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Competences for Solving Complex Problems: A Cross-Sectional Survey on Higher Education for Sustainability Learning and Transdisciplinarity

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Abstract: Successfully coping with complex, real-world challenges, such as those related to sustainable development and the resilience of coupled human–environment systems, calls increasingly for adapted forms of education and extended competences. Hence, we argue that, beyond knowledge and expertise in professional domains, additionally, personal, systemic, creative, and sociocultural competences are required to meet such challenges. Herefor, institutions of higher and continuing education play a crucial role. In this paper, universities as institutions of higher education are critically considered in relation to delivering education for sustainable development by raising awareness and providing the necessary competences to cope with complex problems such as sustainable development through effective forms of higher and continuing education as well as training. Research on attitudes and perceptions regarding sustainable development and the perceived need for comprehensive competences required to deal with such complex problems is still lacking. Our study provides a first attempt to elucidate core aspects of these attitudes, perceptions, and competences aiming to contribute to future, more tailored education approaches. We discuss the outcomes of a survey on sustainability in teaching and learning conducted at four Austrian universities. The analyzed sample comprised 3200 students as the recipients of, and 498 lecturers as the providers of, sustainability education in various academic disciplines at four distinct Austrian universities. Applying a questionnaire-based investigation of self-reported sustainability-related perceptions, attitudes, and competences and conducting factor analysis and cluster analysis, five sustainability types were identified that revealed a type of specific core awareness of sustainability and the perception of required competences related to sustainable development. The results presented are positioned to build a basis for further investigation that goes beyond the self-reported assessments to enable a comparison with sustainability-related, real-world problem-solving performance.

Keywords: complex problems; coupled human–environment system; sustainable development; sustainable development goals (SDGs); SD values; resilience; higher-education institutions (HEIs); transdisciplinarity; problem-solving competences; C2P2S Competence Framework

1. Introduction

In the 21st century, humanity is facing unprecedented challenges associated with interactions with Earth’s natural systems as well as with humankind’s societal systems and their political and

technological impacts. Coping with sustainable development on all levels means addressing the challenges of an uncertain future. New world orders on a global level have given rise to political and cultural changes but also to enormous technical developments. Rapidly increasing governmental changes are, in turn, causing changes on economic, ecological, social, and cultural levels. Unforeseen occurrences in the last several decades have produced uncertainties overnight that have changed the whole world. These include but are not limited to the terrorist attacks of September 2001 (9/11), the financial crisis of 2008, the Fukushima Daiichi nuclear disaster in 2011, unprecedented human migration flows in Europe in 2015, or the recent COVID-19 pandemic. New and old democracies have been forced to find solutions for unexpected crises. Such rapidly arising events require swift and adequate reactions, while predictable changes demand appropriate action. Therefore, the demand is strong for competences that support systems thinking and understanding larger coherences. Being prepared for this uncertain future is critical, not only in regard to actions and reactions resulting from individuals' decisions but also group decision-making and scenario-planning for forward thinking.

Discussing the effects of coupled human—environment systems on well-being in the context of sustainable development cannot be decoupled from understanding the comprehensive, complex system. Contemporary real-world problems can be characterized as ill-defined, multifaceted, highly interconnected, and uncertain with respect to their development paths and dynamic change patterns, which might be further aggravated by various forms of internal and external disturbances [1–3]. To understand future development patterns, “human systems must be aware and be able to perceive, sample or acquire information for the material–biophysical environment. [...] However, perception and environmental awareness also includes not only a cognitive but a motivational component [...]” [4]. All these challenges require the collaboration of not only various individuals with a broad variety of competences but also, particularly, interdisciplinary (collaboration between various disciplines) and transdisciplinary (mutual learning between science and society) problem-solving processes, which have the potential to sustainably address societal challenges and enable humankind to cope with crises [5–7].

1.1. Quality Education for Higher Education

A global approach to this sustainable development, which attempts to compress the complexity of its many facets, is the Agenda 2030, whose 17 Sustainable Development Goals (SDGs) represent individual systems. These United Nations (UN) SDGs (Agenda 2030) comprise current guidelines for ongoing learning processes following the UN Decade of Education for Sustainable Development (2005–2014). SDG 4 (quality education), in particular, addresses, among other factors, higher-education institutions (HEIs) and their curricula. In this vein, understanding a complex system is related not only to content but also to its organizations and changing structures over time [8–12].

SDG 4 aims to ensure education that is inclusive, equitable, and of good quality and promotes lifelong learning opportunities for all [10]. Subitems of SDG 4 include assured education; preprimary education; professional, vocational, and university education; more competent labor and inclusion; literacy and numeracy competences; education for sustainable development; accessible education; and scholarships for developing countries and competent teachers. Universities and colleges are fundamentally concerned with SDG 4.7 (“4.7 by 2030 ensure all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture’s contribution to sustainable development”) especially points 4.b and 4.c: by education of competent teachers and the development of meaningful curricula [13]. UNESCO Director-General (2009–2016) Irina Bokova stated in 2015 that there is no stronger transformative power than education to promote people’s rights and dignity, to prevent poverty, and to deepen sustainability to build a better future for all. All of these are based on values whose aspects are fundamental to our humanity: equality and social justice, respect for cultural diversity, shared responsibility, and international solidarity.

For these reasons, it is critical to rethink education in a changing world, and dialogue across the board is necessary [14].

1.2. Education for Sustainable Development

Over the past few decades, higher education has developed a series of new concepts, which operate discursively under the common term Education for Sustainable Development and include climate protection education, health education, UN documents, transformative learning, global citizenship, etc. [9,11]. Moreover, student movements such as Fridays for Future and the like have found their way to the university level and contribute to the fact that the topic of sustainable development can no longer be ignored. Organizational, local, regional, national, supranational, and global changes and challenges call for pioneers at all levels of society (e.g., industry, policy makers, politicians, public administration, science, special interest groups, citizens) who are able to grasp the broader societal system as well as the ecological, economic, social, and cultural implications of future scenarios. Such decision-makers should also be able to provide guidance to a range of stakeholders and disciplines in a collaborative effort to find creative and innovative solutions to complex societal challenges aimed at maintaining and advancing a functioning civilization and a healthy natural environment. Finally, a high order of comprehensive education is critical to develop the competences needed.

Higher education today is very concerned with sustainability, due not only to national and international political pressure but also to a global rethinking and emphasis on preserving the natural world and solving global crises [9,10,15]. Thus far, research structures continue to be bound to thematic siloes, and this situation needs to be overcome in order to transform science as a force in itself [16]. However, cooperation beyond disciplines, not to mention beyond universities, remains the exception and needs to become the norm [17].

We have not yet succeeded in jointly developing a program based on a clearly defined educational concept that has been and continues to be proven in practice. The disparities in universities' and colleges' curricula, which are continually being redeveloped and supplemented, are an indication of educational matters. Thus, it is important to ask the question: What do people need to "know" for a sustainable future? Universities can support sustainable development by providing expertise in relevant fields, educating future decision-makers to be able solve complex problems and make reflective decisions, and fostering a dialogue with society in order to identify societal needs and integrate scientific knowledge into research processes [18,19].

1.3. Research Gap

Literature provides a range of definitions of competences, for example "professional competences for intervention toward sustainability", which is defined as "the combination of knowledge, skills, behaviours and attitudes that enable a person to devise, in a process of consultation with relevant stakeholders, one or several solution(s) or decisions for a sustainability issue and subsequently successfully conduct the change process toward sustainability" [20]. Wiek et al. [11] provide an extensive review on key competences in sustainability, which shows that single concepts such as "system-thinking-, anticipatory-, normative-, strategic-, and interpersonal competences" are only rarely considered in a comprehensive manner. A general reflection on competence frameworks for complex problem solving from various disciplines and with a strong focus on the distinction between U.S. and European schools is provided by Steiner [11].

Understanding and dealing with the sustainable development of society as part of a coupled human–environment system calls for literacy and competence in order to perceive, define, and frame the interrelated systems and the respective societal or environmental challenges together with intervention-related rebound effects [4,21]. This further requires the understanding of stakeholder specific perceptions and potential future development paths of the investigated system and its relevant environment.

However, research on personal attitudes and perceptions regarding sustainable development and the perceived need for comprehensive competences required to deal with such complex problems is still lacking, as discussed in various prior publications [9–12,15,20]. This concerns the functional dimension, since most competence frameworks and surveys do not explicitly consider the competences needed for understanding those complex systems, its interrelatedness, and dynamics; underlying sociocultural peculiarities; as well as creative capabilities for imagining future scenarios and potential solutions [9]. Second, discipline- and stakeholder group-specific peculiarities, to our knowledge, find only marginal consideration [9,11].

Our study provides a first attempt to elucidate core aspects of these attitudes, perceptions, and competences aiming to contribute to future, more tailored education approaches. The core research questions within our study are gaining a better understanding and systematization of (1) the self-perception of involved agents (i.e., students and teachers) with respect to personal characteristics, attitudes, and competences needed to cope with complex problems such as the sustainable development of society as part of a coupled human–environment system and (2) their collaborative capabilities.

2. Empirical Analysis

2.1. Survey on Higher Education for Sustainability Learning

Since the aims of sustainability education may be understood as being positioned along the above-outlined spectrum of awareness-building, on the one hand, and problem-solving competences, on the other, within the underlying empirical work that is the main focus of this paper, we consider this spectrum as an orientation framework for the analysis and positioning of sustainability-oriented educational institutions. The empirical analysis focuses on students' and faculties' perceptions of and attitudes toward sustainable development and the provision of education for sustainability-related competences by universities and colleges (for most recent empirical investigations on the congruence between explicit and implicit attitudes toward sustainability, see [22]).

The purpose of this survey was to explore the research questions of what type of person with what attitudes and competences will be needed in the future to cope with the complex problems of a sustainable society, and what must universities as educators and trainers offer in this respect? What type of person has a specific core awareness of sustainability and the necessary competences in relation to sustainable development? We developed two questionnaires on the basis of the research questions (what type of person with what attitudes and competences is needed to cope with the complex problems of a sustainable society, and what do universities have to offer as training and further education providers?) to gain the attitudes and perceptions on the topic of higher education for sustainability learning from both target groups, i.e., students and teachers, to draw a comparison between sustainable development (SD) contents actually conveyed by teachers and SD contents actually perceived by students. On this basis, the attitudes toward SD and personal behavior toward SD in private as well as at work (at the university) were determined. As a result, possible competences were identified on the basis of Steiner's C2P2S (Creativity, Professional, Personal, Systemic, and Sociocultural) competence framework [9,10,12].

2.2. Competence Framework C2P2S

We define competence as “[...] the problem solver's abilities, knowledge, and skills needed to adequately deal with a complex real-world problem; competence depends on specific underlying mental models, which themselves are not stable but change over time; and they also depend on the specific features of the environment” [9].

Our empirical analysis focused on students' and faculties' perceptions of and attitudes toward sustainable development and the provision of sustainability-related competences in curricula. We consulted Steiner's C2P2S (Creativity, Professional, Personal, Systemic, and Sociocultural) framework of problem-solving competences [9,10,12], because it describes the competences needed for

solving complex problems. At this point, it must be anticipated that a strategic, developing process, such as the sustainable-development process, must comprise more than one person, and therefore, different competence focal points at different steps of the process are required. Steiner's framework is used because it responds to complex real-world problems and focuses on capabilities with respect to mutual learning processes, collaboration, and crisis management, among others.

Real-world, complex problem-solving processes with the aim of creating innovative solutions in response to crises and unsustainable system patterns tend to depend heavily on collaborative efforts, where collaborative effort refers to more than the simple aggregation of individual performances. The C2P2S framework of problem-solving competences states that complex problem-solving, such as that achieved by innovation-based entrepreneurial processes, requires the dynamic and holistic interplay of the following factors: Professional domain competence, i.e., domain-specific knowledge, skills, and methods (in contrast to the other four competence dimensions, this focuses on specific disciplines or domains); Systemic competence, i.e., understanding and dealing with complex processes, events, and systems; this includes the design of problem-solving processes and the choice of methods to be applied); Sociocultural competence, i.e., the ability to cope with different social and cultural settings as part of effective communication and interaction processes among disciplines and between organizations and stakeholder groups; Personal competence, i.e., an individual's capabilities for reflection and personal development; this is also a prerequisite for sociocultural competence; and Creativity competence, i.e., the capability to create novel, original solutions for ill-defined, open-ended problems as a precondition for the development of innovation; this extends beyond routine problem-solving [8].

2.3. Sample

The survey was conducted at four Austrian universities: The University of Natural Resources and Life Sciences, Vienna (BOKU) [23]; the University of Graz (KFU) [24]; the Medical University of Graz (MUG) [25]; and the Graz University of Technology (TUG) [26]. The target population comprised students as well as teachers at these universities. During data collection, a total of 61,728 students and 7480 teachers were registered at the four universities, and all were invited by email to complete an online questionnaire. The study was internally approved by the academic presidency and respective internal committees of all four participating universities. The final sample consisted of 3200 students and 498 teachers who provided complete questionnaire data for an overall response rate of 5.3%. Table 1 provides a detailed description of the final sample and response rates stratified by university, gender, and status (students versus teachers).

Table 1. Number of participants and response rates for the final sample by university, gender, and status.

		BOKU	KFU	MUG	TUG	Total
Students	Female	852 (15%)	394 (2%)	189 (8%)	302 (12%)	1737 (6%)
	Male	571 (9%)	144 (1%)	141 (8%)	607 (5%)	1463 (5%)
	Total	1423 (12%)	538 (2%)	330 (8%)	909 (6%)	3200 (5%)
Teachers	Female	62 (9%)	59 (5%)	44 (9%)	14 (4%)	179 (6%)
	Male	99 (9%)	55 (4%)	96 (16%)	69 (4%)	319 (7%)
	Total	161 (9%)	114 (4%)	140 (13%)	83 (4%)	498 (7%)

Note: Response rates are given in parentheses. Abbreviations: M = mean, SD = standard deviation, BOKU = University of Natural Resources and Life Sciences in Vienna, KFU = University of Graz, MUG = Medical University of Graz, TUG = Graz University of Technology.

To evaluate the representativeness of the study sample in regard to gender distribution, the official university statistics for students and teachers were used to calculate expected frequencies. These were compared to observed frequencies using a chi-squared test. At BOKU, KFU, and TUG, statistically significant deviations among students were found, indicating that a higher proportion of women than expected completed the survey (p -values < 0.001). By contrast, among teachers at these three universities, no statistically significant differences emerged between observed and expected gender

frequencies (p -values > 0.29). However, the proportion of participating male teachers at MUG was higher than expected ($p = 0.001$), while no statistically significant gender differences among students were found between observed and expected frequencies ($p = 0.55$). We were limited in our ability to assess the comparability of other traits in responders versus non-responders.

Students' mean age was 25 years (standard deviation (SD), 6.4 years), whereas, among teachers, the average age was 44 years (SD = 10.7 years). Table 2 provides an overview of the ages of all participants stratified by university, gender, and status (students versus teachers).

Table 2. Mean age of participants in the final sample by university, gender, and status.

		BOKU		KFU		MUG		TUG		Total	
		M	SD	M	SD	M	SD	M	SD	M	SD
Students	Female	24.40	5.18	25.24	7.94	24.14	5.78	23.43	5.90	24.39	6.12
	Male	25.99	6.66	28.82	9.84	25.22	7.19	24.95	5.34	25.76	6.69
	Total	25.04	5.87	26.20	8.63	24.60	6.42	24.44	5.57	25.02	6.42
Teachers	Female	41.27	9.87	40.57	11.06	43.57	9.26	39.29	11.77	41.46	10.28
	Male	46.47	10.75	43.09	12.36	48.00	8.44	43.54	10.80	45.71	10.57
	Total	44.47	10.70	41.80	11.73	46.61	8.91	42.82	11.01	44.19	10.66

Abbreviations: M = mean, SD = standard deviation, BOKU = University of Natural Resources and Life Sciences in Vienna, KFU = University of Graz, MUG = Medical University of Graz, TUG = Graz University of Technology.

Table 3 shows the scientific disciplines of all participants stratified by gender and status. Participants were able to choose more than one discipline.

Table 3. Scientific discipline by gender and status.

		Natural Sciences	Technical Sciences	Medicine	Agriculture and Forestry, Veterinary Medicine	Social Sciences and Economics	Humanities	Art
Students	Female	49%	29%	10%	18%	21%	11%	1%
	Male	42%	51%	10%	15%	13%	5%	1%
	Total	45%	39%	10%	17%	17%	8%	1%
Teachers	Female	32%	11%	25%	7%	16%	20%	0%
	Male	31%	28%	30%	12%	10%	6%	0%
	Total	31%	22%	28%	10%	12%	11%	0%

2.4. Materials and Procedure

A survey on sustainability in teaching and learning was conducted within the project SUSTANICUM—Sustainability in University Teaching—of the four universities, which was supported by the Federal Ministry of Education, Science, and Research. It aimed to create a platform with sustainability contents for university teachers [27], therefore we decided on the four participating universities.

At the outset, a pretest was conducted with a smaller group of students and teachers; in addition, several individuals from different administrative levels of the universities were asked to provide feedback on the initial version of the questionnaire, which was then adapted accordingly (mainly related to the terminology).

The questionnaire comprised 23 online pages including demographic data and took about 30 to 40 min to complete. It consisted of both inductive as well as deductive categories. The comprised 24 items related to sustainability, such as personal relevance of sustainability, perceived relevance of sustainability in teaching, organizational means in support of sustainability, competences for acting sustainably, contributions to society with sustainability impacts, and global perspectives. Responses to the 24 items were made using a six-point rating scale (1–6, with 1 being the lowest rating). At each of the four universities, two distinct groups (students and teachers) were targeted. Questionnaires were largely identical, with only minor differences in the way they were worded to address students versus teachers, as well as different response options for students and teachers, e.g., “working environment”

(teachers) and “study environment” (students) or “making a contribution to society from a teacher’s point of view” and “making a contribution to society from a student’s point of view.”

The survey was conducted by means of an online questionnaire at all four universities. The number of persons contacted was equal to the official number of 61,728 registered students and 7480 teachers in the academic year 2011–2012. The questionnaire was available online for six weeks and was distributed via the central e-mail server of the University of Graz (KFU) to all other universities.

2.5. Statistical Analysis

In order to evaluate the internal structure of all 24 items related to sustainability and to obtain a data reduction with unrelated factor scores for the cluster analysis, an exploratory factor analysis using principal component analysis as the method of factor extraction was performed. To determine the number of factors, a parallel analysis of 1000 pseudo-random samples was conducted. Orthogonal factor rotation according to the varimax criterion was performed, and z-standardized factor scores were calculated. Differences in these factor scores by status (students versus teachers) and gender were analyzed using a two-factorial analysis of variance. In order to obtain homogeneous subtypes of the thought patterns of potential future leaders, a cluster analysis was conducted. As a first step, a hierarchical cluster analysis according to the method described by Ward [28] was conducted. The number of clusters was determined by a visual inspection of the structogram. In the second step, a non-hierarchical k-means algorithm was applied using the cluster centroids obtained by the Ward method as initial cluster centers in order to improve the homogeneity of the clusters. Finally, these clusters were compared with respect to age, gender, status, university, and scientific disciplines, using either analysis of variance or a chi-squared test, depending on the measurement of the dependent variable. In order to evaluate the unique contribution of each regressor on the membership type, a regression analysis for mixed-scaled variables (categorical as well as metric) was conducted using a generalized linear model (GLM) with membership type and age, gender, university affiliation, status (students versus teachers), and scientific discipline as criteria. All tests were two-sided, and a p -value of 0.05 was considered statistically significant.

3. Results

3.1. Factor Analysis

According to the parallel analysis, a factor solution with seven potential dimensions was chosen. Overall, the 24 items related to general sustainability issues or to competences for sustainability were subsequently compressed to seven factors. Together, these dimensions accounted for 57% of variance. Varimax rotated factor loadings are shown in Table 4 and summarized below.

Analyses of variance for these factor scores by status (students versus teachers) and gender revealed several statistically significant differences but with very small effect sizes (partial $\eta^2 < 0.023$). Teachers scored somewhat higher on pro-environmental sustainability, acting sustainably, and contribution to society, and on reflective-responsible systems understanding and creative problem-solving but lower on economic sustainability and general conditions in support of self-responsibility (p -values < 0.033 , partial $\eta^2 < 0.023$). With respect to gender, females scored higher on sociocultural sustainability, collaboration and know-how, acting sustainably, and contribution to society, reflective-responsible systems understanding and creative problem-solving, and general conditions in support of self-responsibility (p -values < 0.010 , partial $\eta^2 < 0.018$). There was no statistically significant interaction of status and gender (p -values > 0.065 , partial $\eta^2 < 0.001$).

Next, these factors were examined to identify types using cluster analysis. Each resulting type signifies a general sustainability orientation as well as specific characteristics of competences.

Table 4. Rotated factor solution: underlying items and factor loadings.

	F1	F2	F3	F4	F5	F6	F7
Personal Relevance of							
1 Relevance of economic sustainability	0.08	0.01	0.15	−0.17	0.16	0.80	−0.01
2 Relevance of ecological sustainability	0.13	0.07	0.79	0.10	0.08	0.07	0.04
3 Relevance of social sustainability	0.37	0.01	0.63	−0.08	0.22	0.06	0.00
4 Relevance of institutional sustainability	0.47	0.10	0.40	0.04	0.21	0.18	0.22
5 Relevance of cultural sustainability	0.73	0.04	0.12	−0.08	0.26	0.00	0.06
Perceived Relevance of Sustainability in Teaching							
6 Relevance of economic sustainability	0.28	0.09	−0.01	0.23	−0.12	0.76	−0.05
7 Relevance of ecological sustainability	0.29	0.14	0.50	0.47	−0.20	0.18	−0.07
8 Relevance of social sustainability	0.63	0.08	0.28	0.28	−0.07	0.17	−0.09
9 Relevance of institutional sustainability	0.66	0.12	0.16	0.34	−0.08	0.21	0.05
10 Relevance of cultural sustainability	0.84	0.08	−0.03	0.10	0.05	0.06	−0.05
Organization Means in Support of Sustainability							
11 Regulations	0.11	0.06	0.19	0.24	0.00	0.00	0.74
12 General conditions in support of self-responsibility	0.07	0.04	0.00	0.09	0.11	0.01	−0.80
Competences for Acting Sustainably							
13 Systems understanding	−0.11	0.15	0.28	0.14	0.49	0.11	−0.09
14 Process design	0.07	0.20	−0.21	0.14	0.49	0.44	0.14
15 Reflection and self-responsibility	0.16	0.08	0.09	0.12	0.68	0.02	−0.10
16 Know-how (within and across professional domains)	−0.05	0.62	−0.05	−0.07	0.01	0.28	0.05
17 Critical thinking and responsible acting	0.04	0.34	0.35	0.03	0.44	−0.04	−0.03
18 Interdisciplinarity collaboration	0.15	0.74	0.10	0.08	0.17	−0.03	0.03
19 Collaboration with external stakeholders	0.20	0.62	0.01	0.16	0.16	−0.01	0.11
20 Creative problem solving	0.29	0.37	0.03	0.12	0.42	−0.08	0.04
Contribution to Society with Sustainability Impact							
21 Sustainable acting within university life	0.16	0.19	0.38	0.56	0.07	0.05	0.15
22 Contribution to society through university activity	0.10	0.06	0.04	0.77	0.11	0.05	0.01
23 Contribution to society in private life	0.08	−0.05	0.07	0.63	0.29	−0.09	0.05
Global perspective							
24 National contribution to sustainability	−0.01	0.04	0.53	0.20	0.07	−0.09	0.13

Note: Factor-loadings > |0.40| are set in bold. F1 accounted for 11% of the variance and describes “sociocultural sustainability” (including institutions). F2 accounted for 9% of the variance and describes “collaboration and know-how” (within and across professional domains). F3 accounted for 9% of the variance and describes “pro-environmental sustainability”. F4 accounted for 8% of the variance and describes “sustainable behavior”. F5 accounted for 7% of the variance and describes “sustainability competences”. F6 accounted for 7% of the variance and describes “economic sustainability”. F7 accounted for 5% of the variance and describes “regulative organizational framework”.

3.2. Cluster Analysis

We performed cluster analysis using the combined sample of students and teachers because the differences between them were relatively minor. From this combined sample, five distinct types (clusters) were extracted. Table 5 provides an overview of the cluster centroids of these clusters. A graphical representation of these centroids with their 95% confidence intervals (95% CIs) is displayed in Figure 1.

Table 5. Cluster centroids.

	Type 1 (N = 956)		Type 2 (N = 620)		Type 3 (N = 503)		Type 4 (N = 437)		Type 5 (N = 1182)	
	M	SD	M	SD	M	SD	M	SD	M	SD
Sociocultural sustainability	−0.31	0.95	−0.05	0.93	0.02	1.02	−0.76	0.98	0.55	0.75
Collaboration and know-how	0.47	0.66	−1.41	0.79	−0.01	0.98	−0.01	0.87	0.37	0.64
Pro-environmental sustainability	0.42	0.68	0.23	0.77	−1.69	1.01	0.21	0.77	0.18	0.60
Sustainable behavior	0.12	0.87	0.17	0.87	−0.26	1.04	−1.22	0.93	0.37	0.77
Sustainability competences	−0.30	0.87	−0.07	0.96	−0.59	1.18	0.88	0.94	0.20	0.76
Economic sustainability	0.00	1.00	0.41	0.91	−0.10	1.06	−0.51	0.96	0.01	0.94
Regulative organizational framework	−0.89	0.77	0.00	0.90	0.09	0.85	0.39	0.95	0.54	0.77

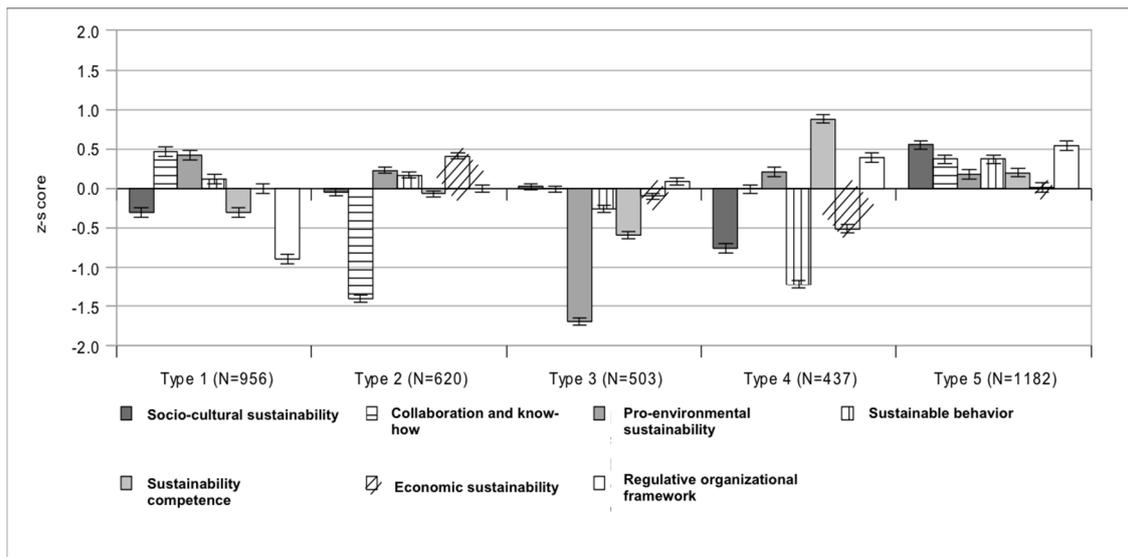


Figure 1. Cluster centroids. M = mean; SD = standard deviation. *Note:* Error bars denote 95% confidence intervals.

The following description of the five extracted types reveals the core awareness and attitude structure of competences and values in the context of sustainable development. Further details about the differences among these types by age, gender, status, affiliation, and discipline are provided in Table 6.

Type 1: The Green Type

It is strongly opposed to any “regulative organizational framework.” “Sociocultural sustainability” and “sustainability competences” are considered as rather less important. For these individuals, “collaboration and know-how” and “pro-environmental sustainability” tend to be more relevant. This type is typically represented by a male lecturer, less than 30 years of age, who is embedded in the “natural sciences” or “technical sciences.”

Type 2: The Overview Type

This type demonstrates a lack of interest in “collaboration and know-how” and considers only “economic sustainability” as significantly relevant. Type 2 scores distinctly low on all other factors. This type is equally prevalent among students and teachers, has an average age of 27, is predominantly male, and stands out in the academic discipline of art.

Type 3: The Protest Type

This type differs from Types 1 and 2 insofar as the subject has more negative scores than average in almost all factor dimensions but especially on “pro-environmental sustainability;” “sustainability competences” are considered irrelevant. This type shows no interest in “sustainable behavior” or “economic sustainability.” He or she tends to take only a mildly positive view of a “regulative organizational framework.” Type 3 is represented predominantly by male students approximately 25 years old and is typically found among medical students.

Type 4: The Lone Wolf Type

This type considers “sustainability competences” and a “regulative organizational framework” critical for university life. However, this type perceives “sociocultural sustainability” and “economic sustainability” negatively and “sustainable behavior” as significantly negative. Type 4 is represented among male as well as female teachers around the age of 30, mainly at the University of Graz; moreover, this type is represented mainly within the discipline of the humanities.

Type 5: The Sunny Type

This type, although scoring average in most dimensions, demonstrates an equally significant focus on “sociocultural sustainability” and on “regulative organizational framework” in university life. “Collaboration and know-how” and “sustainable behavior” are also noticeably positively connoted. Type 5 leans toward “pro-environmental sustainability.” This type is primarily represented by female students around the age of 27 who study mainly at the University of Natural Resources and Life Sciences, particularly in the ecological and social science disciplines.

Table 6. The five types by age, gender, status, university affiliation, and affiliation with a scientific discipline.

	Type 1	Type 2	Type 3	Type 4	Type 5	<i>p</i>
Age (mean ± SD)	28.45 ± 10.21	27.22 ± 9.34	25.57 ± 8.3	29.63 ± 10.69	27.22 ± 9.38	<0.001
<i>Gender</i>						<0.001
Female	23.4%	15.0%	11.8%	11.5%	38.3%	
Male	28.5%	18.6%	15.5%	12.2%	25.1%	
<i>Status</i>						<0.001
Students	25.1%	16.8%	14.5%	10.3%	33.3%	
Teachers	30.7%	16.9%	7.8%	21.5%	23.1%	
<i>University</i>						<0.001
BOKU	30.0%	16.9%	9.0%	8.1%	36.1%	
KFU	18.1%	17.8%	12.1%	17.6%	34.4%	
MUG	22.6%	14.9%	18.7%	12.1%	31.7%	
TUG	25.9%	16.8%	19.6%	13.8%	23.9%	
<i>Scientific discipline</i>						
Natural Sciences	28.4%	16.7%	10.9%	10.8%	33.2%	<0.001
Technical Sciences	28.3%	15.6%	15.2%	11.2%	29.7%	0.005
Medicine	22.5%	15.2%	18.3%	13.2%	30.8%	0.014
Agriculture and Forestry, Veterinary Medicine	31.7%	15.4%	9.2%	5.4%	38.3%	<0.001
Social Sciences and Economics	26.8%	16.0%	9.5%	7.7%	39.9%	<0.001
Humanities	16.5%	15.5%	11.7%	19.0%	37.3%	<0.001
Art	10.0%	20.0%	15.0%	10.0%	45.0%	0.519

Abbreviations: Type 1 = Green Type, Type 2 = Overview Type, Type 3 = Protest Type, Type 4 = Lone Wolf Type, Type 5 = Sunny Type; BOKU = University of Natural Resources and Life Sciences, Vienna; KFU = University of Graz; MUG = Medical University of Graz; TUG = Graz University of Technology.

Using a general linear model (GLM), we evaluated the unique contribution of each regressor on type membership with Type 3 as the reference category (because cluster centroids of this type were close to the average on nearly every parameter) and university affiliation with KFU as the reference category (because it differs from the other universities in that it represents many different disciplines). The results of these analyses were similar to those of the univariate analyses shown in Table 6, with the exception that the scientific disciplines of Medicine and the Humanities were no longer statistically significant (see Table 7).

Table 7. Regressors for type membership: results of regression analysis for mixed-scaled variables according to the general linear model.

Predictor	Beta	<i>p</i>	Zero-Order Correlation
Age	0.08	<0.001	−0.01
Gender = Male	−0.08	<0.001	−0.10
University affiliation	−0.12	<0.001	−0.13
Status = Teacher	−0.10	<0.001	−0.06
Natural Sciences	−0.04	0.023	−0.07
Technical Sciences	−0.04	0.026	0.02

Table 7. Cont.

Predictor	Beta	p	Zero-Order Correlation
Medicine	0.04	0.086	0.04
Agriculture and Forestry, Veterinary Medicine	−0.07	<0.001	−0.12
Social Sciences and Economics	−0.08	<0.001	−0.10
Humanities	−0.01	0.644	0.02
Art	−0.01	0.520	−0.01

Overall-statistics: Multiple R = 0.22, adjusted R² = 0.04, $p < 0.001$. Optimized quantification equations for z-standardized dummy parameters of categorical variables with more than two distinctive categories. Type membership = 0.74 * Type 1 + 0.34 * Type 2 − 0.11 * Type 4 + 1.13 * Type 5. University affiliation = −0.87 * BOKU − 0.71 * MUG + 0.10 * TUG. Note: The criterion variable was the membership type with Type 3 (Protest Type) as the reference category using a dummy coding. University affiliation was expressed by means of a dummy coding using the KFU as the reference category. Abbreviations: BOKU = University of Natural Resources and Life Sciences, Vienna; KFU = University of Graz; MUG = Medical University of Graz; TUG = Graz University of Technology.

3.3. Discussion of the Five Types

By applying factor and cluster analysis, five identified types revealed the core awareness and attitude structure of competences and values in the context of sustainable development, i.e., the Green Type, Overview Type, Protest Type, Lone Wolf Type, and Sunny Type. The investigation indicated that the five types (clusters) showed different competences and accesses to sustainability thinking and acting on the basis of seven factors (Table 5). For illustration purposes, we exemplify the varied interactions of all five types in the context of a fictional project, i.e., the implementation of climate protection measures in a given company.

The Green Type, who has a strong pro-environmental orientation and a tendency toward reflection and self-responsibility, critical thinking, and responsible actions and collaboration with other stakeholders, has, in terms of the C2P2S framework, strong competences such as personal competences and sociocultural competences. Such a person could be the project leader who is personally able to bring different interest groups together and critically takes on tasks for which a high degree of responsibility is required. This type has a strong relation to environmental belongings and can overcome critical situations within the team because of his/her ability to reflect potential setbacks or the individual needs of his team members.

The Green Type would be well complemented by the Overview Type. He or she is not necessarily good in social or environmental issues, however, has a strong understanding of the system and can make good economic decisions. The Overview Type can be considered the opposite of the Green Type. This type tends to have no professional domain competences or any sociocultural competences yet sees economic sustainability as highly important. In regard to the competence framework, this means that this type has systemic competences with respect to the subdimensions of system understanding and process design.

The Protest Type seems uninterested in sustainable development. This type appeared as statistically functional on the basis of the factor analysis; however, with respect to the investigated factors, there were no significant figures that fit into the framework of C2P2S. It is striking that this type clearly protests against pro-environmental sustainability as well as sustainability competences. In the context of the C2P2S competence framework, this means that this type is opposed to systemic competences and professional domain competences. One can imagine that such Protest Types exist in every company and that they are exactly the ones who are in principle against any kind of constructive contribution but were forced to participate in this project from a higher level. Such persons represent challenges and opponents throughout the strategic development procedure. Furthermore, the Protest Type is a perfect sparring partner within training situations since such a non-sustainable type often forms an integral part of a development team.

The Lone Wolf Type shows no interest in contributing to society with sustainability impacts or a personal interest in sustainable development. His or her competence is a creativity competence,

which means, primarily, capabilities for creative problem-solving. This is the quiet type without big words. However, once the project goals have been set, he or she is the one who can think outside the box, because he or she possesses the extraordinary imagination to design solutions to problems in a way that results from non-conformist, creative thinking.

The Sunny Type has strong tendencies toward social relationships and collaboration with others and is characterized by reflection and self-responsible acting. The Sunny Type, similar to the Protest Type, is not explicitly mirrored in the competence framework; however, this type can be considered as having the most positive attitude and optimistic charisma. In a real-world problem-solving process, it could make sense for a team to have one of these types. Conceivably, this type of person could be doing well in solving problems of human nature together with the project manager. Through his or her way of looking at things positively, emerging conflicts can be quickly contained and, for example, types such as the Overview Type can be encouraged to cooperate constructively with incentives.

The survey described here was a first check for such reflections; however, it has analyzed only individual accesses to competences with respect to sustainable development and not the collaborative elements of competence portfolios of groups or teams. The selected five types represent one part of the sum and, taken together, result in a larger reality when people voice their opinions respectively and show their characters in decision-making. However, most teams comprising different characters and competences are lethargic and infecting when collaborating, as different competences are most commonly seen either as obstacles or even as personal attacks. Sustainable development per se is a highly complex phenomenon and requires solutions that are seen from different perspectives in order to solve serious problems. Where could individuals be better trained for this than at HEIs?

Since collective and cross-boundary forms of policy-making, decision-making, and problem-solving processes are becoming increasingly important for sustainable development progress, it is not necessary for a single individual to possess competences of the highest degree in each dimension. However, from a group perspective, all competences should be represented throughout different levels and represented by different persons. In terms of a transdisciplinary approach, such a team can be composed of industrial experts or other stakeholder groups from the society.

3.4. What Does This Mean for Higher Education Systems?

With respect to sustainability, Austrian universities are doing very well in 2020. However, to act sustainably also means to update and reflect on sustainable aims at frequent intervals to reach medium- and long-term aims such as the SDGs 2030 and climate protection goals by 2050. Therefore, we need people willing to compromise as well as to be assertive for a sustainable future and curricula that go into sustainable development teaching and training in depth, a university faculty willing to engage with sustainability goals and didactics, and last but not least, a system-wide university policy that encourages and enables creative strategies to ensure competences for future challenges.

As a good practice example, the Austrian UniNEtZ project (Universities and sustainable development goal) [29], which stands for the establishment of such developments, deserves mentioning. The project was officially initiated in January 2019 and has the following aims: (a) to provide a catalogue of consistent and integrated options for actions to the Austrian government on how the SDGs can be implemented in Austria; (b) to foster cross-university and interdisciplinary cooperation; (c) to integrate sustainability into research and teaching; (d) to interact with stakeholders from all fields of the society; and (e) to build capacity among researchers, teachers, and students regarding sustainable development. The project was prepared between 2017 and 2019. During this phase, mapping identified existing expertise on sustainability topics at those universities that were involved and helped to integrate different strengths and thematic focus fields into the project [30]. This mapping formed the basis for including a variety of disciplines. Collaboration and interdisciplinary work are essential parts of UniNEtZ. In order to develop options for action to implement the SDGs, artists exchange ideas with engineers on questions related to poverty; economists discuss the future of work with physicians and theologians; and lawyers develop ideas for a peaceful and just society.

4. Conclusions

Sustainable development means dealing with highly complex challenges on different system levels and in various environmental, social, economic, political, and cultural aspects. It should be evident that, within these collaborative problem-solving processes, the effects on societal, natural, and planetary health [31] will differ and call for a sufficient understanding of the complex system. It shows that system understanding is the prerequisite of resilience policies as well as of sustainable development [32,33]. What all involved elements on our planet have in common is a drive to survive. With respect to scientific findings including all dimensions of sustainability research, human society and nature at large are striving to survive in the long term. Agenda 2030 is currently a common agreement for a sustainable future for the next decade(s) and reduces the complexity of the sustainability dimension to make actions more accessible.

It seems that there is no stronger transformative power than education to promote human rights and dignity, to eliminate poverty, to combat the loss of biodiversity and climate change crises, to increase the resilience capacities of the coupled human–environment system, and, ultimately, to enhance one’s health and planetary health. All of this is based on values whose aspects are fundamental to our humanity: equality and social justice, respect for cultural diversity, shared responsibility, and international solidarity. That is why we need to rethink education in a changing world. For this, we need a dialogue across the board (see [14]).

Teaching and training skills for strengthening competences represents a major challenge for the tertiary education sector. Didactics and methodologies would have to be conceived, and more chairs would have to be created that could be dedicated to transdisciplinary theorizing and didactic implementation.

In sum, only the cooperation of disciplines and stakeholders will allow the solving of complex sustainability challenges. Higher research education institutions have the opportunity here to set a good example by increasing their efforts toward interdisciplinary, transdisciplinary research and responsible teaching and education. The project UniNEtZ is one example of how such cooperation can yield fruit and slowly start to break down the walls of disciplines.

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