Challenges in modelling and measuring sustainability competencies crucial to successful sustainability transitions

Ratinen Ilkka, Kashani Jubeen Sharbaf, Linnanen Lassi

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Ilkka Ratinen (corresponding author)
University of Lapland, Finland
Faculty of Education
P.O. Box 122, FI-96101
Rovaniemi, Finland
Email: ilkka.ratinen@ulapland.fi

Jubeen Sharbaf Kashani

Department of Sustainability Science,
LUT University, Mukkulankatu 19, 15210 Lahti, Finland;
Jubeen.Sharbaf@lut.fi

Lassi Linnanen

Department of Sustainability Science,
LUT University, Mukkulankatu 19, 15210 Lahti, Finland;
lassi.linnanen@lut.fi

Abstract

Current environmental risks, such as climate change and nature loss, force us to look for solutions in every sector of society. A successful sustainability transition requires the manipulation of deep systemic leverage points. Hence, a deep leverage point framework based on sustainability competencies is needed to conceptualise sustainability transitions. In this study, we present an approach to measuring citizens' sustainability competencies. The methods used to validate the measurement scales are exploratory and confirmatory factor analysis, while a structural equation modelling technique is applied to analyse the causal relationships proposed in the model. The fit indices did not indicate a good overall fit for this extended model. The results show that further efforts are needed to validate the measurement of sustainability competencies.

Keywords: sustainability competency, sustainability transition, measurement, structural equation modelling, SDG 4.7: quality education

Introduction

To foster sustainability transitions, we must ensure that climate change mitigation, nature conservation and other global societal goals are simultaneous concerted efforts. As sustainability initiatives require human involvement, it is essential for people to have the right mindset and competencies with regards to sustainability challenges. In this context, we define *sustainability competency* as a combination of skills, knowledge and attitudes that enable a particular task to be performed or a problem to be solved by fostering individuals' systems thinking, futures thinking, values thinking, strategic thinking, and collaboration competencies (Wiek et al., 2011; Wiek et al., 2016; Brundiers et al., 2021).

Alongside the continuous development of the field of sustainability, many sustainability competencies have been identified in recent times (Redman & Wiek, 2021). Meanwhile, the extant literature has identified several competencies as key sustainability competencies, which in this study were operationalised into five key competencies. *Systems thinking competency* enables the understanding of complex systems locally and globally across different sectors (i.e., the social, environmental and economic realms). This favours problem resolution by seizing opportunities and taking advantage of technologies in a holistic and interconnected manner (Wiek et al., 2011; Wiek et al., 2016; Redman & Wiek, 2021). Moreover, reducing consumption and a critical examination of economic growth are important goals in building a sustainable future (Costanza, 2023). *Futures thinking competency* helps to simultaneously analyse and evaluate the prospective impact that local and short-term decisions will have on the environment, society and the economy in the long term and on a global scale (Wiek et al., 2011; Wiek et al., 2016; Redman & Wiek, 2021). *Action-oriented competency* (or *implementation competency*) is "the ability to act, or to consciously implement interventions" using knowledge empowered by strategic thinking (Brundiers et al., 2021; Redman & Wiek, 2021). This competency is key to effectively designing sustainability transition strategies (Wiek et al., 2011; Wiek et al., 2016). *Values thinking competency* enables the design, reconciliation and application of sustainable values, principles and targets with internal and external stakeholders (Wiek et al., 2011; Wiek et al., 2016; Ploum et al., 2018; Redman & Wiek, 2021). *Collaboration competency* (or *inter-personal competency*) enables the conducting of collaborative and participatory sustainability research as well as problem solving (Wiek et al., 2011; Wiek et al., 2016). This competency includes all those skills that have an influence on interaction with other people and that promote teamwork and alliances, such as communication, leadership, negotiation and empathy (Redman & Wiek, 2021). The significance of sustainability competencies in promoting a sustainable future in Europe has been more recently highlighted by the development of GreenComp as a European sustainability competence framework (Bianchi et al., 2022).

In recent years, exploring the leverage points in a system has been introduced as a crucial approach to addressing sustainability challenges. In 1999, the late Donnella Meadows introduced 12 leverage points as "places in a system where relatively minor interventions can lead to relatively major changes in certain outcomes" (Fischer & Riechers 2019; Meadows 1999). Meadows differentiated between easy interventions with limited impact and interventions that are difficult to implement but have transformative impacts on the system (Fischer & Riechers 2019). Later, Abson et al. (2017) labelled these interventions as shallow and deep, and sorted them into four realms, in which altering a system's *parameters* (using for example taxes, subsidies, material stocks and flows) or its *feedbacks* (such as system delays, and negative or positive feedbacks) are considered shallower leverage points with limited systemic impact, whereas changing a system's *design* (such as its rules and access to information within it) and its *intent* (such as its goals and the mindset that creates it) are considered deeper leverage points with higher systemic impact. In this paper, we argue that due to their foundational role in sustainability transition on different levels, sustainability competencies can be viewed as deep leverage points.

Sustainability competency can support people in gaining systemic and critical thinking skills, which can be measured using a questionnaire (Bianchi et al. 2022). For example, leaders' sustainability competency in the tourism sector (action-oriented, system, interpersonal and normative) positively affect their social entrepreneurial orientation and green innovation performance (Álvarez-García et al., 2022). A multidimensional framework challenges the measurement of sustainability competencies. Therefore, by developing relevant tools for measuring sustainability competencies, we can obtain a better understanding of how we can support people's action-oriented competency to foster agency in sustainability transition (Fischer & Newig, 2016). In recent years, various instruments have been developed to measure sustainability competencies (Waltner et al., 2019) and teachers' competence in education for sustainable development (Malandrakis et al., 2019).

In this study, the five sustainability competencies described above were operationalised in a large-scale survey, as previous studies have not demonstrated how sustainability competencies can be applied to a large-scale population survey. This study explores the importance of citizens' ideas about sustainability competencies in the context of climate change and nature loss. Following the recommendations of Redman et al. (2018), this study focuses on action-oriented competency, while systems thinking, futures thinking, values thinking, and collaboration competencies are operationalised into a questionnaire.

The exploration of action-oriented competency is central to understanding how individuals engage proactively in addressing complex challenges, particularly in the realm of environmental sustainability. This study aims to accomplish two main objectives: first, to construct a measurement model, and second, to explore the dimensions of sustainability competencies. These objectives will be achieved through the testing of a structural equation model to assess the functionality of the constructed model. Brundiers et al. (2021) propose that competencies in systems thinking, futures thinking, values thinking, and collaboration collectively contribute to the problem-solving process, leading to action-oriented competency, specifically in implementing actions. Salgado et al. (2018) highlight proficiency in political strategy, goal-oriented action, ethical communication, complexity management, and stakeholder collaboration as essential for implementing sustainable interventions. These competencies form a foundational framework, equipping individuals with the ability to comprehend interconnected systems, envision future possibilities, align actions with personal and societal values, and collaborate effectively. Ferreras-Garcia et al. (2021) and Remington-Doucette and Musgrove (2015) contribute to the understanding that women tend to exhibit higher levels of action-oriented competency compared to men. This gender-based disparity prompts an exploration into the underlying factors shaping women's proactive engagement in environmental issues. Remington-Doucette and Musgrove (2015) highlight a positive correlation between educational attainment and action-oriented competency. This prompts an investigation into how higher levels of education equip individuals with the knowledge and skills necessary for informed decision-making and proactive involvement in sustainable practices. The European Social Survey (2018) suggests that action-oriented competency is higher in younger individuals compared to their older counterparts. This observation sparks an inquiry into the generational differences that contribute to varying attitudes and behaviours toward environmental challenges. Olsson and Gericke (2016) found that students' sustainability consciousness dips in adolescence which means that the relationship between age, sustainability consciousness and action-oriented competency (Redman & Wiek, 2021) needs to be critically examined. Kollmuss and Agyeman (2002) propose a positive correlation between knowledge of climate change and nature loss and pro-environmental behaviour. This underscores the role of knowledge in enhancing action-oriented competency, emphasizing the importance of an informed citizenry. Vasiljevic-Shikaleska et al. (2018) suggest a positive correlation between environmental awareness and pro-environmental behaviour, particularly reflected in a smaller carbon footprint. Mikuła et al. (2021) and Poortinga et al. (2004) posit that on the national level, environmentally friendly behaviour is positively correlated with income. This means that when a country is prosperous enough, environmental measures can be financed and thus emissions reduced. However, it is very complicated, because wealth also allows for consumption and therefore higher emissions, because, as Huang et al. (2024) found, there is a direct correlation between household income and carbon footprint.

Our hypothesis posits that relying solely on the sustainability expertise of specialists may prove insufficient; a comprehensive approach involving the collective engagement of all individuals is imperative to effectively address the challenges posed by sustainability. This discussion is framed by a series of hypotheses that draw on diverse studies, each shedding light on distinct facets of the factors influencing action-oriented competency (Table 1).

Table 1. Hypotheses

H1	(a) Systems thinking competency, (b) futures thinking competency, (c) values thinking competency, and (d) collaboration competency can foster action-oriented competency.
H2	Women's action-oriented competency is higher than that of men's.
H3	Action-oriented competency is higher in more educated people.
H4	Younger people's action-oriented competency is higher than that of older people.
H5	Knowledge of climate change and nature loss increases action-oriented competency.
H6	A lower carbon footprint increases action-oriented competency.
H7	Higher spending is linked to the level of action-oriented competency.

In essence, these hypotheses collectively contribute to a nuanced understanding of the multifaceted nature of action-oriented competency. The aim of the study is to test the sustainability competency model and the examination of the effect of demographics (age, education, carbon footprint, spending) on action-oriented competency by examining the interplay of competencies, gender dynamics, educational backgrounds, age-related trends, environmental awareness, and economic factors.

Material and Methods

This study is part of a long-term research project that aims to increase the knowledge of Finns' sustainability competencies for the sustainability transition of Finnish society (Ratinen and Linnanen 2022a; 2022b; Ratinen et al. 2023). The present study focuses on the challenges of measuring sustainability competencies. The sample consisted of 2,006 Finns living in Finland, except for Åland, which is a Swedish-speaking autonomous region in Finland. The survey was conducted in September 2021 exclusively in Finnish; therefore, Åland was excluded. Data collection was carried out by Feedback Group using a web survey tool. Feedback Group is a research agency which collects information for research purposes. Web consumer research panels of the Cint Panel Exchange (CPX) network were used to define quotas and acquire participants. CPX is one of the world's largest consumer networks for digital survey-based research. Participants were selected from several different research panels, thus preventing a possible panel-specific structural skew. Demographic panels were used in this study. These panels consist of people who share similar demographic characteristics such as age, gender, education level, occupation. Participants were recruited to various web panels using a registration form that asked participants about their background information. Based on their backgrounds, participants could be queried and quota-selected. Upon registration, the participants also agreed that research invitations could be sent to their email addresses. Thus, at the beginning of study, consent to participate in the study was no longer specifically requested, as the participants had already given their consent. All participants were aware of the objective of the survey, which was stated in the questionnaire. Overall, the study and its data collection followed the guidelines of The Finnish National Board on Research Integrity TENK and no separate ethics committee opinion was required. At the sampling stage, participants were determined based on the demographic structure of Finland (Table 2). Email invitations to the survey were sent to all participants who participated in the target group selection. During data collection, additional invitations and reminders were sent to those who had not responded. The average age of the participants was 47.8 years, and the sample was composed of 52.1% women, 47.5% men, and nine respondents (0.4%) who did not want to state their gender. There were no missing data for items measuring sustainability competencies because answering the questionnaire required an expression of opinion for each question. Some participants did not want to express their age (2) or education (24), (Table 2).

Table 2. Respondents' background

Gender	Frequency	Data sample (%)	Finnish population[1] (%)
Female	1,045	52.1	50.6
Male	952	47.5	49.4
No answer	9	.4	-
Age			
16–24	156	7.8	9.9
25–34	342	17.0	12.8
35–44	390	19.4	12.9
45–54	311	15.5	12.1
55–65	431	21.5	13.2
65–	374	18.6	22.3
No answer	2	.1	-
Education			
Basic school	150	7.5	17.1
Vocational school	471	23.5	33.5*
High school	228	11.4	
College	366	18.2	7.6
University of applied science	311	15.5	10.3**
University, bachelor	151	7.5	
University, master	305	15.2	8.7
No answer	24	1.2	-

[1] Statistics Finland 2021; * Secondary education: vocational school and high school and **Higher education bachelor level: university of applied science and university combined.

Data Analysis

Exploratory (EFA) and confirmatory factor analysis (CFA) were used for testing hypotheses and validating measurement scales, while analysing the causal relationships proposed in the model was done through a structural equation modelling technique. Principal components and factors with eigenvalues greater than 1 were accepted, indicating that they explain more variance than individual variables (Matsunaga, 2010). Principal components and factors with higher factor loadings above .4 were considered meaningful and retained (Matsunaga, 2010).

Two scales, one for the understanding of climate change and nature loss, and another one for sustainability competencies were used in the present study. Both scales were used in the structural equation model because previous studies (Ratinen & Linnanen, 2022b) indicated the need to conduct a more thorough investigation of the factors influencing the action-competency model. To measure Finns' understanding of climate change and nature loss, participants were questioned about climate change and biodiversity issues. Each response could be rated on a five-point Likert scale: *strongly disagree* = 1, *disagree* = 2, *no disagreement or agreement* = 3, *agree* = 4, or *strongly agree* = 5. Principal component analysis (PCA) was conducted by

SPSS to calculate the principal scores using a regression method. PCA were chosen because it summaries the information from a given set of variables and reduces it into a fewer number of components (Fabrigar et al., 1999). The principal scores were used for a structural equation modelling technique while retaining important information to extract maximum variance from the data with the component (Metsämuuronen, 2017). The Kaiser–Meyer–Olkin (KMO) value was .861, indicated the sampling was adequate (Schreiber, 2021). A varimax rotation method was chosen. Finally, two scales were created: understanding (α = .79) and misunderstanding (α = .76). Only the understanding was used for the structural equation modelling technique (SEM) model, because of the simplified SEM model, only the impact of scientifically correct understanding on action-oriented competency was examined (Ratinen & Linnanen, 2022b). The principal component solution accounted for 43.1% of the total variance (Table 3).

Table 3. Finnish people's understanding of climate change and nature loss (*N*= 2006). Understanding means the first principal component loadings

	Understanding
Burning fossil fuels releases carbon dioxide into the atmosphere, which binds heat and causes climate change.	.714
The main reason for the decline in biodiversity is that we do not recognise well enough the environmental impact of product production chains (manufacturing–distribution–disposal).	.671
Climate change is caused by greenhouse gases such as carbon dioxide, which increase the amount of methane and nitrous oxide in the atmosphere.	.664
The loss of biodiversity is the result of humanity's current exploitation of nature, which causes habitat loss.	.650
The increase in palm oil consumption has reduced biodiversity.	.635
Scientists are sure that people are definitely the cause of the current rapid climate change.	.611
Eigenvalue	*3.874*
Exp. of total variance (%)	43.1

Note: Only the first principal component is presented.

To assess the sustainability competencies of individual Finns, participants were requested to evaluate their competency using indicators. These indicators were constructed based on the assessment of five key sustainability competencies (Table 4). The questions used to analyse the sustainability competencies can be labelled as a competence self-report. The design principles of Braun et al. (2012) were considered in the questionnaire: multiple indicators per competency were used to address a competency's full complexity, context was given for the competencies and instruments, and the indicators described concrete behaviour. The rationale underlying the formulation of the statements was to pinpoint robust indicators indicative of the sustainability competencies related climate change mitigation and nature loss prevention. The questionnaire is an original attempt to produce a coherent measure, and there are no comparable measures to be found in the literature. Therefore, two external sustainability education experts participated in the evaluation of the selected items. The complete questionnaire can be acquired by sending a request to the corresponding author. Given the substantial length of the questionnaire, it omitted reversible statements that might otherwise introduce variability in response difficulty. Each response was rated on a five-point Likert scale: 1 = *strongly disagree*, 2 = *disagree*, 3 = *neither agree nor disagree*, 4 = *agree* or 5 = *strongly agree*.

To measure Finns' individual estimations of their personal annual carbon footprint (participants' average selected range = 9500–12499 kg CO_2ekv), the respondents chose the option that best described them (Ratinen et al., 2023). To gauge Finns' personal estimates of their monthly spending in euros, the respondents indicated how much they spend per month in euros (participants' average selected range = 500–1499 €/month). We did not control for participants' income level because we were interested in spending not income levels.

Piloting and scale construction

In the first phase of the model construction, the questionnaire was piloted ($N = 300$; 75 items). Based on the PCA, 20 items were removed due to the skewness of the distribution (graphical evaluation) and because after the removal of variables ($\alpha < .7$) the principal component structure fit the theoretical model of the five competencies (Cho & Kim, 2015). Finally, 55 items included to the second phase (Table 4) and explorative factor analysis by SPSS (EFA) was used to extract a coherent factor structure from the questionnaire data (Table 5). Kaiser–Meyer–Olkin (KMO) values and Bartlett's test values were calculated for all competencies, (Schreiber, 2021), (Table 4). Factor loadings based on principal axis factoring and varimax rotation with Kaiser normalisation were chosen. For three variables, the communality (h^2) was below .3 (Table 4).

Table 4. The Kaiser–Meyer–Olkin (KMO) values of competencies.

Sustainability competencies	KMO	Bartlett's test	No. of items
Systems thinking competency (SYS)	.941	(df45) = 9,998; $p < .000$	10
Futures thinking competency (FUT)	.847	(df36) = 6,664; $p < .000$	9
Values thinking competency (VAL)	.905	(df55) = 8,947; $p < .000$	11
Action oriented competency (ACT)	.908	(df136) = 13,449; $p < .000$	17
Collaboration competency (COL)	.913	(df28) = 7,798; $p < .000$	8
Total			55

Table 5. Reliability, means, standard deviations, standardised factor loadings and commonalities of exploratory factor analysis for the sustainability competency items (N = 2006)

	Item			Exploratory factor analysis	
		M	***SD***	**Loading**	h^2
	Fac1: Systems thinking competency, SYS α = .91; Spearman-Brown = .90.				
S1	I can outline the big picture of climate change and find solutions to it in my everyday life and lifestyle.*	3.42	.909	.775	.563
S2	I can help solve the climate crisis in terms of reducing the environmental impact of my lifestyle, such as my own consumption.*	3.56	.882	.743	.541
S3	I recognise which climate measures will significantly reduce my own carbon footprint in terms of Finland's carbon neutrality goal.*	3.31	.965	.741	.531
S4	I can take ecological, cultural and economic considerations into account when dealing with natural disasters.*	3.20	.929	.736	.519
S5	I can look at the connections of the products I buy to the world economy.*	3.25	.947	.709	.477
S6	I can reduce my own environmental impact by starting with the most effective reduction measures.*	3.43	.925	.694	.474
S7	I like to help solve environmental issues based on the overall picture they form.*	3.01	1.001	.695	.458
S8	I can identify the industries with the most urgently required and effective means to tackle climate change.*	3.27	.980	.699	.460
S9	I can arrange different systems (transport, housing, eating) in order of magnitude in terms of their environmental impact.*	3.30	.932	.676	.431
S10	I recognise how different forestry activities in Finland affect biodiversity.*	3.26	.973	.665	.455
	Futures thinking competency, FUT				
	Fac2: Structural skills α = .81; Spearman-Brown = .84				
F1	I believe that in the future, diets must be changed globally to avoid a serious sustainability crisis.*	3.47	1.064	.748	.488
F2	I am ready to vote for decision makers who want to promote solutions that support sustainable living.*	3.43	1.101	.719	.447
F3	I believe that the climate and sustainability crisis will be resolved in the near future through significant changes in housing, eating and traveling.*	3.20	1.032	.665	.411
F4	I believe that material consumption will have to be restricted in the future by legal means.*	3.36	1.015	.682	.415
F5	I trust that the climate and sustainability crisis will be largely solvable in the future if we can change linear economic thinking (raw material -> waste) to circular economy thinking.*	3.42	.920	.442	.264
	Fac3: Dynamic skills α = .83; Spearman-Brown = .84				
F6	I can interpret different climate scenarios, and I know the most effective climate measures.	2.96	.980	.818	.516
F7	I can evaluate how different climate measures will affect the future of the Finnish climate system.	3.04	.946	.748	.506
F8	I can evaluate how current global land use will accelerate nature loss in the future.	3.13	.950	.640	.410
F9	I can imagine what global food production that sustains biodiversity looks like.	3.06	.952	.633	.436
	Values thinking competency, VAL				
	Fac4: Relevance α = .82; Spearman-Brown = .85				
V1	I can also assess climate and sustainability issues in terms of social justice.*	3.31	.920	.753	.529
V2	I recognise and know how to equally solve issues related to climate change mitigation.*	3.07	.897	.704	.457
V3	If necessary, I would critically examine Finland's carbon footprint and relate my own climate impact to other Finns' greenhouse gas emissions.*	3.29	.968	.662	.490
V4	I can critique present perspectives on material economic growth.*	3.08	.999	.636	.365
V5	I can credibly justify how economic growth thinking like we have today needs to be radically transformed into a solution to the sustainability crisis.*	3.06	1.007	.609	.438
V6	I raise even the difficult issues and problems of climate change.*	3.39	.974	.599	.406
V7	I can take part in building an environmentally friendly society.*	3.41	.910	.568	.420

	Fac5: Responsibility α = .80, Spearman-Brown = .80				
V8	I feel that we Finns have a moral responsibility to reduce our own consumption to solve the sustainability crisis.	3.37	1.143	.814	.551
V9	I feel that Finns have a responsibility to preserve biodiversity.	3.77	1.004	.796	.535
V10	I think it would be fair to pay higher taxes on environmentally harmful activities.	3.57	1.101	.633	.393
V11	I understand that technological innovation alone will make it impossible to solve the sustainability crisis in the long run.	3.50	.991	.436	.249
	Action-oriented competency, ACT				
	Fac6: Society α = .82, Spearman-Brown = .80				
A1	I am prepared to pay more in environmental taxes in the future.	2.50	1.239	.687	.555
A2	I am prepared to reduce my own salary if I know for sure that the money saved will be used to repair the damage that we have caused to nature.	2.31	1.180	.660	.502
A3	I have taken part in climate demonstrations.	1.68	1.069	.639	.366
A4	I have donated money to protect the environment.	2.50	1.341	.575	.386
A5	I have voted for an environmental candidate in previous parliamentary elections.	2.89	1.325	.483	.435
	Fac7: Individual α = .81; Spearman-Brown = .83				
A6	I have increased the proportion of vegetarian food in my diet. *	3.26	1.278	.671	.605
A7	I have reduced the use of meat products.*	2.95	1.373	.641	.646
A8	I have reduced my own consumption to reduce the risk of a sustainability crisis. *	3.16	1.153	.638	.502
A9	I sort and recycle all my waste. *	3.91	1.066	.476	.208
A10	I am ready to move into a smaller apartment.	2.54	1.216	.464	.287
A11	I have reduced the use of dairy products. *	2.75	1.337	.464	.463
A12	I am not flying, or I am ready to reduce my air travel to at least half of my current status.	3.55	1.319	.438	.240
A13	I will get an electric car as soon as their operating distance is over 500 km.	2.53	1.208	.432	.227
A14	I have lowered the temperature in my apartment. *	3.15	1.208	.417	.277
	Fac8: No car α = .79, Spearman-Brown = .84				
A15	I do not use/own a car anymore.	2.41	1.481	.808	.529
A16	I have replaced almost all commutes by car with public transport.	2.61	1.419	.773	.564
A17	I walk or cycle almost all trips less than 3 km. *	3.35	1.400	.522	.347
	Fac9: Collaboration competency, COL α = .89; Spearman-Brown = .86;				
C1	I can look at and solve the problems of climate change mitigation and adaptation easily with other people.*	3.28	.882	.808	.600
C2	I recognise the seriousness of nature loss and my ability to discuss its solutions proactively and constructively.*	3.39	.928	.781	.556
C3	I can guide the discussion on climate change mitigation and adaptation to core issues related to consumption and use of natural resources.*	3.21	.920	.780	.568
C4	I can participate constructively and be solution-oriented in the social climate debate.*	3.40	.907	.764	.563
C5	I can think with others about the effects of human activities on nature loss.*	3.52	.896	.752	.513
C6	I can justify on a scientific basis which industries have a key role to play in resolving the climate and sustainability crisis.	3.03	1.010	.660	.439
C7	I can motivate other people to reduce their consumption of materials and energy to achieve significant environmental goals.	3.05	.983	.638	.384
C8	I can listen to and respect the opinions and values of others about climate change. *	3.73	.840	.494	.299

*Variables used in CFA and SEM modelling

Scales and subscales were created through EFA for the originally developed items, in collaboration with experts (as discussed earlier). Systems thinking competency consisted of 10 items and explained 55.8% of the total variance; its factor loadings ranged from .665 to .775, and the mean inter-item correlation was .68. The item with the highest mean for this factor (M = 3.56, SD = .882) was "I can help solve the climate crisis in terms of reducing the environmental impact of my lifestyle, such as my own consumption."

Futures thinking competency was formed by two factors: structural skills and dynamic skills. *Structural skills* consisted of five items and explained 37.7% of the variance. The factor loadings ranged from .442 to .748, and the mean inter-item correlation was .59. The strongest loading item for this factor was "I believe that in the future, diets must be changed globally to avoid a serious sustainability crisis" (M = 3.47, SD = 1.064). *Dynamic skills* consisted of five items and explained 13.6% of the variance. The factor loadings ranged from .633 to .818, and the mean inter-item correlation was .66. The item with the highest mean for this factor (M = 3.13; SD = .950) was "I can evaluate how current global land use will accelerate nature loss in the future."

Values thinking competency included two factors: relevance and responsibility. *Relevance* consisted of seven items, and loadings ranged from .568 to .753, with a mean inter-item correlation of .64. This factor explained 40.8% of the variance, and the item with the highest mean for this factor (M = 3.41; SD = .910) was "I can take part in building an environmentally friendly society." *Responsibility* included four items and explained 9.5% of the variance. The factor loading ranged from .436 to .814, and the mean inter-item correlation was .61. The item with the highest mean for this factor (M = 3.77; SD = 1.004) was "I feel that Finns have a responsibility to preserve biodiversity."

Action-oriented competency consisted of three factors: Society, Individual and No car. *Society* included five items. Its factor loading ranged from .483 to .687, and the mean inter-item correlation was .60. This factor explained 34.4% of the variance, and the item with the highest mean for this factor (M = 2.89; SD = 1.325) was "I have voted for an environmental candidate in the last parliamentary elections." *Individual* consisted of nine items, and it explained 6.3% of the variance. The factor loadings ranged from .417 to .808, with a mean inter-item correlation of .52. The item with the highest mean for this factor (M = 3.91; SD = 1.066) was "I sort and recycle all my waste." *No car* consisted of three items. The factor loading ranged from .522 to 808, and the mean inter-item correlation was .64. This factor explained 4.8% of the total variance. The item with the highest mean for this factor (M = 3.35; SD = 1.400) was "I walk or cycle almost all trips less than 3 km."

Collaboration competency consisted of eight items. The factor loadings ranged from .494 to .808, and the mean inter-item correlation was .67. This factor explained 57.1% of the total variance. The item with the highest mean (*M* = 3.73; *SD* = .840) for this factor was “I can listen to and respect the opinions and values of others about climate change.”

Model validation

In the third phase, model validation, a measurement model was constructed by confirmatory maximum likelihood factor analysis constructed by AMOS (CFA), (Figure 1). Maximum Likelihood (ML) was used estimate model parameters and assess model fit (Mindrilă, 2010). As suggested in an SEM study by Hooper et al. (2008), multiple fit statistics were used in this study to assess the degree to which the data fit the model: the ratio of chi-square to degrees of freedom (χ^2/df), the root mean square error of approximation (RMSEA), the comparative fit index (CFI), and the normed-fit index (NFI). A χ^2/df ratio in the range of 2–5 is viewed as indicating acceptable fit (Kline, 2005; Schumacher & Lomax, 2004, p. 82). Also accepted as indications of goodness of fit were RMSEA, CFI and NFI values of close to .06, .08 and .95 or higher, respectively (Bentler & Bonett, 1980; Hu & Bentler, 1999). This study sought to construct the best possible theoretical model to explain the effects of systems thinking, futures thinking, values thinking and collaboration competencies on action-oriented competency.

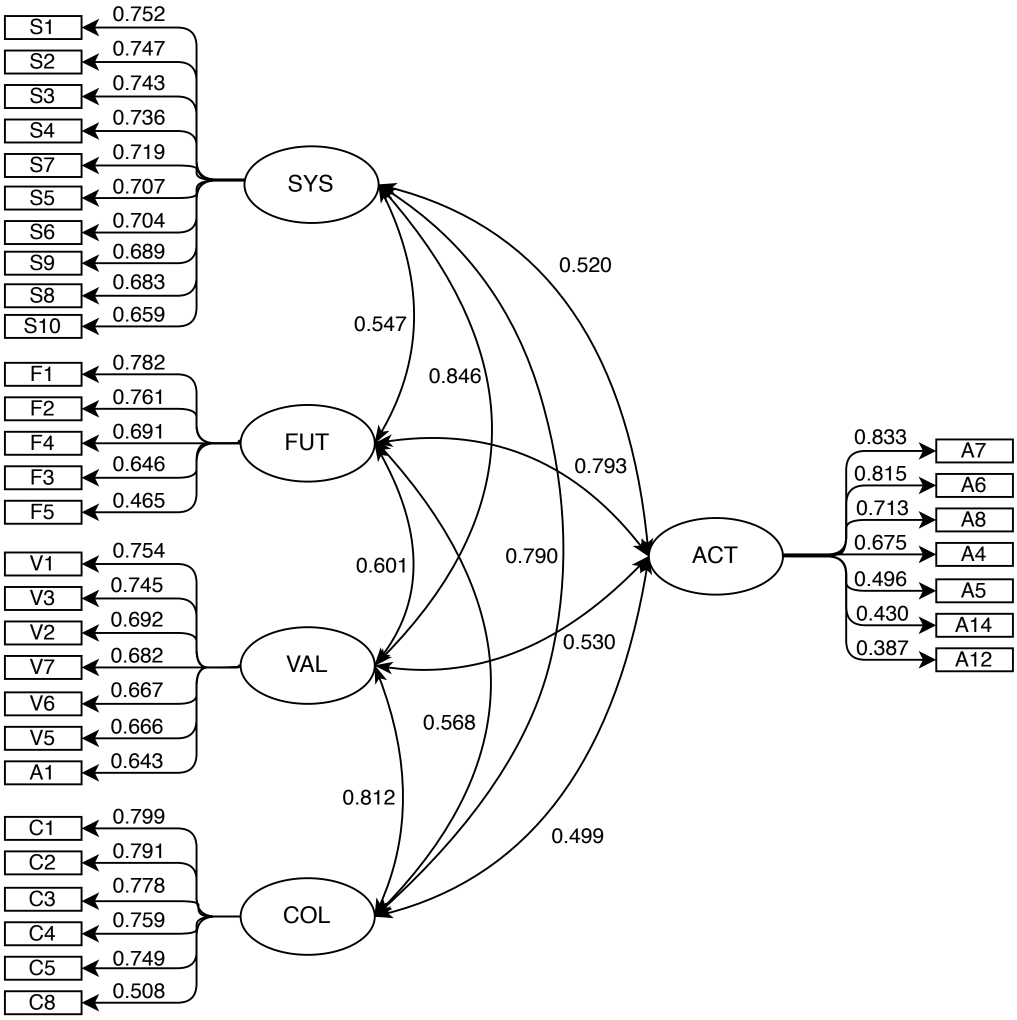


Figure 1. The best fitted measurement model validation based on confirmatory factor analysis (χ^2 = 3,836,363, p < .000, χ^2/df = 6.7, RMSEA = .055, CFI = .91, and NFI = .90)

The first measurement model included all items (Table 5), but the data did not fit the model (χ^2 = 20,306,381; p < .000; χ^2/df = 10.8; RMSEA = .070; CFI = .71). Therefore, also the three-factor model (after removing systems thinking and collaboration competencies) tested and resulted in a poorer fit (χ^2 = 1,401, p < .000; χ^2/df = 9.4; RMSEA = .065; CFI = .92; NFI = .91), indicating that it did not fit well into the conceptual model. The best five-factor model fit indices were χ^2 = 3,836,363, p < .000, χ^2/df = 6.7, RMSEA = .055, CFI = .91, and NFI = .90 (Figure 1). The results showed that the measurement model fit the data. Furthermore, the results showed that for the robustness measure, the correlations between competencies were carefully considered (r < .85; p < .01). Furthermore, average variance extracted (AVE) and composite reliability (CR) values were calculated for the best five-factor model by Excel's stat tool packages (Table 6). AVE measures the level of variance captured by a construct versus the level due to measurement error, and values above .7 are considered very good, whereas the level of .5 is considered acceptable (Fornell & Larcker, 1981). The convergent validity of the measurement model revealed that all the items that did not measure the same construct were consistent with each other (Table 6). CR is a less biased estimate of reliability than Cronbach's Alpha, and the acceptable value of CR is .7 and above (Raykov, 1997). All CR values of the measurement model were acceptable.

Table 6. Reliability and convergent and discriminant validity of the measures (Bolded numbers are the square root of the AVE values, the Fornell–Larcker criterion (.73, .71, .69, .64 and .69)

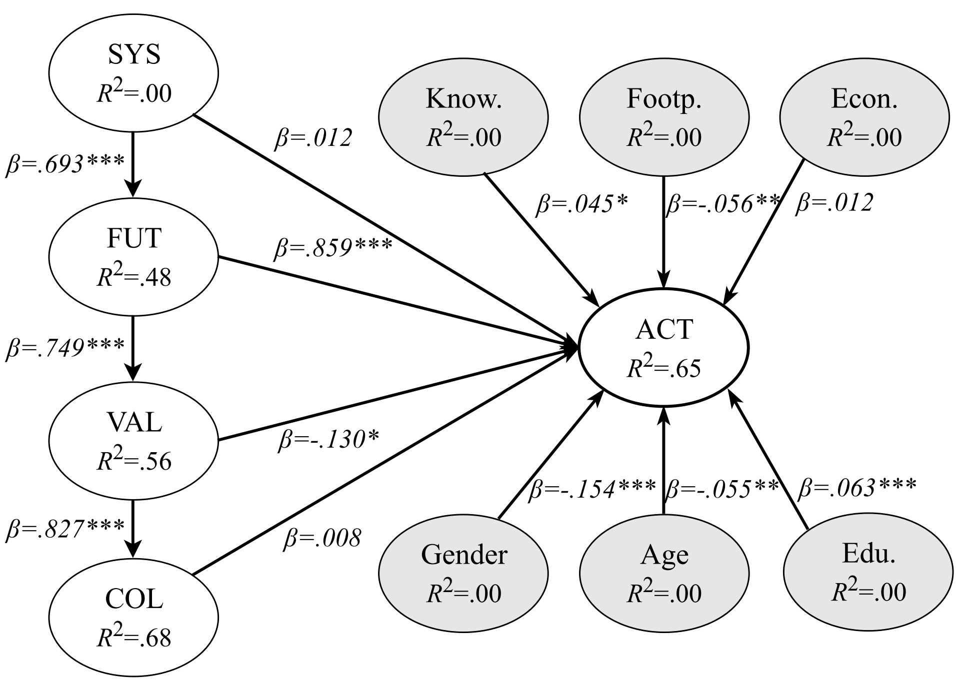
	CR	AVE	No. of items	COL	SYS	VAL	ACT	FUT
COL	.88	.54	6	**.73**				
SYS	.90	.50	10	.79***	**.71**			
VAL	.87	.48	7	.81***	.85***	**.69**		
ACT	.82	.42	7	.50***	.52***	.53***	**.64**	
FUT	.81	.46	5	.57***	.55***	.60***	.79***	**.69**

Significance: *** <.001

Discriminant validity checks of different competencies in the model are distinct from each other. It was tested by comparing correlations between these concepts. They are expected to correlate somewhat, but no more than .85. The Fornell–Larcker criterion evaluates if the square root of the AVE of a concept (.73, .71, .69, .64 and .69) is larger than its correlation with other concepts in the model. As can be seen in Table 6, the variables are not all discriminating between the factors. Attempts were made to improve the model by setting some variables to freely correlate with each other, but this did not substantially improve the fit of the model to the data.

Structural equation modelling

As the measurement model fit the data, SEM was used to test how the theoretical model with control variables fits the actual data (Figure 2). The fit indices indicated an incomplete fit for this extended model (χ^2 = 6,753,986, p < .000; χ^2/df = 8.7; RMSEA = .064; CFI = .84; NFI = .83). Removing any of the control variables did not improve the fit indices.



Significance: *** <.001; ** <.01; *<.05

Figure 2. Action-oriented competency's structural equation model (χ^2 = 6,753,986, p < .000; χ^2/df = 8.7; RMSEA = .064; CFI = .84; NFI = .83)

The chi-square statistic and associated p-value suggest poor model fit. The RMSEA value (.064) is slightly higher than desired, indicating reasonable but not excellent fit. Both the CFI (.84) and NFI (.83) are below the desired threshold, suggesting less than satisfactory fit. Bloum et al. (2018) found that all fit indices are challenging to achieve but CFA confirmed the convergent, discriminant, and construct validity as they merged more variables to action-competency. This approach was tested in this study, but the model did not construct. Because RMSEA = .064 is an acceptable fit value, some cautious interpretations of the model can be done (Table 7). As the fit indices are not ideal, the model is justified by its theoretical basis, practical significance, and opportunities for improvement in the future. From a theoretical development perspective, this is the first measure of sustainability competencies based on a large-scale citizen survey. In practice, the results of the present model could impact practical societal significance and the critical perspective of measuring sustainability competencies with critical deep leverage self-reported statements. Some modifications for the measurements are suggested in the discussion based on discriminant validity analysis.

All standardised statistically significant path coefficient estimates (β) were in the expected ranges, but VAL to ACT indicated that the more critical the respondents were, the less they said they would take sustainability action (β = -.130, Figure 2). The respondents' answers for issues such as social justice and criticism of material economic growth varied significantly (high standard deviations), which might have affected the results (total effects = -.123).

Futures thinking competency and, more specifically, structural skills clearly affect action-oriented competency (β = .859; Figure 2, Table 7). Structural skills refer to learners' abilities to recognise temporal, logical and causal relationships and to build systemic views (Levrini et al., 2021). The squared multiple correlation (SMC) values, or R^2, indicated that none of the control variables or competencies influenced action-oriented sustainability (Table 7). Specifically, the result that systems thinking competency does not affect action-oriented competency is inconsistent with previous research (e.g., Webster, 2019). This result may indicate that the respondents did not consider the statements in the questionnaire to be sufficiently systemic changes. However, equipping the model with sustainability variables that are more broadly relevant to society did not produce a robust structural equation model.

Table 7. Hypothesis testing results

Constructs	**Hypotheses**	**Path coefficient estimates (β)**	**Squared multiple correlation (R^2)**
(a) Systems thinking competency, (b) futures thinking competency, (c) values thinking competency, and (d) collaboration competency can foster action-oriented competency.	a: H1 not corroborated b: H1 corroborated c: H1 not corroborated d: H1 not corroborated	.012 .859*** -.130* .008	.00 .48 .56 .68
Women's action-oriented competency is higher than that of men's.	H2 corroborated	-.154***	.00
Action-oriented competency is higher in more educated people.	H3 corroborated	.063***	.00
Younger people's action-oriented competency is higher than that of older people.	H4 corroborated	-.055**	.00
Knowledge of climate change and nature loss increases action-oriented competency.	H5 corroborated	.045*	.00
A lower carbon footprint increases action-oriented competency.	H6 corroborated	-.056**	.00
Higher spending is linked to the level of action-oriented competency.	H7 not corroborated	.012	.00

Significance: *** <.001; ** <.01; *<.05

Discussion

The validity and reliability of the measures were found to be good (α > .80 – .90). The tested model was based on previous literature, and hypotheses were formulated accordingly (Table 7). However, discriminant validity of the sustainability competency model indicates several limitations (Table 6). As Ploum (2018) points out, action competence has received increased attention, but the measurements based on the present study need more discriminating perspectives between variables, at least when the aim is to produce deep leverage variables. It means that a measurement should be able to differentiate between different sustainability competencies and not confuse them with each other. For example, if two sustainability competency measures are used to assess different attributes, they should yield different results to demonstrate that they are truly measuring different things and are not just different forms of the same phenomenon. As the definition of sustainability competencies has become increasingly broad (Brundiers et al. 2021; Bianchi et al. 2022), the development of a valid competency measure is demanding. This study shows that the measurement model works, but the structural equation model is incomplete due to likely discriminant validity deficiencies. In the future, particular attention should be paid to the measurement of action-oriented competency, as in this study h^2 values were often underestimated for this variable (Table 5). To measure deep leverage action-oriented competency, the wording of the variables to be included in the measure needs to be improved. The questionnaire of the present study was presented to experts in the field of sustainability education for feedback and piloted to ensure the accuracy and appropriateness of item wording for the intended population. After piloting, 20 claims that did not fit the model were removed. However, the result showed that it is difficult to assess one's self-perceived sustainability competency. The questions used in this study to analyse the sustainability competencies labelled as a competency self-report. This must be considered when assessing the results. Sass et al. (2021) found a method to rephrase items in order to better align them with the answer scale options representing different degrees of (dis)agreement. This rephrasing method would be useful for measuring participants' self-perceived sustainability competencies. The demographics of the sample followed the Finnish population quite well. In terms of education, the sample had fewer primary school students compared to the general population. However, it is difficult to assess how this affected the results.

The SEM model's fit to the data is supported by its theoretical basis and the significance of the direct and indirect paths included within it. The following interpretations of the hypothesis can be utilised to construct a new indicator, namely six of the hypotheses were supported by the data. Therefore, the model should not be summarily interpreted as inappropriate for the data; rather, it can be considered an *approximate* model.

The results of H1 are interesting, as they show that among major sustainability competencies only futures thinking can lead to action-oriented competency. Nervousness and anxiety about the future has been continuously growing globally. Online searches of the terms 'climate anxiety' and 'eco-anxiety' have risen substantially in 2023, with the Nordics and Finland being on top of the list (Gilder, 2023), and we are only beginning to explore the psychological impacts of eco-anxiety (Pihkala, 2020; Brophy et al., 2022). Ojala (see e.g. 2023) has emphasized the importance of hope to avoid climate anxiety, which is important for futures thinking competency.

Interaction between futures and action-oriented competency has implications in different fields. In the educational sector, it is crucial that these two are presented together so that raising awareness in students about the harsh realities of climate change and biodiversity loss would leads to action instead of paralysis and despair. The results of this paper also show that if instigating climate action is the purpose, more focus needs to be given to futures competency compared to other competencies such as systems thinking competency or values thinking competency. The interaction between futures thinking and action-oriented competencies needs to be examined further in other settings.

In H2, it was corroborated that women's action competency is higher than that of men's, which may be explained by other factors. Recent surveys in Finland show that 38% of women and 26% of men are very or extremely concerned about climate change, while the same parameter is 46% among women of age 20-39 (Healthy Finland Survey, 2023). Consequently, it can be assumed that for successful implementation of sustainability actions special focus needs to be given to women, both in designing and implementing sustainability solutions.

Corroboration of H3 confirms that higher level education leads to higher action-oriented competency. While historically the share of population with an upper-secondary or tertiary level of education has risen in Finland since 1970's (Tuononen, 2007), the number of university students since 2001 has been relatively constant with a small rise since 2019 (Hämäläinen, 2023). With the relative saturation of students in higher education, one might want to focus on expanding the general sustainability education in all fields to increase sustainability awareness and subsequently, action-oriented competency. Another angle of inquiry can be the role of informal education in educating the public, which should increase action-orientation competency on the societal level.

H4 which states that action-oriented competency is higher in younger people compared to older people is unsurprisingly corroborated. Same as in Europe, demographic trends in Finland indicate an aging population, with the 70–79-year-old group currently being the fastest growing age bracket (Statistics Finland, 2023). While in recent years sustainability activism has reached high schools through movements such as Friday for Futures, swift implementation of sustainability transition actions requires attention from most if not all adult age groups. One plausible solution can be informal climate education for all age groups in form of GreenComp or other EU's lifelong learning initiatives for key competencies.

The interaction between H3 (age) and H4 (education level) and their combined impact on action-oriented competency is another path for further investigation. The growing share of older age brackets means a smaller share of younger people who pursue higher education, which can then negatively impact action-oriented competency and societal agility in implementing climate initiatives.

H7 showcases that higher income (or spending) does not lead to sustainability action. The literature has continuously shown that emissions increase with income level (Akenji et al., 2021, p. 100). For example, Oxfam's seminal report in 2020 showed that the top 10% earners in the world account for 49% of global emissions (Kartha et al., 2020). At the time, when ideas such as carbon rationing, sufficiency, and degrowth are gaining popularity, one wonders what this means for regulating consumption and income-based emissions, especially if a higher income does not lead to increase in sustainability action.

The approximate model results can be interpreted in the light of previous studies. The successful implementation of sustainability competencies in education and training requires assessing the effectiveness of pedagogical efforts in terms of desirable learning outcomes (Redman et al., 2021). As Waltner et al. (2019) pointed out, there is a need for research into the interactions among the various sustainability competencies. The literature review of Annelin and Boström (2023) indicated the importance of investigating how sustainable competencies influence each other and which drivers are stronger for each discipline across different countries. This study responds to this challenge by developing a questionnaire evaluating the deep leverage points of sustainability competencies, such as a shift in worldview towards the necessity of material economic growth. The questionnaire was operationalised (Table 5) to include questions that assess the respondents' awareness of a system's design, architecture and goals related to sustainability, as well as their understanding of how changes in these aspects could impact sustainability outcomes. The questionnaire also included questions assessing the respondents' understanding of systems' components and feedback loops related to sustainability, which are associated with shallow leverage points (such as recycling). The idea was to assess the respondents' understanding of different actions and their potential for sustainability, and how it might be influenced by different interventions and changes. Therefore, an SEM model for action-oriented competency was constructed, and as Van Poeck et al. (2023) noted, action-oriented competency encompasses not just knowledge but also other capabilities and needs. Therefore, when measuring sustainability competencies, it is essential to consider critical values thinking and futures thinking competencies as well.

Sass et al. (2021) developed a CFA model for action-competence with appropriate fit indices but there is no evidence how the same data would work in a SEM model (see also Olsson, 2020). It should also be noted that the sustainability competencies model is considerably more complex than just the action model and several studies such as Waltner et al. (2019) are related to students. No model has been developed to describe citizens' sustainability competencies. Ploum et al. (2018) showed a model of entrepreneurs' sustainability competencies with a good model fit. However, the model for entrepreneurs measured the sustainability on general level and did not identify deep leverage-related competencies. Álvarez-García et al. (2022) found that when measuring leaders' sustainability competencies, the best model indices were obtained when the number of variables entering the model was significantly reduced. This was not the case for the data in this study, as the model was no longer constructed when the number of variables was reduced.

Towards a more valid measure

The results indicate that measuring sustainability competencies is a challenging task since statements measuring different competencies may be collinear with each other, causing controversial path coefficient estimates. Further, respondents may calculate their own responses based on how they respond to other parts of the survey (Schwarz, 1999). For example, in the present study, systems thinking and values thinking are distinct concepts, but the mean for systems thinking is correlated (> .8) with that for values thinking, which makes it difficult to separate their effects. Systems-level sustainability measures require critical values thinking, which makes the link between these competencies clear.

The modelling results of the present study call for developing more specific questions that can potentially reveal marked differences between the items measuring the different competencies. Arnulf et al. (2018) suggested using so-called item-specific response options (Singh, 2004), which implicitly separate individual questions into their own sub-questions. The semantic theory of survey response (STSR) proposes that people respond to items on a survey based on their similarity to other items. This is particularly true for Likert-scale questionnaires.

However, this situation can be remedied if it can be ensured that respondents first understand the meaning of each item. However, as Arnulf et al. (2019) highlighted, STSR in SEM modelling requires more knowledge about the distribution of semantic values and the impact of residuals on model statistics. In conclusion, the findings of this study indicate, in line with Annelin and Boström (2023), that the measurement of sustainability competencies needs to be further developed and tested in various data settings to enhance its effectiveness. Developing a measurement instrument to assess citizens' sustainability competencies is crucial due to the complexity of the phenomenon, which has been proven challenging to measure.

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