the delivery of desired results [9]. In a similar way, the Chartered Institute of Personnel and Development defines a competence as "the behaviours that

employees must have, or must acquire, to input into a situation to achieve high levels of performance" [26] (p. 1). A competence is expressed through performance and, thus, can only be assessed in the actual achievement of a task when solving problems and dealing with challenges [27].

Following the model of the Greek temple [10], a competence encompasses three main components: Knowledge, skills, and attitudes-values. In fact, the three components must be jointly and coherently mobilised in a given context for competent performance. As Dlouhá et al. stated: "Competences underpin not only the instrumental processes of knowledge transfer and appropriation but also activation in goal-oriented, ethically grounded actions in practical situations. In the field of sustainable development (SD), the integrative character of competences is especially important" [28] (p. 2). To solve most societal problems, it is not sufficient to use cognitive functions such as knowledge (theoretical background) or skills (methodological capabilities within an area of practice). Attitudes and values are also important, and so, in addition to the technical and expert components, the normative component is also fundamental as the moral compass for behaviour and decision making. This is especially relevant when competences are required to contribute to and help with important societal issues such as sustainability. Moreover, in this type of competences, an orientation towards the future and their social dimension are keys to managing SI and SD. Considering these arguments, our definition of competence refers to behaviours that are *instrumental* in achieving SD, have a *holistic* and *integrative character* in their components (knowledge, skills, and attitudes-values), are *social* and *future*-oriented, and *context-dependent*.

Furthermore, in the mastery of a competence, we need to distinguish several levels, depending on the complexity of the demands in a specific context. Thus, a proper assessment involves defining the level of complexity required. In addition, the competences are manifested by performance when coping with complex situations, solving problems, or dealing with challenges.

Finally, Stoof et al. formulated the boundary approach to the conceptualisation of competence from a constructivist point of view [29]. They point out that "people", "goal" and "context" are core elements of the definition of competence. They establish the boundaries to define the competence from the "inside" (personal vs. task characteristics; individual vs. distributed competence; specific vs. general; levels of competence vs. competence as a level; teachable vs. non-teachable) and from the "outside", with the pressure of similar or related concepts such as performance, qualification, capability and ability, knowledge, skills and attitudes, and expertise. The authors argue that the concept of competence becomes more viable for different purposes when all these aspects are taken into consideration in the definition of the concept.

Considering the definition of competencies, the acquisition of competences does not fit the traditional way of learning and teaching. First, it implies a shift in the emphasis from teaching to learning that requires "learning by doing in a given context". It also requires supervision and feedback from experts who should properly guide the learning processes. In this way, competence acquisition requires a learner-centred, action-oriented, and context-bounded approach, and it often aims for transformative learning, empowering the person to deal with the current context and pay attention to future contexts [30] (p. 8). Moreover, competence development is associated with increased mental complexity because the uncertain scenarios and complex demands of the contemporary world require new mental models and patterns of action [31]. In a way, it is a special challenge to acquire complex transferable competences that may be fundamental in promoting SI for SD. Finally, assessment of learning is also an essential instrument that may contribute to competence acquisition. Again, this means putting the learner at the centre and having a clear intention to assess what matters, without being guided only by the practicalities of the assessment methods [32].

As Rieckmann pointed out, education for SD aims at "developing competencies that empower individuals to reflect on their own actions, considering their current and future

social, cultural, economic and environmental impacts, from a local and a global perspective, acting in complex situations in a sustainable manner, which may require them to strike out in new directions; and to participate in socio-political processes, moving their societies towards sustainable development" [33] (p. 7). Integrated competence-oriented teaching that leads to the sustainable transformation of both the individual and society requires a holistic learning process that addresses the cognitive, socio-emotional, and behavioural domains of learning in a balanced way. However, the lists of transferable competences usually provided for this purpose do not explicitly offer a consistent model with these aims. In fact, as Wilhelm et al. suggested, "the spectrum of descriptions and lists of competences was so heterogeneous that it could at best serve as a "shopping list", not as a meta-profile for ESD at HEIs" [30] (p. 8). However, in a situation of serious problems, it is important to take a systemic approach and provide an explicit framework that adds coherence to the interventions.

4. A Literature Review of the Competence Models for System Innovation and Sustainable Development

To better identify the main transferable competences involved in SI, we need to pay attention to two main approaches that deal with this issue: (a) the literature on management and professional practice in SI for SD, and (b) the literature on education in SI competences for SD. In Tables 1 and 2 we systematically provide results of previous studies from the two aforementioned approaches.

4.1. The Perspective from Management and Professional Practice in System Innovation for Sustainable Development

The first approach comes from studies on transition and SI management, and it mainly focuses on the analysis of professional practice. It often organises the competences in stages or cycles, providing methods and tools to promote change. Draper summarised the *Forum for Future* approach to SI, suggesting a cycle that includes the following capabilities: (1) See the whole picture; (2) identify connections between the different parts of the system; (3) engage different perspectives; (4) recognise that all models are wrong but some are useful; (5) consider different time scales (long and short term); (6) seek to make effective interventions by understanding patterns in the system; and (7) constantly learn about the system and how to be effective in it [34].

Abercrombie et al. offered a model for system change in two phases: (1) planning for system change and (2) doing it. The planning stage aims "to identify the root causes of problems; identify the key actors; find the points of leverage; help define the system and establish its boundaries; establish what can be controlled, and what can be influenced, and clarify the objectives of taking action" [12] (p. 28). In the "doing it" stage, the authors include: understand needs and assets; engage multiple actors; and map the system. In addition, when it comes to implementing system change, it is important to "build movements, consortia, networks, to amplify your efforts; avoid getting bogged down in the complexity of systems; act on points of leverage where there is a realistic prospect of changing the system; and to learn—and use that learning to adapt what you do" [13] (p. 32). In sum, the principles to put in place to achieve these aims are "work with others, distribute leadership, and foster a learning culture".

Kemp and Rotmans presented a general framework for transition management in a cyclical and iterative process containing four main blocks of activities: (1) establishing and further developing a transition arena for a transition theme (selecting participants and promoting visionary thinking and open discussion); (2) developing a long-term vision and a common transition agenda (shared goals and creation of transition paths through back-casting); (3) initiating and executing transition experiments, and (4) monitoring and evaluating the transition process (paying attention to the actors, the agenda implementation, actions, barriers, and learning process) [35] (see also [36]).

Finally, from a more practical perspective, Stroh [37] provided a guide to solving complex problems, avoiding unintended consequences, and achieving lasting results. He

described four stages of systems change, including several practices (involving competences) and tools in each. The first stage is about building a foundation for change by engaging key stakeholders, establishing a common ground, and building collaborative capacity. The second stage focuses on building understanding through system mapping, which means gathering relevant information, organising it, and carrying out a preliminary analysis that balances simplicity and complexity. Moreover, it is important to engage people in developing their own analysis, bringing mental models to the surface and creating catalytic conversations. The third stage involves making an explicit choice, understanding payoffs in the existing system, and comparing the change to the status quo. It is also important to create "both/and solutions", by making trades-off and dealing with people who are still not aligned. Finally, the fourth stage aims to bridge the gap by identifying high-leverage interventions, establishing a process for continuous learning, and outreaching and integrating multiple interventions. Furthermore, the author recommends cultivating systems thinking, to emphasise the personal transformation that often accompanies social systems transformation.

To summarise this approach, we present the stages and main competences mentioned in Table 1. The four main stages (analyse, anticipate and plan, act and monitor, and evaluate) are recognisable in the contributions reviewed and the competences required to manage systems change for SD across the "cycle" of systems, paying attention to complex management skills and processes.

Table 1. Models of system innovation competences.

	Kemp and Rotmans [35]	**Stroh [37]**	**Abercrombie et al. [12]**	**Draper [34]**
Establishing and further developing a transition arena for a specific transition theme—Building a foundation for change—Planning for system change	Promote visionary thinking and open discussion	Establish a common ground	Identify the root causes of problems	See the whole picture
	Select participants	Engage key stakeholders	Identify key actors	Identify connections between different parts of the system
	Enable process of knowledge coproduction among participants	Build collaborative capacity	Find points of leverage	Engage different perspectives
	Feed participants in the arena with background information knowledge			
Development of long-term visions and common transition agenda—Building understanding through system mapping—Planning for system change	Shared goals	Gather relevant information	Help define the system and establish its boundaries	Recognise that all models are wrong, but some are useful
	Develop transition paths through backcasting	Organise it and carry on a preliminary analysis	Establish what can be controlled	Consider different time scales (long and short term)
	Coordinate action between mutually dependent actors	Balance simplicity and complexity	Understand needs and assets	
	Balance between structure and flexibility	Engage people to develop own analysis and being able to surface mental models and create catalytic conversations	Clarify the objectives of take action	
Initiation and execution of transition experiments—Make an explicit choice—Doing it	Experiment to learn about system innovation and explore uncertainties	Understand payoffs to the existing system	Map the system	Seek to make effective interventions by understanding patterns in the system
	Measure the contribution to sustainability system goals	Compare change case with status quo case	Build movements, consortia, networks to amplify efforts	
	Identify specific niches for experiments	Create 'both/and solutions' making tradeoffs	Avoid getting bogged down in the complexity of systems	
	Link experiments with ongoing innovation projects	End with an explicit choice	Act on points of leverage where there is a realistic prospect of changing the system	
	Run experiments through existing networks	Deal with people who are nor still aligned		
Monitoring and evaluation of transition process—Bridge the gap—Doing it	Pay attention to actors	Identify high-leverage interventions	Learn and use that learning to adapt what to do	Constantly learn about the system and how to be effective in it
	Agenda implementation	Establish a process for continuous learning and outreach		
	Barriers and learning process	Integrating multiple interventions		

4.2. The Educational Perspective on System Innovation Competences for Sustainable Development

The inception of sustainability science "officially" dates from 2001. Since then, a number of studies have tried to identify key competences for promoting SD in higher education institutions [38–42]. Several institutions have formulated models for education [32,43,44], and a number of studies have paid attention to the way these competences are integrated into several types of programs, such as university bachelor studies [45], or they have developed a specialised program for managing SD in which personal and socially oriented competences are proposed for each management function [46]. Stakeholders' perspectives, such as teacher and students' views, were also studied [42,47], and special attention was paid to the pedagogy and education methods for these competences [19,41,48]. Several reviews were also carried out on this topic in the past decade [40,48]. All these studies have identified a number of competences to be taught in higher education programs. Some studies have provided structured proposals based on models or frameworks, whereas other studies have offered a list of competences without a framing structure. Table 2 organises these competences based on the main psychosocial processes emphasised. Taking into account the notion of competence, it is clear that knowledge, skills, and attitudes and values are components of every competence. In addition, the social and future orientation components are also relevant in identifying the key competences for SD.

Many of the competences mentioned mainly focus on complex cognitive processes used to understand and analyse the complex reality and context. Examples are systems orientation and thinking, critical thinking, creativity, capacity to contextualise, analytical work, managing uncertainty, and self-awareness.

Another widely considered block is the one referring to attitudes and values. In fact, competences focusing on normative engagement and values related to sustainability, personal responsibility, and accountability are often strongly emphasised. In addition, several competences are related to emotion management related to oneself and interactions with others.

A third block of competences emphasises social facets. Social relationships, participation, and collaboration, as well as appreciation and respect for cultural differences, are competences mentioned here. Competences related to leadership, working in groups, and motivating others are also important for promoting and participating in collective actions towards SD. The role of being a system innovator for SD requires being competent in becoming aware of the social, cultural, and political arena of SI. It often requires stimulating others, promoting shared views and shared goals, and using catalytic leadership to enhance collective actions for SI towards SD.

The fourth block pays attention to more "behavioural" competences that are closer to the actions that characterise the competence, although their enactment will always depend on the context. Here, the most frequently considered competences are problem-solving and competences related to initiating or managing change, taking action, dealing with complicated problems, leadership for change, etc.

Another important block, although less frequently considered, is the orientation towards the future. These competences are necessary for SD because the concept is clearly future-oriented. This block includes competences such as visioning, anticipation, forecasting, fore-sighting, strategising, and visualising scenarios. Finally, it is interesting to mention the importance a number of authors give to interdisciplinary work and, in some cases, to research competences.

Table 2. Educational approaches for sustainable development competences in higher education.

	Dawe et al. [43]	**Barth et al. [31]**	**Wiek et al. [40]**	**Frisk and Larson [41]**	**UNECE [44]**	**Lambrechts et al. [45]**	**Hesselbarth and Schaltegger [46]**	**Cebrian and Junyent [47]**	**Rieckmann [33]**	**Lozano et al. [48]**	**Eizaguirre et al. [42]**	**Wilhelm et al. [30]**
COGNITION	ability to make critical judgements	distanced reflection on individual and cultural models	Systems thinking	Systems thinking		Systems orientation	Analytical skills	Thinking critically	Systems thinking	Systemic thinking		Shift from knowledge-orientation to action-orientation
	Ability to develop a high level of self-reflection (personal and professional)			Understanding of interconnect-edness		Critical and in-terpretational thinking	Self-learning ability	Contextualise	Critical Thinking	Critical Thinking		
	Ability to bridge the gap between theory and practice						Entrepreneurial thinking	Work and live with complexity	Self-awareness	Change of perspective		
							Information and media literacy			Analytical work		
										Tolerance for ambiguity and uncertainty		
AFFECT/ VALUES	Ability to understand, evaluate and adapt sus-tainability values	empathy, compassion and solidarity	normative		Learning to be: (1) Develop personal attributes	Emotional intelligence	Motivational capabilities	Clarify values	normative	Personal engagement	commitment to environmental preservation	Normative orientation
		self-motivation	strategic		(2) Ability to act autonomously with judgement and responsibility	Responsibility	Self-management	Deal with emotions		Responsibility	Respect for diversity	
						Personal involvement	Self-confidence			Justice, ethics		
							Commitment to principles and values			Empathy		

Table 2. *Cont.*

	Dawe et al. [43]	**Barth et al. [31]**	**Wiek et al. [40]**	**Frisk and Larson [41]**	**UNECE [44]**	**Lambrechts et al. [45]**	**Hesselbarth and Schaltegger [46]**	**Cebrian and Junyent [47]**	**Rieckmann [33]**	**Lozano et al. [48]**	**Eizaguirre et al. [42]**	**Wilhelm et al. [30]**
SOCIAL		Participatory skills	Interpersonal	Stakeholder engagement	Learning to live together: (1) develop partnerships		Ability to cooperate	Participate	Collaboration	Interpersonal relationships and collaboration	Social responsibility	Deal with change agents
		Motivating others		Group collaboration	(2) Appreciation of interdependence and pluralism		communication skills and presentation techniques			communication and use of media	Multiculturality	
		Cosmopolitan perception, transcultural understanding, and cooperation					Ability to handle conflict and criticism					
BEHAVIOURAL	Problem-solving skills in a non-reductionist manner for highly complex real-life problems	Planning and implementing	Problem-solving	Action-oriented skills	Learning to do: (1) develop practical skills	Action taking	Decision-making skills	Work for change	Integrated problem solving			systematic problem solvers deal with wicked and complex problems and ambivalent situations
	Ability to initiate and manage change		Plan, conduct and research on sustainability	Change agent skills	(2) action for sustainable development		Project management	Make decisions				Deal with transformation challenges, initiate and navigate change
							Self-initiative					Transition managers
							Problem-solving abilities					Leadership skills; leaders for change

Table 2. *Cont.*

	Dawe et al. [43]	**Barth et al. [31]**	**Wiek et al. [40]**	**Frisk and Larson [41]**	**UNECE [44]**	**Lambrechts et al. [45]**	**Hesselbarth and Schaltegger [46]**	**Cebrian and Junyent [47]**	**Rieckmann [33]**	**Lozano et al. [48]**	**Eizaguirre et al. [42]**	**Wilhelm et al. [30]**
FUTURE ORIENTED		Foresighted thinking	Anticipatory	Long-term, foresighted strategising	Envisioning change	Future orientation	Strategic sustainability management	Visualise/alternate future scenarios	Anticipatory	Strategic thinking		
					Explore alternative futures and learn from the past				Strategic	Anticipatory thinking		
OTHER		Interdisciplinary work				Research competence		Create a dialogue between disciplines		Interdisciplinary work		

Some authors have emphasised the importance of the interrelationship between these different competences [40]. Raising awareness and systems thinking are important for offering interpretations of the complex situation to others, thus contributing to the emergence of shared meaning and goals. In addition, these interpretations have to consider the normative and value-laden approach to SD and inspire individual and collective behaviours, often guided by future-oriented visions that are collectively shared. An effective competence profile of SI agents to promote SD requires integrating (both individually and in teams) all the facets considered in the aforementioned blocks. As Sipos et al. emphasised, transformative sustainability learning engages the head, hands, and heart and, we might add, both individually and collectively, with a time frame that involves learning from the past but is clearly future-oriented through envisioning better realities [49].

4.3. Integrating Both Approaches and Identifying Strengths and Gaps

The review of the competences presented above shows a number of similarities and differences that may be complementary and make it possible to develop an integrative framework of transferable SI competences for SD. It is worth mentioning that both approaches emphasise transferable competences, whereas specialised disciplinary competences are hardly considered. Moreover, the normative nature and value-laden orientation are also present in both approaches, although they are strongly emphasised in the educational context (where some reflections have been raised about how to avoid "unscientific indoctrination").

Each approach emphasises distinct aspects. The managerial approach pays special attention to structuring the competences according to the intervention cycle, aiming to achieve the system change by considering the different stages. Moreover, the focus is on the professional implementation of the competences. By contrast, the education for SD approach describes competences based on the facets they focus on (cognition, affect and normative, social, behavioural, or future orientation). Furthermore, this is done from the perspective of university graduates' education in SD. Here, the descriptions of the competences are similar to learning outcomes and often related to education and didactic methods.

There are also some gaps in the two approaches. Competences are often presented as multifunctional and context-independent capabilities, but one important component of their effectiveness is that they are always enacted in a given context and time frame [30]. In fact, both the contextual and dynamic timing of their implementation are substantive conditions of their effective enactment, although the role of context is not usually considered in the competence models formulated in any approach. A second gap refers to the fact that competences are not formulated in a useful way for their assessment and evaluation. In only one case, the different mastery levels of the same competence are formulated, and their corresponding standards are presented in a way that allows an evaluation procedure to be developed from them [50].

Finally, a number of challenging issues can be highlighted. First, the structure provided by both perspectives could be integrated to achieve a richer view. The stages in the dynamics of SI cycles and the emphasis on the main psychosocial components of the key competences involved are complementary. Thus, the dynamics of the competences' enactment can be better represented in the CF. Second, although the "natural" focus is the individual and his/her mastery, SI, as a great transformation, involves not only individuals but also collective actors (organisations, groups, institutions). The articulation of individual and collective competences to achieve SI is a challenging and complex issue that needs further elaboration. Third, in this individual-collective interaction, the functions of professionals and leaders require further articulation in the co-creation processes and participatory dynamics. Leadership, in one style or another, and in its individual or collective and distributed forms, is often necessary for SI. It fulfils many important functions (sense-making to promote a shared vision, motivating others to make changes happen, promoting multiple-loop collective learning from previous experience, etc.). Thus, individual

leadership competences may serve SI, even if the whole process has to be collective and co-creative. Leadership is not just about managing SI; it is mainly about contributing and catalysing elements to make collective transformation happen. Leadership competences have to be considered in an SI competence framework. However, given their complexity, they are better described as different but related leadership competences, rather than just as a single competence under the ambiguous label of leadership.

5. Results—The Professional Competence Framework for System Innovation (PCFSI): Development and Validation Process

In the previous sections, we reviewed a number of competence models for SI aimed at SD. We also pointed out several gaps to be addressed. In this section, we present a PCFSI that offers a comprehensive model designed to ground and guide the process of acquisition (learning-by-doing under supervision), self-assessment, experts' evaluation, and certification of the key transferable competences in SI for SD [51]. To do so, we will first discuss the need for a reference model focusing on transferable competences. Second, we will describe how the model was built and validated. Third, we will present the main structural components of the model (blocks, competences, and performance indicators). Finally, we will report on its validation process.

5.1. Why a Transferable PCFSI?

Given the critical changes the planet is experiencing, there is a growing awareness that adaptation requires radical and transformative changes at a systems level. This implies a greater need for competent human capital in leading and promoting innovative system changes. We need professionals and leaders who are competent in finding new ways to meet societies' demands and need for sustainability for current and future generations. In these processes, both institutions and individuals have to be involved and cooperate. Thus, properly balancing individual and collective (organisational and institutional) actions is essential in SI processes. This raises the issue of the profile of the agents who may promote and drive SI through individual and collective actions. These agents should be competent in creating the conditions for individuals, groups, organisations, institutions, and other social formations to change their mindsets, show a definite willingness and take actions that allow the emergence of appropriate innovative systems that enhance SD and improve the legacy for future generations. The purpose of the PCFSI is to identify and describe the core set of competences that change agents should master to lead and promote SI for SD.

Competent performance involves both the specific competences of a specialism and transversal or transferable competences, see [42]. Our model focuses on transferable key competences. This does not mean that competences corresponding to the professional specialisms are less important. However, they are often formally taught and recognised by diplomas or certificates from education institutions. Transferable competences are not formally taught or certified during formal education, and they are usually acquired in non-formal or informal learning during education and/or professional practice. Their acquisition does not follow a systematic framework, and their learning and outputs are hardly visible or transparent. However, they are quite valuable in the current labour market to cope with SD challenges in public and private organisations and institutions. Today, a significant number of professionals in many sectors need to master transferable competences to promote and drive SI. Our framework offers a systematic set of competences integrated into meaningful blocks with well-defined concepts and standards that may guide professional development and its assessment and certification.

Of course, the transferable competences always have to be acquired and then implemented in a given context. In fact, attention is paid to the context where competences are enacted. Moreover, during the acquisition of transferable competences, attention should be paid to the transfer from one context to another because they are going to be useful and necessary in many different contexts of professional practice and different stages of the same SI process. Finally, these competences often require a normative component that emphasises respect for the legitimate interests of multiple stakeholders, for the rights of

future generations, and the conservation of the planet as the great challenge of our society. Thus, promoting SI involves cooperation, flexibility, and normative values and ethics.

The development of the competence framework and the final version of the PCFSI has taken more than four years. During this period, several important inputs have been provided, such as the information from a market study carried out to evaluate the demand for certification based on this competence framework [52], the EIT Climate-KIC strategy [53], and the internal reports and evaluation of the test and pilot implementations of each of the CFs designed. One important change throughout the whole process was the decision to integrate the initial proposal of three componential frameworks of SI (accelerating transitions, driving innovation, and promoting entrepreneurship) into a single framework that would include the core competences of the PCFSI. In the following sections, we describe the development process of this framework and the structure of its final version.

5.2. Methods—A Componential Approach to System Innovation: Accelerating Transitions, Driving Innovation, and Promoting Entrepreneurship

The general steps of the validation process are in Figure 1. To identify the key competences for SI, we first identified the three main bundles of competences for SI: Accelerating transitions, promoting innovation, and driving entrepreneurship. *Transitions* involve profound changes in a system across different dimensions: technological, material, organisational, institutional, political, economic, and socio-cultural. They involve a broad range of actors and typically unfold over long-time spans. In the course of these transitions, new paradigms or mental models emerge, as well as new products, services, business models, and organisations, partly complementing and partly replacing each other. *"Accelerating" a transition* process towards a low carbon society serves to promote sustainability, see [54]. *"Innovation"* aims for the development and implementation of novel and value-creating solutions with a value proposition for society in its broadest sense, encompassing natural resources, biodiversity, climate protection, and climate change adaptation. Innovation involves imagination, creativity, and action designed to generate ideas that have value and search for ways to implement them through either incremental or radical change. In essence, an innovation process involves searching, selecting, implementing, and capturing value from new ideas and intentions. Serving sustainable ends, innovation is a process through which a new product, service, process, position, policy, or paradigm is generated from new ideas, providing solutions for environmental and social problems and needs, see [55]. *"Entrepreneurship"* may involve innovations, but not necessarily. For instance, "copying" an effective business model may not be very innovative, but it requires numerous and extensive entrepreneurship competences. It refers not only to business initiatives but also to social and environmental non-profit initiatives. The goals are to develop and implement innovative business models within both established and start-up organisations. Serving sustainable ends is a process through which the development and use of more sustainable products, services, processes, and/or approaches are pushed forward without compromising the ability of future generations to meet their needs, see [56].

Through a wide search and careful study of the relevant literature, the core competences for each of the components were identified and structured in blocks representing the main stages of the three corresponding macro processes (accelerating transitions, driving innovation, and promoting entrepreneurship) included in SI. All of them were mapped, describing the core transferable competences for each. Each competence was thoroughly described, and a set of four "exemplar" performance indicators were presented to establish the standard for competent performance at the level of the initial stage of independent professional practice. Each reference framework (with the description of the blocks, competences, and performance indicators) was submitted to about 7–8 experts for feedback and evaluation. A revised version of each competence was tested through an evaluation process in which a number of professionals presented a description of how they enacted these competences in a given professional context. After examining these descriptions, the professionals were interviewed by expert consultants to evaluate whether the described behaviours properly reflected the competences assessed. The analysis of these results and the

feedback provided by the consultants were presented in several evaluation reports [57–59], along with relevant information for the validation and refinement of the CFs (see the blocks and competences for each competence framework in Table 3). Moreover, the candidates were surveyed, and the results obtained were used to revise and improve the readability and comprehension of the CFs tested and piloted [60].

WHAT	HOW
1-Initial identification of main competencies and performance indicators (behaviours)	1-Literature review
2-Evaluation and feedback of the initial proposal, and design of revised version	2-Participation of experts
3-Diagnosis of how the competences are enacted in professional contexts	3-Evaluation of professionals
4-Evaluation of degree to which performance indicators (behaviours) describe competences	4-Consultants interviewed professionals
5-Refinement of the competence's framework	5-Feedback by consultants
6-Pilot study, revision and improvement of the readability and comprehension of competences	6-Professionals were surveyed
7-Identification of potential users and/or partners	7-International benchmark study
8-Confirmation that the competences included in the framework match the competences described in the professional activity related to the transition to the green economy	8-Analysis of extant skills/competences
9-Final formulation of the PCFSI	9-Review of the entire validation process

Figure 1. Steps in the validation process.

Table 3. Blocks and competences included in the three componential competence frameworks for the system innovation general framework.

ACCELERATING TRANSITIONS	PROMOTING INNOVATION	DRIVING ENTREPRENEURSHIP
A. Systems Thinking	A. Addressing challenges	A. Identifying or creating opportunities
A1. Analysis—Demonstrating systems thinking	A1. Perceiving systems and patterns	A1. Spotting opportunitites
B. Visioning and defining goals	A2. Identifying needs and thinking in opportunities	A2. Developing ideas
B1. Defining problems	A3. Analytical thinking	B2. Analysing and refining
B2. Visioning	B. Creativity	B1. Knowing capabilities and resources
B3. Sensemaking	B1. Managing context for creativity	B2. Developing model for realising ideas
B4. Backasting and setting objectives	B2. Generating new ideas and solutions	B3. Developing business plan
C. Experimenting and implementing change	B3. Guiding co-creation processes	C. Fostering cooperation
C1. Experimenting and initiating change	B4. Evaluating potential solutions	C1. Convincing others
C2. Providing strategy and coordinating action	C. Envisioning and planning	C2. Connecting with others
C3. Dealing with uncertainty	C1.Envisioning and anticipating	C3. Inspiring and empowering others as leader
D. Strategic networking and communication	C2. Appraissing the dark side of innovation	C4. Collaborating within a team as a member
D1. Transdisciplinary and transboundary communication	C3. Verifying viability and feasibility	D. Implementing the business model
D2. Networking and collaboration	C4. Formulating strategy and planning	D1. Steering the enterprise operationally
D3. Motivating and mobilising others	D. Leading innovation	D2. Maintaining strategic overview
E. Monitoring and adapting	D1. Catalytic leadership	D3. Attrackting customers in a responsible manner
E1. Monitoring	D2. Sensemaking and mobilising others	E. Deciding, learning, adapting
E2. Adaptation	D3. Showing perseverance	E1. Learning and experimenting
	E. Flexibility and learning	E2. Making decisions and managing uncertainty
	E1. Learning	E3. Dealing with failure and adapting
	E2. Flexible adaptation	

Moreover, a benchmark study was conducted in five European countries (Finland, France, Germany, Spain, and Hungary) and at the European level to collect information on existing policies, relevant stakeholders, enterprises, and education providers that could be potential users and/or partners [61]. The study was based on desktop research, input provided by national Climate-KIC partners (questionnaires; good practice examples for validating competences), and interviews with 16 national and international experts. Several possibilities were identified in the Higher Education context, in Adult Education, and the Continuing Vocational Education and Training context. At the enterprise level, possibilities were identified in the context of employer associations, in cooperation with professional associations, cluster initiatives, and Public Employment Services and Certifying Bodies.

Finally, to further validate the CFs, a study was carried out where information on recent studies dedicated to Green Economy transition and the skills/competences identified were reviewed to examine to what degree they matched the competences included in the CFs [62]. Moreover, a detailed content analysis was performed of 64 examples of competence descriptions taken from candidates' dossiers provided during the certification pilot phases for "Accelerating Transition" and "Promoting Innovation", to identify work experiences and tasks stated by candidates to demonstrate each specific competence and the references to environmental areas and professions. This information was relevant for creating a detailed skills/qualification profile and work task analysis of 250 job advertisements, mapping the match between the competences of the CFs and the work tasks and skills/qualification profiles of the job advertisements. The study concludes that the jobs advertised for project managers and consultants showed that many competences in the Frameworks "could be mapped with the tasks and skills profiles of the job ads. The job titles for these jobs were quite homogenous for some keywords such as Sustainability, Innovation and Change Management" [62] (p. 64).

5.3. Outcome I—The PCFSI: The Stages and Blocks of Competences

To provide a more definite focus on SI, an integrated competence framework was developed in which the twenty key competences from the three components were selected and, in some cases, revised based on the previous evaluation and validation process. In this way, we formulated the integrated *Professional Competence Framework of System Innovation for Sustainable Development* (PCFSI) [63,64]. The framework structure includes five blocks of competences, with four competences in each block and four performance indicators for each competence. Next, we will present the rationale for the blocks, and in the following sections, we will focus on the competences and performance indicators included in the model.

The literature on the SI process often identifies stages in the change process. For instance, the model formulated by the *Forum for Future* distinguishes between the following stages: (1) Experience the need for change, (2) diagnose the system, (3) create pioneering practices, (4) enable the tipping point, (5) sustain the transition, and (6) establish the rules for the new mainstream [34]. Stroh describes a four-stage process of systems thinking: (1) build a foundation for change; (2) help people face the current reality; (3) help people make an explicit choice in favour of what they really want, and (4) bridge the gap, identifying leverage points and establishing a process for continuous learning and expanded engagement [37]. De Vicente identifies four stages or phases: (1) Making sense of or understanding the system, (2) Framing or identifying the trajectory of change to work on, (3) Delivering or ideating and implementing experiments and solutions, and (4) Sustaining or keeping the innovation trajectory alive by implementing a learning loop [65]. Based on these efforts, we have established five stages in the SI process, briefly characterised as *Exploring*, *Framing*, *Designing*, *Implementing*, and *Strengthening* (see Figure 2). Even though the five stages represent a logical progression towards SI, they usually unfold in a non-linear, not strictly sequential way, and the real paths reflect iterative, recursive, and dynamic development, with two stages that overlap and unfold concurrently because they correspond to complex change processes.

In any case, these stages are useful for giving a meaningful structure to the bundle of core competences for SI. In our view, a CF should be more than just a collection (or "laundry list") of competences. Instead, relationships between competences must be considered as well, and the structure of the stages includes the competences in the stage where they are especially relevant. However, this does not mean that these competences will only be relevant in that stage, or that their enactment is sequential according to the stages considered. Thus, depending on the context and the particular dynamics of change, the sequence of the competences to be enacted may be different, and several competences may be enacted at the same time in a number of circumstances throughout the process. Moreover, these competences always have to be contextualised, taking into account the different levels of SI development described earlier (niches, socio-technical regimes, and landscape developments).

Figure 2 (see also Appendix A for a detailed description of each competence) presents the competences of the PCFSI organised in the following five stages:

1. "Exploring" refers to competences related to understanding systems' complexity and their interconnectedness.
2. "Framing" includes competences related to imagining change scenarios, facets involved, and ways to achieve the transformation.
3. "Designing" reflects how leaders can define and compare alternative ideas and formulate strategies to achieve the transformation involved in SI.
4. "Implementing" encompasses competences of cooperation with others and mobilising resources to implement, test, and improve transformative interventions.
5. "Strengthening" considers leaders' capacity to review their transformative interventions and adapt them to relevant circumstances that challenge their solutions, persisting despite obstacles and learning from change experiences.

This conceptual logic is based on a step-by-step method to describe the model in a simpler way. However, the reality is more complex, and multiple paths may occur in practice. Professionals and leaders can "jump" from one stage to another (and even back) without following the sequence and they can implement competences at the same time that are presented in different stages in the model. This complexity also exists at the competence level. As previously mentioned, each competence is included in the stage where its enactment is more plausible and required more often, but this does not mean that they are grouped in silos or that the stage where each is included is the only one where it is relevant (in fact they may be relevant in many stages throughout the change processes). Nor does it mean that the sequence of enactment of these competences is linear; instead, non-linear patterns, loops, and overlapping often occur in the processes for systems change.

The PCFSI includes the four traditional components: "cognitive" (C) (information processing involved in transformations); "social" (S) (transformation is only possible with the adequate implication of other participants or stakeholders); "attitudes-values" (A) (transformation requires a different attitude toward the change and the role of professionals and leaders); and "behavioural" (B) (actions to be implemented). In addition, transformative changes underlying SI require professionals' "orientation towards the future", envisioning possible scenarios and anticipating obstacles, opportunities, alternatives, and pathways. For this reason, we add a fifth component, which is "future orientation" (F). Each competence can include the five components. However, we identified two prevalent components of each competence (see Appendix A and Figure 2) to present the profile that best characterises it.

Navigation through the stages describes a progressive transformation. Each stage reflects a particular context for the professional or leader to achieve SD through SI. The differentiation between niche, regime, and landscape from a dynamic perspective helps to understand the process [13]. Transformations usually take their first steps in co-existence with the previously established paradigm. There are "niches" (contexts) characterised by concrete spaces where radical and strange ideas can be incubated and encapsulated within the dominant paradigm. Generally speaking, the first two stages of the model (*Exploring*

and *Framing*) refer to competences of professionals and leaders that allow the creation of these niches. The complexity of the possible new reality is analysed, mobilising resources and other stakeholders and creating shared visions of the transformation. The third and fourth stages (*Designing* and *Implementing*) describe a context based on the transition from the niche(s) to a new "regime", a structured and stable paradigm composed of both social and technological facets, taking advantage of positive circumstances for change (e.g., people's beliefs about climate change). Here professionals and leaders formulate strategies, question the status quo, and implement coordinating actions to replace the previous socio-technical regime with a new one. Finally, the last stage includes the competence (*Strengthening*) of managing a context that goes from changes in the regime to the transformation of the socio-technical "landscape". The landscape refers to external factors (culture, macro-economy, macro-politics, technological trends). It is the most structured and stable level supporting an extant paradigm, including the material reality (e.g., organisation of cities) and consolidated values (e.g., consumerism). Through the change in the regime(s), professionals and leaders modify the landscape by producing long-lasting effects and transferring the intervention to other sectors, organisations, spaces, etc.

Although all the competences include the five components, some components prevail over others. Considering the model in general (Figure 2), cognitive facets are more prevalent in the first three stages (*Exploring*, *Framing*, and *Designing*) because they focus on contexts where the creation of niches and the initial transition towards a new regime(s) are expected. When professionals and leaders navigate in these contexts, complex analysis, creation of shared visions, collective creativity, and the processing of new ideas and solutions become prevalent. By contrast, in the last two stages (*Implementing* and *Strengthening*), the relevance of social, attitudinal (and values), and behavioural components are increasingly prevalent. When professionals and leaders deal with these contexts, characterised by the change in the regime and in the landscape, aspects such as mobilising others, implementing actions, and changing attitudes and values become increasingly important.

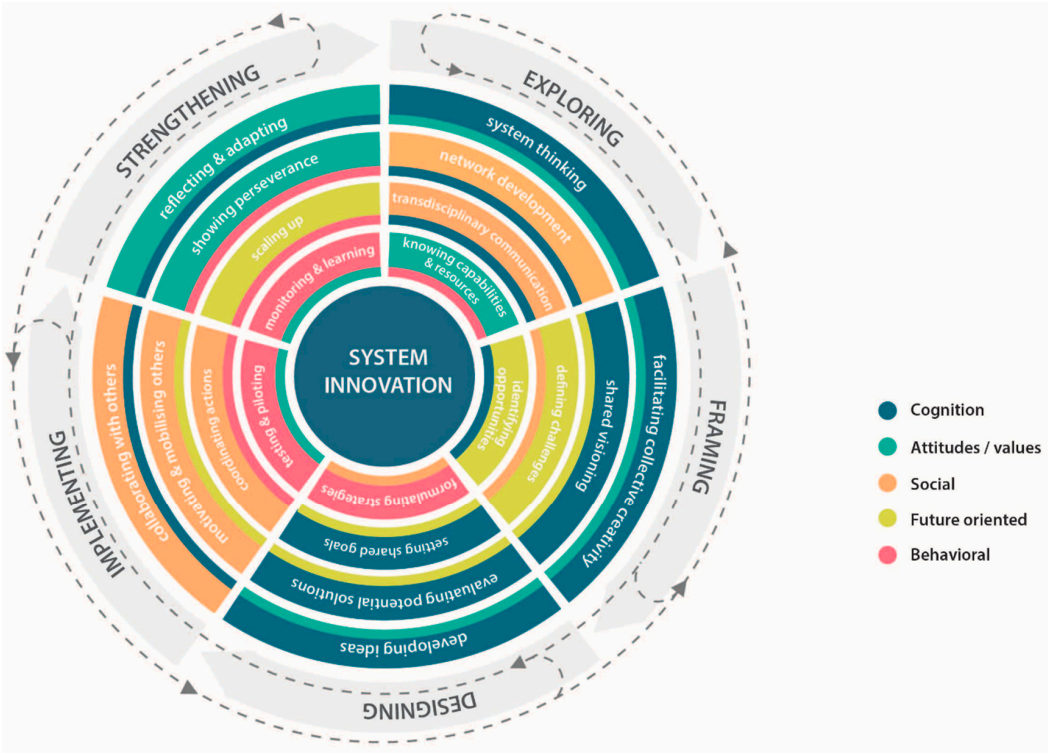

Figure 2. The transferable competence framework of system innovation.

SI will never take place without the participation of significant actors such as individuals, groups, or other collectives (organisations, institutions, etc.). It is always the result of a collective endeavour, and it implies shared mindsets and visions, as well as participation in goal setting and project definition. SI also involves the concurrence of multiple agents to co-create new situations and realities that imply shared learning towards a big shift that is often uncertain or unknown. Thus, agents aiming to lead and drive system changes need to be competent in displaying important individual and social actions that may facilitate the progress towards this system change. They have to contribute to "maturing" the necessary transformative change through the learning processes (often through errors) needed for SI to happen and succeed. Amazingly enough, this will imply the transformation of the actors, including those who aim to lead the change process. With all this in mind, it is important to note that the real and timely implementation of each competence, regardless of the stage in which it is included, is expected, based on the context contingencies and circumstances. The full process is "navigated" and "surfed" in a suitable sequence that leads toward system change using the levers to overcome barriers and make successful progress towards the landscape level of the consolidated new system.

5.4. Outcome II—The Performance Indicators and Learning Outcome

Models of competences have usually described the competences they include, but very few have offered more specific operationalisations of learning objectives and levels of mastery e.g., [50] or performance indicators. The PCFSI is designed to promote the acquisition, self-assessment, professional assessment, and certification of the competences included, facilitating its social "readability" and recognition. In a similar way to the model presented by Wiek et al., the PCFSI operationalises the competences by offering four "exemplar" behavioural indicators that are formulated at the basic level of professional independent practice (without supervision) [50]. This level assumes that the individual under assessment has a minimum professional practice experience of three full years. Then, each competence is presented with four performance indicators that offer exemplar performance facets to indicate the standards to be achieved. A *performance indicator* describes what the individual is expected to demonstrate to pass the assessment. Nevertheless, given its "exemplar" character, it is still formulated in a rather generic way. The candidate has to contextualise these "exemplar" types of performance in a given context when enacting the competence. The performance indicators can also be considered learning outcomes. The European Centre for the Development of Vocational Training, CEDEFOP, defines learning outcomes as a "Set of knowledge, skills and/or competences an individual has acquired and/or can demonstrate after completion of a learning process" [66] (p. 164). They are usually formulated in "statements of what a learner knows, understands and can do after the completion of a learning process" [66] (p. 165).

Next, we provide a few examples of performance indicators. Anyone interested in knowing more about the complete set of performance indicators should contact the corresponding author. For instance, one of the performance indicators of *"transdisciplinary communication"* is "Candidate demonstrates his/her understanding of different expert jargons and relates them to mainstream discourses". Another one, corresponding to *'Motivating and mobilising others'*, states: "Candidate makes clear that he/she paid special attention and explains how he/she dealt with passive or active resistance of actors to increasing the probabilities of the interventions' success". Finally, a performance indicator corresponding to *'scaling up'* states: "Candidate defends achieved SI and overcomes tendencies toward inaction and backsliding, through advocacy, lobbying, and strategic coalition building".

The system of indicators for each competence has been evaluated using several methods. First, all of them were reviewed by experts whose coalition-building provided feedback on the framework, and their suggestions and amendments were discussed and included when agreed. Second, the consultants who evaluated the dossiers of the candidates and interviewed them to assess their competences (during the testing and pilot phases) pro-

vided detailed feedback about their assessment experiences. They systematically reviewed the content and wording of each performance indicator to improve its formulation and the fulfilment of its proposed functions. All these actions contribute to the validation of the framework. Moreover, a second assessment was performed in many cases. The analysis of this "blind" double assessment of the same candidate has shown satisfactory consistency and reliability, and when there were discrepancies the two consultants jointly clarified the criteria behind their opinions.

5.5. The Competences' Assessment

The competences are acquired through learning-by-doing in a given context under supervision. Thus, the assessment of a given competence requires knowing the context, and it takes it into account to better understand and appraise the meaning and effectiveness of the behaviours. The context is, thus, an essential component in understanding whether behaviours are competent. It not only includes the physical environment, but also the social one and its dynamic person-environment interaction across time. Assessment of the competences requires being aware of the context in which they are displayed. Moreover, they come to the fore in performance. This means that the most direct way to measure competences is through the assessment of their behavioural manifestations in a given context. Behaviours often produce outputs that we can also analyse and assess as indirect but valid evidence of the competences used during their production. It is possible, then, to assess competences based on the behaviourally anchored report on how an actor has dealt with the complex issue at hand. This is especially fruitful when an expert consultant analyses the report and then carries out a structured interview based on the information obtained from the candidate´s description of his/her contextualised performance.

The methodology adopted in the PCFSI to assess the competences has three steps: First, a self-assessment exercise requires filling in a dossier with relevant information about the context, the candidate's role, and the description of the behavioural episode that shows how the candidate mastered or demonstrated the competence assessed. Second, an expert analysis of the dossier and then assesses the competence of the behaviours reported in a structured interview. Third, the consultant provides feedback to the candidate. See more detailed information in Figure 3.

In sum, the competence assessment exercise becomes one of the most enriching learning experiences for candidates. First, it is a good experience because candidates perform an in-depth analysis and reflection on their experiences, strengths, and weaknesses in the practice of each competence assessed. Second, experts draw their attention, through the interview, to relevant issues regarding behaviours for implementing the competence under review in the given context. Third, candidates receive systematic feedback about their competences assessed through the dossier and the interview. This 'portfolio + personal interview' approach is useful for candidates who gained practical work experience in an informal or non-formal learning context, and for those who gained their practice in a more formal educational context (e.g., internship or experiential learning environments).

Instructions provided to the candidates for the preparation of the dossier

For each of the competencies, the candidate chooses to present evidence that he or she must describe:

1. About the context: Please describe the context in which you mastered/demonstrated the competence under evaluation. The description can include a short project description, main goals of the initiative/project/program, main stake-holders involved, institutional structure, duration of the initiative/project/program, size of the team you worked in, etc. You can copy and paste the context description of another competence if it is identical (max. 100 words).
2. About the role of the candidate: Please indicate your role and your main tasks in the given context (initiative/project/program). Description can include your job title, a task description, your official/unofficial relationship with other stakeholders, your personal goals, etc. You can copy and paste the role description of another competence if it is identical. You may also prefer to describe other aspects of the role relevant to this particular competence (max. 50 words).
3. About the episode showing your mastering of the competence: Please indicate how you mastered/demonstrated the competence in the given context. Make sure to relate it to all four performance indicator statements. The description can include how you dealt with obstacles, how you learned from your practical experience, how you applied your theoretical knowledge, etc. (max. 300 words).
4. About how to provide evidence. Once the candidate has completed the competences from a given block or stage, he or she is invited to upload to the platform sup-porting documents providing evidence about the competences fulfilled in that block. Through the preparation of the application, individuals can self-reflect on their work experience, and it is an excellent way for candidates to get to know themselves and value their strengths and sharpen their weaknesses. The application takes approximately 10–12 h to complete.

Information about the interview

Once the consultant has reviewed the dossier, the candidate will receive an appointment for a one-hour online interview with one of the consultants – an experienced systems innovation professional. The consultant, through a semi-structured interview, explores and seeks additional evidence about the competences chosen by the candidate, to judge the fit of the assessed competence to the standards. Personal interviews are used to clarify open issues and improve the understanding of the evidence provided. Consultants are professionals in the field who are trained in well-defined assessment criteria for evaluation (see [64]). This step can be quite valuable for candidates because they get to delve into their experience and their competences. According to participants in trial phases, the interview is great practise for job interviews because they have to provide good examples based on their experience and competences.

Feedback for the candidate

Every candidate receives a customised feedback report from the consultant based on his/her dossier and the interview. Through the feedback report, candidates gain valuable external insights about their competences.

Figure 3. Description of the assessment process and instructions provided to the candidate.

6. Discussion and Conclusions

This article focused on answering the two research questions set out in the introduction: (1) What competences do change agents need to innovate socio-technical systems in a long-term sustainable manner and (2) how can these competences be assessed and validated? Thus, it contributes to the SI literature with regard to agency and leadership for SD, where empirical research is still lacking. We did this by identifying 20 core competences and clustering them into five stages (see Figure 2). The competences were operationalised through performance indicators and learning outcomes for validation purpose. For the

competences' assessment we proposed a qualitative three-step assessment process consisting of a self-assessment, an expert analysis and a structured interview.

6.1. Implications for Research

Our competence's framework presents a number of benefits for research. From a general perspective, our proposal fulfils the requirements of applied research. It combines social relevance with rigour. To do so, a systematic validation process helps to produce useful knowledge related to the competences for SI oriented to SD. In addition, a participative process is considered where researchers are co-creators, together with other relevant participants (experts and professionals). Finally, research has an emancipatory character, pursuing competences that permit inclusive long-term sustainability of our world. This effort opens the door for future investigations extending the implications of developing and certifying the competence's framework.

The competence's framework also contributes to knowledge in more concrete aspects. First, it is based on professional competences. Most previous efforts have focused on competences within the educational context (e.g., developing competences in universities). By contrast, the PCFSI considers the real performance of professionals. Transferable competences become increasingly relevant in managing transformation, but they are usually learned in informal contexts and workplaces outside educational institutions. Therefore, validating the PCFSI is fruitful. Second, the framework has an integrative character that considers the main types of competences found in previous proposals. Accordingly, a total of 20 competences are organised in five stages: *Exploring*, *Framing*, *Designing*, *Implementing*, and *Strengthening*. Third, the framework combines complex stages and contexts. The aforementioned five stages describe a clear and logical process, but the framework proposes a more complex view where actions can be carried out in different stages simultaneously, and professionals can go forward and backwards in the sequence. In addition, the PCFSI follows a contextualised definition of competences because being competent makes sense when the person shows effective behaviours for a specific situation. Some competences (*Exploring* and *Framing*) are especially relevant for managing niches, whereas others are more useful for transformations in contexts characterised by the transition to regimes (*Designing* and *Implementing*) and even, on occasions, landscapes (*Strengthening*). Fourth, a complete picture is provided of the psychosocial components of competence. Each competence is based on cognitive, social, attitudinal (and values), behavioural, and future-oriented components. Nevertheless, the prevalence of components in each competence depends on the context or stage. During the first stages (*Exploring*, *Framing*, and *Designing*), cognitive competences prevail, whereas social, attitudinal and values and behavioural components become increasingly important in the last stages (*Implementing* and *Strengthening*).

6.2. Implications for Practice

A central aim of the present article is to discuss the implications of the PCFSI for practice. The PCFSI fulfils a number of functions that may enhance human capital SD of which the five most important are described below:

1. Mapping the competences of agents to promote, plan, implement, monitor, and evaluate system innovation. The PCFSI provides a roadmap for increasing change agents' awareness of the different functions and contributions they need to implement to produce the transformation of a given system. These actors must become competent in mastering relevant processes for effective systems transformation. It requires mastering the combined individual and collective processes: from identifying needs and framing the situations through envisioning the new system, implementing ways to reach it, progressing towards its consolidation, and scaling up to reach a new "state of things" that improves the former reality.
2. Guiding the education, training, and continuous professional development of system innovation actors. The PCFSI is an excellent roadmap for educating and training

professionals in SI competences and guiding their practise under supervision. The different clusters of competences tackle important areas where professionals need to be educated and trained if they want to play an active and significant role in SI in cooperation with others. Thus, the PCFSI may guide curriculum development on managing SI. The knowledge, skills, and attitudes required by each competence in the model should be identified and elaborated as part of the curriculum. Afterwards, in a practicum or internship, the trainees should practice these competences, at the basic level, in a real context, under supervision, and with well-established and effective feedback systems that enhance the opportunities to learn these competences through practice.

3. Self-assessment and professional development through reflexivity. Professionals in different positions within a system play roles to promote changes in the system to adapt it to changes in the context. In a number of cases, the necessary changes are deep and systemic, to achieve new states that are substantively different from the existing state. Through interaction, mutual influence, debate, cooperation, conflict management, negotiations, and political actions, professionals contribute to these changes, and they often drive and lead them. The reflexivity of the professionals who lead SI in these complex interactions and influence processes may help them to better understand why different results were achieved and why some were more successful than others, in addition to learning from experience and improving their own competences in their endeavours. These reflexivity processes can greatly improve the professionals' competences, and the use of the CF provides a systematic reflexivity process that can be extremely useful for their professional development. Moreover, these reflexivity processes may also be carried out in groups and teams, and they help to increase the team's competences to better contribute to SI.
4. Assessment of Human Resources in organisations. Organisations usually have a catalogue or system of competences that guides their Human Resources practices and establishes the corporative, general, and specialised competences that are required to fulfil their mission and strategy in accordance with their values and achieve their leadership in their context. However, in this catalogue, the competences for radical system change have not usually been included because they are not considered necessary in regular businesses. Nevertheless, organisations are increasingly operating in very dynamic, complex, uncertain, and turbulent environments, in which learning and adaptation require radical changes and SI. In these cases, the PCFSI provides an excellent guide and tool for HR departments to assess the competences of their employees to identify their capacity to lead innovative changes at the system level. Moreover, the framework also helps to plan the actions to be taken to develop the competences professionals have to acquire or strengthen if they are to fulfil the leadership role or make significant contributions to systems change.
5. Certification processes for competence recognition. In the current dynamic labour markets, most valuable contributions require professionals to master a wide array of competences of different types. Of course, they have to be competent in enacting the competences corresponding to their specialism, which are often formally recognised by diplomas or certificates. By contrast, soft and transferrable competences developed through practice usually result from non-formal or informal learning that is hardly visible and transparent to employers but of critical value in the current labour market. This learning includes the competences to promote and drive SI. Therefore, valid and reliable certification systems to validate these competences are needed. Well-defined standards and reliable procedures are needed to assess and certify a professional's competence profile. The PCFSI also presents a certification process that establishes standards and performance indicators for each competence. It consists of a personalised assessment method with a self-reflective dossier and a one-hour online interview with an expert consultant that leads to the certification decision and a customised feedback report for the applicant. This certification makes the preparation

of human capital in Europe readable and transparent for managing changes, to make innovative changes and accelerate the transition to a more sustainable world with a systems innovation approach. Professionals and significant actors with responsibility and the capacity for innovating systems will benefit from the certificate because it will make them more aware of the competences for SI. Furthermore, they will be able to provide evidence of their expertise to employers and other decision-makers. Employers may find the certification useful because it can facilitate their selection processes, helping to identify the necessary human capital for the different projects. Those responsible for the education and training of new employees may be inspired to redesign the curricula by including PCFSI training during formal education.

As noted elsewhere "in the path towards a climate-resilient society, the world needs motivated people who are capable of driving systemic change within organisations of every stripe. Unlike other innovation certificates, this one is based on competences rather than knowledge—and is meant for professionals who can think and act systemically—because these are the innovation professionals who can better understand the complexity of the problems we face, and who can provide the real solutions needed to tackle them" [67] (p. 6). In sum, the certification contributes to increasing "the portability of skills by improving the information on the competences and skills that are gained through various learning channels", as stressed in the Priorities for policy action of the OECD Innovation Strategy [21] (p. 13).

6.3. Limitations and Future Research

To what extent our observations can be generalised outside of the context from which they emerged is open to debate and further research that we would like to stimulate with our article. A useful area to be explored is the consideration of individual and group levels of competences. Given the complex nature of SI oriented toward SD, positive effects may improve—beyond the individual—when the right mix of competences exists at the group level (e.g., team). Therefore, both the evaluation of competences and the examination of their effects could include the group of professionals and leaders working on complex projects oriented toward SD. Moreover, since SD and SI are two extremely dynamic fields that are always subject to strong and rapid change processes, our PCFSI is a snapshot. The requirements placed on change agents can change in a very short time and with them the necessary competences.

Despite these limitations, we believe that the analysis presented in this article provides useful and fresh insights into enabling leadership and agency for sustainability transitions. Future efforts can achieve additional fruitful developments based on the Climate-KIC PCFSI. One interesting avenue involves testing the effects of competence training. Once competences and learning outcomes are established in the framework, it is possible to design effective training activities to stimulate them in professionals, examining the effects on SD performance and considering different contexts as moderators. This is expected to lead to adequate human capital needed to promote and manage SI for sustainable futures.

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Appendix A. Stages and Competences of the System Innovation Professional Competence Framework

Appendix A.1. Exploring: Understanding the System and Its Interconnectedness

Systems Thinking. Candidate identifies the need for change in a relevant system (e.g., his/her organisation or community). He/she perceives the system as a whole, made up of interconnected and interdependent parts, and senses emerging patterns. The candidate conducts an analysis of system components and their relationships. Following a system mindset, he/she aims to identify patterns, paying attention to subsystems (e.g., social, technical, political etc.) and different actors' perspectives (e.g., selected companies, politicians, citizens). Moreover, the candidate takes into account the different levels of the system, such as the individual, groups and organisation, as well as their relationships

Knowing Capabilities and Resources. The candidate is aware that he/she is part of the targeted system (and not an external agent) and understands his/her role in it as an innovator. He/she understands his/her interaction with the system and his/her opportunities to influence it. For this purpose, the candidate appraises his/her own personal and professional strengths and weaknesses and proactively addresses identified weaknesses through self-development and learning. The candidate also identifies existing and needed resources (e.g., financial, social, intellectual, cultural, political) and takes action to mobilise those not already available.

Network Development. The candidate is aware of the need to identify the relevant actors and network effectively with them to understand the system. Network Development at this stage is mainly about bringing in relevant perspectives to make sense of the whole system. The goal is to get a common understanding of the system and its context that is as diverse and rich as possible. The candidate engages others in building the system analysis and participating in upcoming efforts to innovate the system.

Transdisciplinary Communication. Candidate actively listens to and understands the reasoning of experts from different disciplines, including their usual jargons, and relates them to mainstream discourse of the actors involved. Moreover, he/she crafts distinct

narratives oriented toward different stakeholders or sectors while staying compelling. This includes translation and communication into terms in common use and vice versa. Thus, the candidate communicates effectively with a wide range of actors about system and context analysis, policy development, business and action plans, public relations, user-producer interaction, etc.

Appendix A.2. Framing: Envisioning System Innovation and Its Potential Pathways

Defining Challenges. The candidate reflects on the weaknesses, inconsistencies, problems, and unsustainable situations of existing practices using a system thinking lens. He/she scrutinises the context, searching for relevant information to identify the system's challenges. Candidate exchanges his/her views about potential challenges with others and, with them, define the challenge(s) to be addressed. As a result, actors are ready to frame important challenges and decide which one(s) they want to work on.

Identifying Opportunities. Candidate identifies relevant trends (e.g., environmental, societal, economical, technological) and their interdependencies for system innovation. He/she subsequently explore stakeholder needs and the system's potential for future development. Based on this analysis, the candidate—in interaction with relevant actors—identifies and generates a shared view of the opportunities for creating sustainable value through system innovation.

Facilitating Collective Creativity. Candidate uses a collaborative approach to knowledge and idea generation, making the stakeholders co-designers of alternative trajectories of change from the current situation to the desired future. He/she identifies factors that may condition, foster, and/or influence his/her own and others' creativity. Candidate modifies single elements of the environment to facilitate co-creation processes. He/she is aware of the importance of generating creative tension, being able to constructively manage conflicting situations to finally achieve a shared view of innovation paths.

Shared Visioning. Based on the critical analysis of the current system's state and the multiple opportunities emerging, the candidate stimulates a shared vision to provide a long-term perspective of a more sustainable system. He/she works with other actors on formulating future scenarios and prioritising the one that may serve as a point of reference for goals and future developments. In this way, a collective, shared, creative and inspiring vision is built.

Appendix A.3. Designing: From Ideas to Strategies

Developing Ideas. The candidate generates and develops alternative views of the system—both individually and together with other actors—aiming to identify different design concepts that could inspire system innovation. He/she is prone to questioning the ways things have traditionally been done or explained (critical thinking). The candidate is eager to produce and discuss new ideas or combine ideas in unique ways with other actors. In doing so, he/she enhances unusual (divergent) thinking processes and independent thinking among the group members and facilitates productive management of conflicting views. This leads to potential alternative configurations of the system to take advantage of the opportunities and shared vision.

Evaluating Potential Solutions. The candidate compares different overall views and ideas generated, taking into account stakeholder needs and the shared vision. With other actors, he/she discusses the different innovative solutions while evaluating their potential advantages, disadvantages, and overall feasibility. Candidate—individually and together with others—analyses risks, identifies weaknesses and evaluates negative side-effects and costs that are likely to be caused by the intended innovation. In this way, he/she envisions short- and long-term potential impacts of the intended innovation. Candidate fosters collective decision-making through negotiation and consensus-building, even under uncertainty, to prioritise the innovations to work on. This includes working with assumptions and insufficient information positively and proactively.

Setting Goals. Based on the selected innovations to work on, the candidate—together with the other actors—sets the goals to be achieved and formulates the criteria for success. In doing so, they start from the vision and its ultimate goals and engage in an iterative working-backwards process to derive intermediate objectives and main stepping-stones. The candidate supports the group in identifying the technical, institutional, and behavioural problems that are to be solved, aiming to connect the present situation with the envisioned future system.

Formulating Strategies. The candidate—together with other actors—formulates the strategies to achieve the goals of the intended system innovation. They work carefully in the development of an action plan to ensure that the different stakeholders are working towards the common goals and share the main strategies to reach the intended results. Candidate promotes among the actors the clarification of the conditions, inputs, and processes required for the strategies' realisation. He/she stimulates the actors to consider potential adjustments under contextual changes and new scenarios. The candidate uses adaptive planning techniques, if deemed necessary, and supports collective decision-making, managing uncertainty, ambiguity, and incomplete information.

Appendix A.4. Implementing: From Experimenting to Making Things Happen

Testing and Piloting. The candidate—with others—designs and dimensions one or several innovative interventions (prototypes) to initially test their feasibility and outputs, as well as identifying strengths, weaknesses, and needs for adaptation and improvement. He/she is open-minded and eager to learn from experiments, paying special attention to failure, mistakes, or unexpected outcomes, using them as a chance to improve the designed intervention. Candidate cooperates with others in the redesign of the interventions to pilot them so that assumptions, inputs, processes, outcomes and impacts are assessed and improved and further developed when needed.

Motivating and Mobilising Others. The candidate convincingly presents to others the limitations and problems of the status quo and the need for change. He/she shows the benefits of the proposed interventions to different actors and encourages them to take action towards the achievement of the intended goals. Candidate maintains momentum for those already actively involved and interacts with passive or reluctant actors to convince them to get involved in the project of change. Quality of dialogue (based on active listening and on well elaborated and timely messages through a range of communication channels) is important to transition from the old system identity to the new one.

Collaborating with Others. The candidate works together with others in the process of making the innovation of the system happen. He/she actively promotes shared mental models about the intended innovation and makes clear the contributions of his/her role and those of the other actors to this endeavour. The candidate understands the expectations and interests of the different actors involved in the innovation process and contributes to their alignment with the goals of the intervention. He/she contributes to building trust among the actors and is aware of the challenges of getting the actors out of their "silos" in the system. The candidate promotes cooperation across boundaries to facilitate transition processes and supports a culture of open feedback for improvement and learning in a climate of psychological safety.

Coordinating Action. Being clear about the supra-ordinated goals, the candidate establishes different coordinating strategies between partners (e.g., mutual adaptation, task coordination, coordination through goal-setting, or coordination through shared vision, mission, and culture). He/she implements with other suitable structures and operation processes, reviewing them regularly to enhance quality and effectiveness. The candidate pays special attention to interfaces among different actors and unites their interdependencies, frictions, and conflicts and deals with unintended consequences, ripple effects, diversity, and ambiguity.

Appendix A.5. Strengthening: Learning from, Adapting and Deepening Innovations

Reflecting and Adapting. Under changing circumstances, candidate adapts his/her working style and revises his/her "mind-set" with a clear view of the intended innovation. This includes revisiting previous activities and stages in the process and avoiding a "what is done is done" mentality. He/she also promotes reflexivity among actors in the collective vision, objectives, strategies, and processes of innovation and the eventual need to adapt them to current or anticipated circumstances. Candidate handles dynamic situations in an agile and flexible manner, implementing adaptive solutions and helping others to do so.

Monitoring and Learning. Candidate monitors the implementation of the intervention, checking whether it is on track and contributes to the intended changes. He/she identifies circumstances or contextual factors that deviate the change processes from the expected course towards the realisation of the vision. Through monitoring, the candidate identifies opportunities for learning and improvement. He/she shares these learning opportunities with others to promote organisational learning, not only correcting malfunctions of ongoing processes, but also improving and innovating processes and, when demands change, coming up with new solutions. The candidate uses, as deemed, different learning processes, such as "learning-by-doing", vicarious learning, learning from failures, learning from feedback, network learning, and learning communities.

Showing Perseverance. Despite difficulties, obstacles, or discouragement during the innovation process, the candidate shows steady persistence towards the achievement of the intended innovation. Thus, he/she remains motivated and focused, even under pressure and when confronted with criticism and resistance, and he/she works towards convincing others of the importance of continuing to try. The candidate shows resilience when confronted with difficulties, setbacks, and failures, keeping a positive attitude, showing an ability to regulate emotions, and identifying helpful feedback from the situation. Under these conditions, he/she enables the group to carry on a rational analysis of what might have gone wrong and search for paths that might be more productive.

Scaling-up. Candidate takes action to consolidate the innovation established by the intervention and produce long-lasting effects. He/she transfers interventions and/or lessons learned to other locations, sectors or organisations, aiming for the expansion of successful innovations, impacting more people, and, thus, finally embedding the innovation in the mainstream. This process involves the institutional spread of the innovation, from "frontrunners" and the niche level to incumbent organisations and the regime level, by enabling an environment for change. To do this effectively, the candidate requires social, political, and resource mobilisation skills.

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