

"The world is a complex, interconnected, finite, ecological-social-psychological-economic system. We treat it as if it were not, as if it were divisible, separable, simple, and infinite. Our persistent, intractable, global problems arise directly from this mismatch"

(Meadows, 1982, 101)

Systems Thinking Among Students in Sustainability Programs: A Pilot-Study

Dr. Stefan T. Siegel, University of St Gallen, Switzerland

Prof. Dr. Robert Kordts, University of Bergen, Norway

Prof. Dr. Birgit Kopainsky, University of Bergen, Norway

Invited Symposium “Evidence-informed Sustainability Education in Higher Education”
EARLI 2025 Conference, 25–29 August 2025, Graz, Austria

Agenda

1. **Theory:** Systems Thinking | Scholarship of Teaching and Learning
2. **Methods:** Literature Review | Online-Survey
3. **Results:** ST Measures | ST Competencies & Correlates
4. **Discussion:** Strengths, Limitations & Future Research



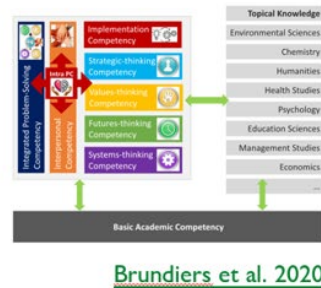
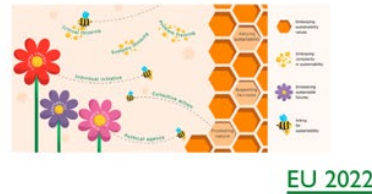


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Theory

From insight to impact.

Systems Thinking as a (or maybe the) Key Competency in / for Sustainability (Education)



A frequently used definition:

“ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks” (Wiek et al. 2011, 207; Highlights St.S.).

→ Multifaceted construct



Lineare Denkweise



Vernetzte Denkweise

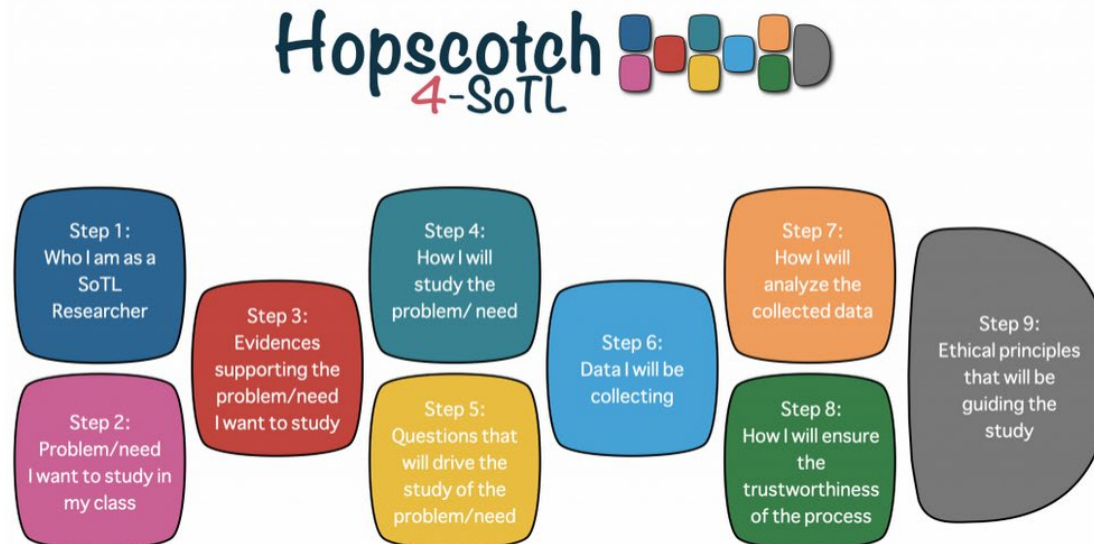
 Ausrichtung	Mechanistisch Deterministisch Produktorientiert Technokratisch	↔ ↔ ↔ ↔	Evolutionär Ganzheitlich Funktionsorientiert Kybernetisch
 Themen- betrachtung	Einzelaspekte des Systems Statisches System Isoliertes System Genauigkeit in den Details Fachlich isoliert	↔ ↔ ↔ ↔ ↔	Vernetzungen im System Dynamiken des Systems System im Zusammenspiel mit der Umgebung Das Ganze Interdisziplinär
 Ziele	Quantität und Geschwindigkeit erhöhen Bestimmte Zustände erreichen Output maximieren Komplexes Problem lösen	↔ ↔ ↔ ↔	Funktionsfähigkeit und Lebensfähigkeit stärken Bestimmte Fähigkeiten des Systems sicherstellen Funktionen optimieren Komplexes Problem in den Griff bekommen
 Methoden/ Hilfsmittel	Korrelationsanalysen zu Ursache und Wirkung Umfragen Prognosen Hochrechnungen Trendanalysen Lobbyeinflüsse		Systemanalysen Wirkungsgefüge Szenarien Simulationen

<https://www.wandelvernetzdenken.de/was-ist-vernetztes-denken/>



Background

- Birgit Kopainsky's course and program on systems thinking (ST) at the University of Bergen (UiB)
- But what is ST? How can it be measured (well)? How ST-competent are learners?
- Collaboration with two university teachers (UiB, HSG): Project "Scholarship of Teaching and Learning" (SoTL)



Research Questions

- RQ 1: Which **measures** are **suited** for higher-education instructors to **assess their students' ST competences**, suitable for disciplines outside of the natural sciences and engineering?
- RQ 2: How are **ST competencies related** to students' **demographic characteristics**?
 - RQ 2.1: Are there **gender differences** between male and female students regarding ST competences?
 - RQ 2.2: Which relations exist between ST and **age**?
 - RQ 2.3: How does students' ST differ between their **disciplinary backgrounds**?





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Methods

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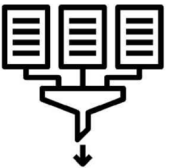
Research Design

Approach & Context:

- Collaborative **Scholarship of Teaching and Learning (SoTL) project** to investigate students' systems thinking (ST) competencies at **University of Bergen**, which offers specialized **and interdisciplinary master's programs in System Dynamics and Sustainability**

Unsystematic rapid literature review on approaches to measure ST (Sutton et al., 2019)

- Databases: *ERIC*, *PsycInfo*, *Google Scholar*
- Search terms: systems thinking, instrument, assessment and related terms.
- Eligibility criteria: publications in English; published within the last 20 years (2005 through 2025); new or revised ST measure



Survey Study on ST Competences

- Participants: **$N = 65$ master's students** (2 courses, 4 cohorts, 2023–2025; 60% female; $M_{\text{age}} = 29.36$; $M_{\text{workexperience}} = 8.91$ years) completed two ST measures; age and work experience varied but showed no significant group differences



Data Analysis

- Descriptive statistics, scale computations, internal consistency checks, and correlation analyses via SPSS29
- Study programs were categorized by faculty and ecological relevance to test for group differences





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Results

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RQ 1: – ST Measurement

Included: 15 publications met initial eligibility criteria, however only 4 instruments met all criteria (quantitative, general-purpose, economical for higher education)

Of these selected

- **15-question questionnaire by Davis & Stroink (2016): cognitive aspects** of ST (e.g., “The Earth, including all its inhabitants, is a living system”)
- **30-question questionnaire by Camelia & Ferris (2018): affective aspects** of ST factors (e.g., “I enjoy using models, mind maps, rich pictures, causal loop diagrams or graphs to understand problems”)
- **Scale Reliability & Validity:** Both instruments showed acceptable reliability ($\alpha \geq .72$ overall; some subscales borderline but usable); intercorrelations confirmed **complementary, partially overlapping constructs**

Scales (as defined by the authors)	Cronbach alpha
Scale 1: Preference or inclination towards whole of system perspectives	.62
Scale 2: Interest in the intended purpose or application of the system under consideration or development	.72
Scale 3: Inclination towards and participation in seeking a coherent, whole, system solution	.63

RQ 2: ST competencies relationships to students' demographic characteristics

Gender Differences (RQ 2.1)

- No significant gender effects on cognitive aspects of ST Davis & Stroink (2016) scale.
- However, for affective aspects of ST Camelia & Ferris (2018), women scored significantly higher on Scale 1 (whole-system perspective), $p = .012$; no gender differences for Scales 2 and 3.

Age Relations (RQ 2.2)

- Weak negative correlation between age and ST (Davis & Stroink), $r = -.21$, $p = .09$ (marginal); no significant age correlations for Camelia & Ferris scales.

Disciplinary Backgrounds—Programs (RQ 2.3):

- No significant differences in ST scores between students in System Dynamics and Sustainability programs on either scale; pattern of higher values for Scales 1 & 2 vs. Scale 3 was consistent across groups.



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Discussion

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Discussion: Summary and Interpretation of Main Findings

1. Existing ST assessment reviews differ from this study's findings, highlighting the **fragmented nature of current tools** and the need for a more coherent, education-focused framework.
2. The two applied questionnaires revealed **complementary perspectives**: Davis & Stroink (2016) **captured cognitive aspects of ST** reliably, while Camelia & Ferris (2018) offered nuanced **affective dimensions**, despite some reliability issues.
3. Affective ST showed a **marginal gender difference (female students favored whole-system perspectives more)** suggesting emotional dimensions may reveal differences missed in purely cognitive assessments.
4. **Younger students scored higher in cognitive ST**; affective ST remained stable across ages, indicating divergent developmental or curricular influences.
5. **No disciplinary differences in ST were found**, challenging common assumptions and supporting inclusive, cross-disciplinary ST education.



Discussion: Limitations & Future Research

Limitations

- Rapid, unsystematic literature review limits the scope and depth of ST measures considered (Sutton et al., 2019)
- Small, self-selected sample of the survey study reduces representativeness; larger, more diverse samples are needed for generalizability
- Some scales (affective) showed low reliability; future research should refine instruments and consider mixed-method approaches for richer insights

Implications for Future Research & Teaching Systems Thinking

- Use larger, more diverse samples and validate ST assessment tools
- Explore how prior education and backgrounds shape ST competencies
- Tailor teaching to age and motivation—avoid assumptions/prejudices based on demographics
- Combine content-based and critical approaches; assess both cognitive and affective ST dimensions





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