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The Technical Knowledge Paradox - How Environmental Understanding Creates Action Barriers Among German University Students

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ABSTRACT:

Background and Aims: Technical students demonstrate significantly higher environmental awareness than business students, yet exhibit challenges in translating this knowledge into consistent behavior. This study examines a phenomenon we term the "Technical Knowledge Paradox" - where comprehensive environmental understanding creates action barriers rather than promoting behavioral implementation. Gender effects in academic environments are also investigated.

Methods: A cross-sectional survey of 318 German university students (174 technical, 144 business) employed the Federal Environmental Agency's validated questionnaire. Mann-Whitney U tests compared groups across environmental affect, cognition, and behavior dimensions. Chi-square tests analyzed specific behavioral actions. Qualitative responses provided additional contextual insights.

Results: Technical students demonstrated significantly higher environmental consciousness (M=5.82, SD=2.15 vs M=5.03, SD=2.38) yet showed mixed behavioral implementation patterns. Only 10.4% engaged actively in environmental causes, revealing a knowledge-action gap where comprehensive understanding created analytical paralysis rather than motivation. Technical students exhibited strong emotional responses to environmental issues but appeared constrained by their deep understanding of problem complexity. This pattern suggests that extensive environmental knowledge may complicate rather than facilitate action pathways. Gender differences were less pronounced than disciplinary ones, though selective patterns emerged in specific behaviors. A systematic consciousness-behavior gap appeared across all student groups, often accompanied by frustration with current environmental policies.

Conclusion: The findings indicate that enhanced environmental education requires approaches beyond knowledge transmission. Universities should develop discipline-specific interventions, particularly addressing the analytical paralysis observed among technical students who possess comprehensive understanding of environmental complexity. This consciousness-behavior disconnect represents a previously unrecognized challenge in sustainability education.

Keywords: environmental psychology; higher education; pro-environmental behavior; engineering education; sustainability science; behavioral barriers

1. Introduction

Academic disciplines shape environmental consciousness differently, yet few studies examine how technical versus business education influences student environmental behavior. Sustainability integration varies significantly across curricula, with technical programs emphasizing scientific methodology and systems thinking while business education focuses on economic and strategic perspectives (Vicente-Molina et al., 2013;

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Lozano et al., 2019). These educational differences may create distinct patterns of environmental awareness and behavior among students (Sammalisto et al., 2015).

Cross-cultural research demonstrates significant variations in sustainability practices among university students from different disciplines (Grossmann et al., 2025), indicating that the relationship between academic background and environmental consciousness requires deeper investigation. Adomßent et al. (2014) note that sustainability education in higher learning institutions aims to promote social change through innovative teaching approaches, yet effectiveness varies significantly depending on students' disciplinary background.

Disciplinary socialization theory (Becher & Trowler, 2001) describes how academic disciplines shape students' ways of thinking and professional identities. Technical education's emphasis on scientific methodology and systems thinking may foster different environmental consciousness patterns compared to business education's focus on economic and strategic perspectives. This theoretical framework suggests that disciplinary differences in environmental behavior may be more pronounced than traditionally assumed demographic factors.

While disciplinary socialization theory explains how different educational backgrounds shape cognitive frameworks, it does not fully account for the mechanisms through which technical knowledge becomes a barrier rather than an enabler of environmental action. Research on the knowledge-action gap provides crucial insights into this phenomenon. Kollmuss and Agyeman (2002) demonstrate that psychological barriers frequently prevent the translation of environmental awareness into behavior, particularly when individuals perceive environmental problems as overwhelmingly complex and feel powerless to effect meaningful change. Building on this framework, Bamberg and Möser (2007) identify perceived behavioral control as a key predictor of pro-environmental action. The present study suggests that technical students' comprehensive understanding of environmental complexity may paradoxically diminish this sense of control, resulting in analytical paralysis despite heightened awareness - patterns this research identifies as the "Technical Knowledge Paradox." Cognitive load theory (Sweller, 1988) provides additional insight into why technical knowledge may become paralyzing rather than empowering. This theory demonstrates that excessive information processing demands can impair decision-making capacity when working memory becomes overloaded. For technical students, comprehensive understanding of environmental systems—including complex interdependencies, feedback loops, and systemic trade-offs—may create cognitive overload that overwhelms decision-making capacity. Rather than facilitating action, detailed environmental knowledge may exceed students' cognitive resources for translating understanding into behavioral choices. This mechanism may compound the diminished perceived behavioral control identified by Bamberg and Möser (2007), transforming environmental knowledge from an asset into a psychological barrier.

Two central questions guide this research:

1. How do technical students' environmental consciousness and behavior compare to business students?
2. How do gender differences in environmental attitudes manifest within specific disciplinary contexts?

These questions address the identification of a "Technical Knowledge Paradox" - a phenomenon where comprehensive technical understanding may create barriers rather than pathways to environmental action.

The study contributes to environmental psychology theory and provides practical insights for developing more effective sustainability education strategies.

2. Literature Review

2.1 Sustainability in Higher Education

Higher education institutions became crucial catalysts for developing sustainability competencies following the concept's introduction by the World Commission on Environment and Development (1987). Contemporary sustainability education emphasizes the interconnected "Triple Bottom Line" approach, balancing environmental protection, economic viability, and social equity (Elkington, 1997). However, Elkington himself later became highly critical of his own concept, arguing that it had failed to achieve its original transformative goals and had been reduced to a mere accounting tool rather than driving the system change it was meant to inspire (Elkington, 2018).

This critique proves particularly relevant for understanding current challenges in sustainability education. Despite widespread adoption of sustainability frameworks in higher education, questions persist about whether these approaches actually transform student behavior or merely provide theoretical knowledge without practical implementation—a concern that directly relates to the "Technical Knowledge Paradox" identified in this study.

Implementation varies considerably across academic disciplines. While sustainability appears in institutional mission statements, curricular integration follows discipline-specific patterns. Academic fields emphasize different aspects of the three sustainability pillars depending on their methodological traditions and professional orientations (Stephens et al., 2008).

The gap between sustainability education goals and actual behavioral outcomes reflects broader challenges in environmental education. Universities may successfully teach sustainability concepts while struggling to bridge the knowledge-action gap that prevents students from translating awareness into consistent environmental behavior (Leal Filho et al., 2019).

This multi-dimensional approach and its disciplinary implementation has gradually transformed sustainability approaches in educational contexts, establishing the foundation for investigating how technical and business education create different pathways to environmental awareness and behavior (Adomßent et al., 2014).

2.2 Gender Perspectives in Environmental Consciousness

Gender differences in environmental consciousness show up consistently across research studies, though the reasons behind these patterns are still debated. Cross-cultural meta-analyses reveal that gender differences in environmental attitudes are remarkably consistent across different societies, with women typically demonstrating stronger environmental attitudes, greater willingness to engage in environmentally responsible behaviors, and higher levels of concern about environmental degradation (Zelezny et al., 2000). Women generally express higher environmental concern is more sceptical about government environmental efforts, and engage more in everyday environmental behaviors like buying eco-friendly products (BMU & UBA, 2019).

These differences show up in what people prioritize and how they act. Women tend to see environmental protection as more important and do more daily sustainable things, while men participate more in environmental investments - though this might just reflect income differences rather than caring more about the environment (BMU & UBA, 2019). The socialization hypothesis suggests that gender differences emerge through differential childhood experiences, with girls being socialized toward nurturing and caring behaviors that extend to environmental concern (Zelezny et al., 2000). When researchers studied university students, they found that different factors influence each gender's environmental behavior, and men seem more likely to change their behavior when programs target them specifically (Vicente-Molina et al., 2013).

Whether these traditional gender patterns hold up in university settings, especially across different fields of study, is still an open question that needs more research (Vicente-Molina et al., 2013). Universities might change the usual gender differences because everyone gets similar access to environmental information and education (Sammalisto et al., 2015). Also, what students learn in their specific disciplines might matter more than gender socialization - research shows that faculty members who don't integrate sustainability into their teaching are mostly men (Lozano et al., 2019).

Engineering and technical fields have long been male-dominated, while business education has become more gender-balanced over time (Sammalisto et al., 2015). These different academic environments might create different opportunities for learning about environmental issues and could either strengthen or weaken the usual gender patterns in environmental behavior. Most research examines gender and academic discipline separately, without considering their potential interactions in shaping environmental consciousness within higher education environments (Vicente-Molina et al., 2013).

2.3 Knowledge-Action Gap in Environmental Psychology

Environmental psychology research consistently documents a persistent gap between environmental knowledge and pro-environmental behavior. Kollmuss and Agyeman (2002) identify multiple barriers preventing individuals from translating environmental awareness into action, including external factors (infrastructure, economic constraints) and internal factors (motivation, environmental knowledge, awareness, and emotional involvement).

Meta-analytic evidence confirms that environmental knowledge alone is insufficient to predict behavioral outcomes. Attitudes, personal moral norms, and perceived behavioral control are stronger predictors of environmental action than factual knowledge about environmental problems (Bamberg & Möser, 2007).

Building on Bamberg and Möser's (2007) identification of perceived behavioral control as a key predictor, this study proposes that technical knowledge about environmental systems can paradoxically reduce this sense of control. When comprehensive understanding reveals overwhelming complexity and interconnectedness, it may create analytical paralysis - a specific manifestation of diminished perceived behavioral control that transforms knowledge from an enabler into a barrier to action.

2.4 Research Gap

Existing literature establishes general patterns in sustainability awareness among students, yet several critical gaps remain. Few studies directly compare environmental consciousness and behavior between technical and business students, despite their fundamentally different educational approaches to sustainability (Vicente-Molina et al., 2013).

The interaction between academic discipline and gender in shaping environmental behavior remains understudied, particularly in higher education contexts. Most research examines either disciplinary or gender effects separately, without considering their potential interactions (Lozano et al., 2019).

The mechanisms underlying potential knowledge-behavior gaps in technically oriented disciplines have not been systematically investigated. This study addresses these gaps by examining both environmental consciousness and behavior across disciplines while considering gender effects, contributing to theoretical understanding and practical implications for sustainability education (Sammalisto et al., 2015).

3. Methodology

3.1 Research Design and Sample

This quantitative study employs a cross-sectional survey design to examine environmental consciousness and behavior among German university students. The research specifically focuses on comparing technical and business disciplines while considering gender differences in environmental attitudes and behaviors. Based on disciplinary socialization theory, the study hypothesizes that technical students demonstrate higher environmental consciousness than business students, while gender effects may be moderated by academic context.

The initial dataset comprised 328 students from German universities. Through systematic data cleaning, ten students (3.0%) were excluded due to unclear gender entries (n=8), unclear study program classification (n=1), or programs outside the technical/business scope (n=1), resulting in a final sample of 318 students. All remaining participants could be unambiguously classified into the required binary categories. This binary classification approach, while necessarily simplifying the diversity of gender identities and academic programs, serves specific methodological objectives. First, it maximizes statistical power to detect the hypothesized disciplinary socialization effects that constitute this study's primary research question. Second, by focusing on clearly distinguishable disciplinary traditions (technical vs. business education), it minimizes confounding variables that could obscure the mechanisms underlying the "Technical Knowledge Paradox." Third, the binary framework enables direct comparisons with previous research (Vicente-Molina et al., 2013; Sammalisto et al., 2015) that employed similar categorizations. Alternative approaches such as continuous measures of technical knowledge or multiple disciplinary categories would introduce additional complexity that, given the exploratory nature of investigating the Technical Knowledge Paradox, could obscure rather than illuminate the core phenomenon. This methodological choice prioritizes internal validity and theoretical clarity for initial theory development, with the explicit understanding that future research should examine intersectional identities, hybrid programs, and non-binary participants (see Section 5.6 for detailed discussion of these limitations).

The final sample consists of 318 students from German universities, with technical students comprising 54.72% (n=174) and business students 45.28% (n=144). The gender distribution shows 54.40% female (n=173) and 45.60% male (n=145) participants. Most respondents (61.76%) are between 21 and 25 years old, representing a typical undergraduate student population.

Table 1: Sample Demographics (N=318)

Characteristic	N	%
Study Program		
Technical Studies	174	54.72
Business Studies	144	45.28
Total	318	100,00%
Gender		
Female	173	54.4
Male	145	45.6
Total	318	100,00%
Age Groups		
17-20	71	22.33
21-25	196	61.64
26-30	44	13.84
30+	7	2.20%
Total	318	100,00%

For detailed program classifications and methodological approach, see Appendix A.

3.2 Survey Instruments

The questionnaire used in this study is adapted from the Environmental Consciousness Study 2018 conducted by the German Federal Environmental Agency (Umweltbundesamt) (BMU & UBA (2019)). The instrument measures three key dimensions of environmental engagement: Environmental Affect (questions 1-8), Environmental Cognition (questions 9-15), and Environmental Behavior (questions 16-23).

Questions 1-20 use 10-point Likert scales to assess participants' emotional responses to environmental issues, cognitive understanding of sustainability concepts, and self-reported behavioral practices. Questions 21-23 employ dichotomous response options (Yes/No/Don't know) to measure specific behaviors including green electricity usage, environmental donations, and active engagement (BMU & UBA (2019)). The complete questionnaire is provided in Appendix B.

Additionally, participants were invited to respond to an open-ended question about their general opinion on sustainability, yielding qualitative perspectives that complement quantitative analysis.

3.3 Data Collection and Analysis

Data collection took place between September and October 2024 using online survey platforms. Statistical analyses were conducted using MATLAB, employing non-parametric tests appropriate for the data types and sample characteristics. For Likert-scale questions (1-20), Mann-Whitney U tests were used to compare independent groups, as this approach is suitable for ordinal data without assuming normal distribution. For nominal questions (21-23), Chi-square tests examined group differences in categorical responses.

3.4 Statistical Methods

Statistical significance was evaluated at two levels: significant ($p < 0.05$) and highly significant ($p < 0.001$). To ensure transparency and reproducibility, the study reports comprehensive statistical metrics including:

- Z-values and rank sums for Mann-Whitney U tests
- Chi-square values (χ^2) for nominal data analyses
- Means and standard deviations for each group
- Exact p-values for all statistical comparisons

These statistical approaches allow rigorous examination of differences between technical and business students, as well as gender-based variations in environmental consciousness and behavior.

4. Results

4.1 Differences between Technical and Business Students

Table 2 presents selected **key findings** from the Mann Whitney U Test analysis comparing technical and business students across questions 1-20. The questions are categorized into three dimensions: "Environmental Affect" (questions 1-8), "Environmental Cognition" (questions 9-15), and "Environmental Behavior" (questions 16-23). The results shown below represent the most significant differences, organized thematically by category. Complete statistical documentation of all 20 questions is available in Appendix C.

Table 2: Selected key differences between Technical and Business Students (Mann Whitney U test, SD = Standard Deviation) n=318 (10-point Likert scale: 1 = strongly disagree, 10 = strongly agree)

Category	Question	Mean Technical	SD Technical	Mean Business	SD Business	z-value	p-value	Conclusion
Environmental Affect	1. Human-made environmental issues such as deforestation or plastic in the world's oceans outrages me.	7,80	1,86	5,02	3,07	7,71	0,00000000	Technical students show significantly higher environmental concern.
Environmental Affect	6. I get annoyed when others try to tell me that I should live in an environmentally conscious way.	5,49	2,68	7,49	2,81	-6,26	0,00000000	Business students are significantly more annoyed by environmental demands.
Environmental Affect	7. Environmental issues are greatly exaggerated by many environmentalists.	4,59	2,74	7,02	2,97	-6,89	0,00000000	Business students believe significantly environmental issues are more exaggerated.
Environmental Cognition	10. More environmental protection also means more quality of life and health for everyone.	7,37	2,38	5,37	3,01	5,82	0,00000001	Technical students significantly link more environmental protection to quality of life.

Environ mental Cognition	13. For the sake of the environment, we should all be willing to limit our current standard of living.	6,34	2,48	3,7	3,2	7,48	0,00000 000	Technical students are significantly more willing to adjust lifestyles.
Environ mental Cognition	15. We need more economic growth in the future, even if it burdens the environment.	3,92	2,2	4,26	1,89	-1,93	0,05391 238	No significant difference (borderline significance).
Environ mental Behavior	16. When buying household appliances, I choose especially energy-efficient devices (A+++ or A++ energy efficiency labels).	3,93	1,48	2,93	1,56	5,56	0,00000 003	Technical students prioritize energy efficiency significantly more.
Environ mental Behavior	18. When shopping, I choose products with environmental labels, for example, Blue Angel, EU Organic Label, or EU Ecolabel.	3,21	1,51	2,32	1,49	5,23	0,00000 017	Technical students choose eco-labeled products significantly more.
Environ mental Behavior	19. I buy food from certified organic farming.	3,51	1,43	2,26	1,43	7,36	0,00000 000	Technical students buy organic food significantly more.

While the Likert-scale questions (16-20) revealed significant behavioral differences between technical and business students, the analysis of concrete environmental actions through dichotomous questions (21-23) provides additional insights into actual engagement patterns. The Chi-square analysis in Table 3 examines three specific behaviors: green electricity usage, environmental donations, and active environmental engagement.

Table 3: Differences between Technical and Business Students (Chi-square test)

Question	Technical %	Business %	X²	p-value	Conclusion
21. Do you currently use green electricity?	Yes: 25.88% No: 35.88% Don't know: 38.24%	Yes: 19.59% No: 64.19% Don't know: 16.22%	29.68	0.00000036	Technical significantly more

22. I donate money for environmental and climate protection.	Yes: 10.23% No: 86.93% Don't know: 2.84%	Yes: 3.57% No: 96.43% Don't know: 0.00%	7.83	0.01991795	Technical significantly more
23. I am actively engaged in environmental and climate protection.	Yes: 15.52% No: 78.74% Don't know: 5.75%	Yes: 1.80% No: 97.30% Don't know: 0.90%	19.37	0.00006227	Technical significantly more

The analysis reveals consistent and significant differences between technical and business students across all three environmental dimensions:

- **Environmental Affect (Q1-8):** Technical students demonstrate significantly higher emotional engagement with environmental issues (e.g., Q1: M=7.80 vs M=5.02, $p<0.001$). Conversely, business students show greater resistance to environmental demands (Q6: M=7.49 vs M=5.49, $p<0.001$).
- **Environmental Cognition (Q9-15):** Technical students show stronger cognitive understanding of sustainability concepts, particularly regarding willingness for lifestyle adjustments (Q13: M=6.34 vs M=3.70, $p<0.001$).
- **Environmental Behavior (Q16-23):** Technical students consistently report higher sustainable behaviors across measured areas, from energy efficiency choices to active environmental engagement (Q23: 15.52% vs 1.80%, $p<0.001$).

For detailed statistical analysis and complete boxplot visualizations of these differences, see Appendix C.

4.2 Differences between Female and Male Students

The analysis now shifts to examining gender differences in environmental consciousness and behavior. While the disciplinary differences between technical and business students proved substantial, the gender-based patterns reveal a more nuanced picture with selective but meaningful variations. Table 4 presents selected key findings from the Mann Whitney U Test analysis comparing male and female students across questions 1-20, showing the most significant differences organized thematically. Complete statistical documentation of all 20 questions is available in Appendix D.

Table 4: Selected key differences between Female and Male Students (Mann Whitney U test, SD = Standard Deviation) n=318 (10-point Likert scale: 1 = strongly disagree, 10 = strongly agree)

Category	Question	Mean Male	SD Male	Mean Female	SD Female	z-value	p-value	Conclusion

Environmental Cognition	9. We should not consume more raw materials than can be regenerated.	7.36	2.43	8.13	1.97	-2.76	0.0058	Female participants show significantly higher agreement.
Environmental Cognition	10. More environmental protection also means more quality of life and health for everyone.	6.19	2.71	6.85	2.87	-2.27	0.0235	Female participants link environmental protection to quality of life significantly stronger.
Environmental Cognition	11. We need to find ways to live well independently of economic growth.	6.91	2.67	7.7	2.01	-2.31	0.021	Female participants support lifestyle adjustments significantly more.
Environmental Behavior	20. I eat meat with the main meals.	4.03	1.51	3.33	1.53	4.01	0.0001	Male participants consume meat significantly more frequently.

The Likert-scale analysis reveals limited but significant gender differences, primarily in environmental cognition rather than emotional responses or behaviors. To complete the gender analysis, the Chi-square tests examine concrete environmental actions. Table 5 shows the results of questions 21-23.

Table 5: Differences between Male and Female Students (Chi-square test)

Question	Female %	Male %	X²	p-value	Conclusion
21. Do you currently use green electricity?	Yes: 13.64%	Yes: 29.20%	110.429	0.004	Male significantly more.
	No: 54.55%	No: 41.61%			
	Don't Know: 31.82%	Don't Know: 29.20%			
22. I donate money for environmental and climate protection.	Yes: 7.74%	Yes: 7.35%	0.0615	0.9697	No significant difference.
	No: 89.68%	No: 90.44%			
	Don't Know: 2.58%	Don't Know: 2.21%			
23. I am actively engaged in environmental	Yes: 9.68%	Yes: 10.45%	0.62	0.732	No significant difference.
	No: 87.74%	No: 85.07%			

and climate protection.	Don't Know: 2.58%	Don't Know: 4.48%			

Summary of Gender Differences: The gender-based analysis reveals a more nuanced pattern compared to the pronounced disciplinary differences, with selective but meaningful variations between male and female students:

Environmental Affect (Q1-8): No significant gender differences were observed across all emotional response questions, indicating similar baseline environmental concern between male and female students.

Environmental Cognition (Q9-15): Female students demonstrate significantly higher agreement on key cognitive sustainability aspects, including sustainable resource consumption (Q9: F=8.13 vs M=7.36, p=0.006), linking environmental protection to quality of life (Q10: F=6.85 vs M=6.19, p=0.024), and supporting growth-independent living (Q11: F=7.70 vs M=6.91, p=0.021).

Environmental Behavior (Q16-23): Gender differences in behavior show selective patterns. Male students report higher meat consumption (Q20: M=4.03 vs F=3.33, p<0.001) and higher green electricity usage (Q21: 29.20% vs 13.64%, p=0.004). No significant differences were found in other behavioral measures.

For complete statistical documentation of gender-specific differences, see Appendix D.

5. Discussion

5.1 Interpretation of Main Findings

Technical students demonstrated significantly higher environmental consciousness than business students across all measured dimensions yet exhibited challenges in translating this awareness into consistent behavioral implementation - something we call the 'Technical Knowledge Paradox.' For example, technical students feel much more outraged about environmental problems like deforestation (M=7.80 vs M=5.02, p<0.001), but when it comes to doing something, they revealed complex behavioral implementation patterns. Adoption rates varied significantly across behavioral measures, but only 10.4% get actively involved in environmental causes. Gender differences were observed but proved less pronounced than disciplinary factors in determining environmental behavior.

5.1.1 Disciplinary Differences (Technical vs Business)

Technical and business students demonstrate fundamentally different approaches to environmental issues, reflecting their distinct educational socialization. These patterns align with disciplinary socialization theory (Becher & Trowler, 2001), which explains how different academic disciplines shape students' emotional responses and professional identities.

The most striking finding is not simply that technical students score higher, but how they process environmental information differently. Technical students demonstrate intense emotional engagement with environmental problems (Q1: M=7.80 vs M=5.02, p<0.001), yet this heightened awareness creates unexpected barriers to action. Business students, conversely, show systematic resistance to environmental demands (Q6: M=7.49 vs M=5.49, p<0.001) and skepticism about problem severity (Q7: M=7.02 vs M=4.59, p<0.001).

Table 6: Data and Boxplots referred to Questions Q1, Q7, Q13 and Q19

Q1: Human-made environmental problems outrage me	**Q7: Environmental issues are greatly exaggerated by many environmentalists**
Technical students show significantly higher environmental outrage (M=7.80, SD=1.86) than business students (M=5.02, SD=3.07, p<0.001), demonstrating the emotional foundation of the paradox.	Conversely, business students believe significantly more strongly that environmental issues are exaggerated (M=7.02, SD=2.97) than technical students (M=4.59, SD=2.74, p<0.001), revealing fundamental skepticism.

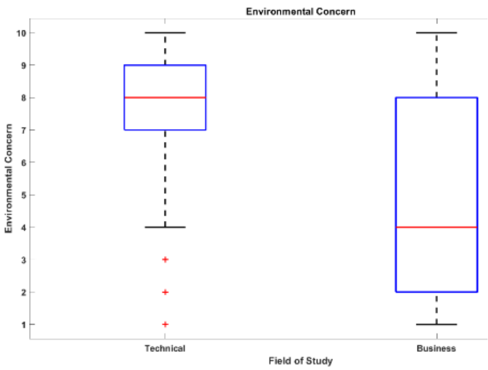

Figure 1: Boxplot Q1

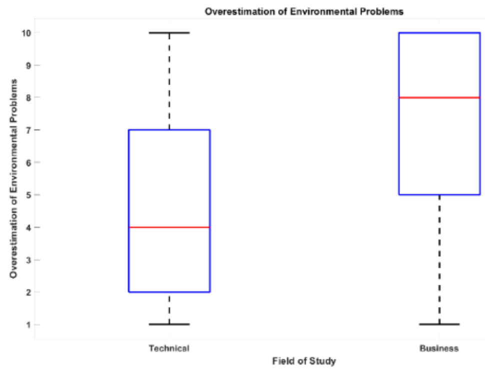

Figure 2: Boxplot Q7

Q13: We should limit our standard of living for the environment	**Q19: I buy food from certified organic farming**
Technical students show significantly higher willingness to adjust lifestyles for environmental protection (M=6.34, SD=2.48) compared to business students (M=3.70, SD=3.20, p<0.001), reflecting cognitive commitment.	Technical students buy organic food significantly more than business students (M=3.51 vs M=2.26, SD=1.43, p<0.001), demonstrating how consciousness translates into specific behaviors despite the overall paradox.

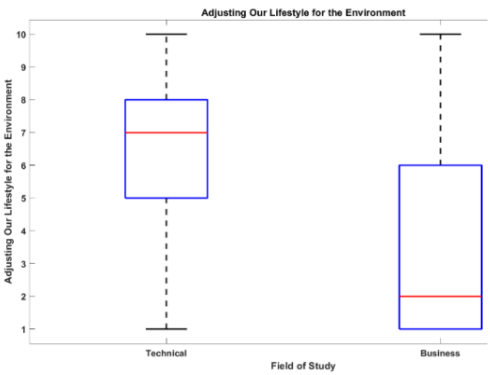

Figure 3: Boxplot Q13

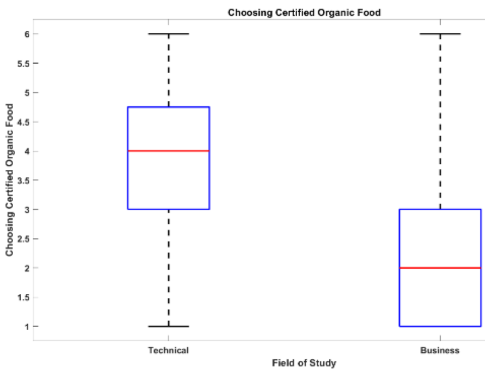

Figure 4: Boxplot Q19

The results point to what appears to be a Technical Knowledge Paradox: technical students understand environmental problems more deeply, but this understanding seems to be complicated rather than simplify their path to action. The gap between high environmental consciousness and selective behavior shows up most clearly in complex environmental activities that require ongoing commitment. Technical students react strongly to environmental issues emotionally, but their thorough grasp of environmental systems appears to highlight just how big and interconnected these problems are - potentially making individual efforts seem inadequate. This pattern aligns with previous research demonstrating that environmental knowledge does not automatically translate into corresponding behavioral outcomes (Kollmuss & Agyeman, 2002; Bamberg & Möser, 2007).

These visualizations clearly illustrate that disciplinary differences represent the most pronounced factor in environmental consciousness among German university students (complete boxplot analyses available in Appendix C).

5.1.2 Gender Differences (Male vs Female)

Gender differences prove more nuanced than traditional environmental research suggests, with the academic environment moderating established patterns. Unlike the consistent disciplinary differences, gender effects manifest selectively across specific domains.

The most unexpected finding challenges conventional assumptions: male students show significantly higher adoption of green electricity (29.20% vs 13.64%, p=0.004), despite females demonstrating stronger cognitive sustainability frameworks. Women score higher on resource consumption awareness (Q9: M=8.13 vs M=7.36, p=0.006) and support for growth-independent living (Q11: M=7.70 vs M=6.91, p=0.021), yet this cognitive advantage doesn't translate consistently into all behaviors.

Table 7: Data and Boxplots referred to Questions Q9, Q11, and Q20

Q9: We should not consume more raw materials than can regenerate	**Q11: We must find ways to live well independently of economic growth**
Female students show significantly higher agreement about sustainable resource consumption (M=8.13, SD=1.97 vs M=7.36, SD=2.43, p=0.006), reflecting stronger cognitive sustainability frameworks.	Female students show significantly higher support for lifestyle adjustments independent of economic growth (M=7.70, SD=2.01 vs M=6.91, SD=2.67, p=0.021), suggesting different approaches to economic sustainability.

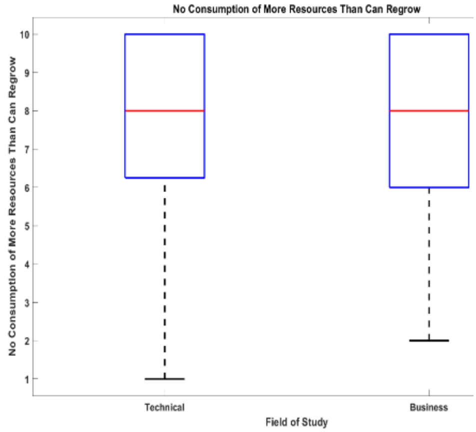

Figure 5: Boxplot Q9

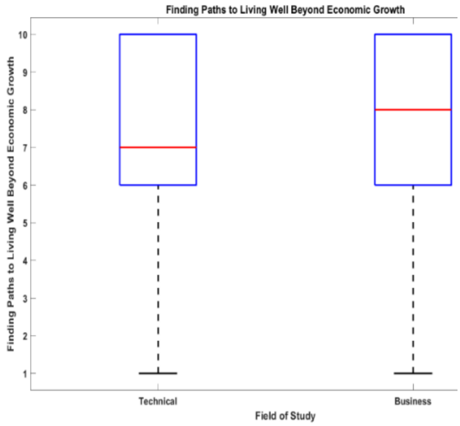

Figure 6: Boxplot Q11

Q20: I eat meat with the main meals.

Male students show significantly higher meat consumption than female students (M=4.03, SD=1.51 vs M=3.33, SD=1.53, $p<0.001$), aligning with established dietary patterns.

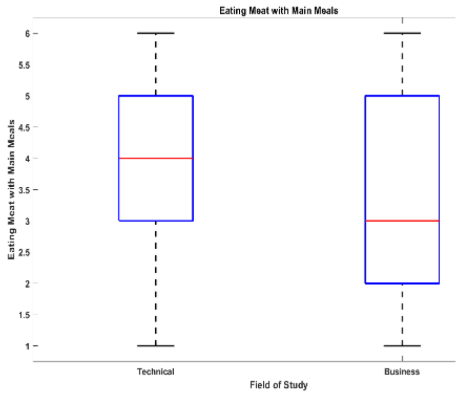

Figure 7: Boxplot Q20

These findings suggest that gender differences in environmental behavior may be less pronounced in university contexts than traditional research indicates, with disciplinary socialization appearing more influential than demographic factors. The selective nature of gender differences contrasts sharply with the systematic disciplinary patterns observed between technical and business students (complete gender-specific analyses available in Appendix D).

5.1.3 Knowledge-Action Gap (Across All Groups)

Across all participant groups, the categories "environmental affect" and "environmental cognition" consistently show higher mean values than "environmental behavior," revealing a systematic gap between environmental awareness and actual behavioral implementation.

This gap is evident in the varying adoption rates of different behaviors, with notably lower engagement in complex behaviors such as active environmental engagement

(10.4%). This pattern supports the identification of the "Technical Knowledge Paradox" and suggests that translating environmental consciousness into action remains challenging regardless of disciplinary background.

This systematic pattern transcends both disciplinary and gender boundaries, suggesting fundamental challenges in translating environmental awareness into comprehensive action.

5.2 The Technical Knowledge Paradox

A systematic knowledge-action gap emerges across all student groups, regardless of discipline or gender. Students consistently exhibited higher levels of environmental awareness and concern relative to actual behavioral implementation, revealing the persistent challenge of translating consciousness into action documented in environmental psychology research (Kollmuss & Agyeman, 2002).

This gap manifests most clearly in behavior adoption rates, with only 10.4% participating in active environmental engagement. The disparity aligns with meta-analytic findings that perceived behavioral control and practical barriers are stronger predictors of environmental action than knowledge or attitudes (Bamberg & Möser, 2007).

The pattern varies by behavioral complexity, with simple, well-defined actions showing high adoption while complex decisions requiring personal sacrifice remain limited. This supports theoretical frameworks suggesting that comprehensive environmental knowledge can create feelings of helplessness when problems appear too large for individual action (Kollmuss & Agyeman, 2002).

The universality of this gap across both disciplinary and gender boundaries indicates fundamental psychological barriers that transcend demographic categories, supporting the identification of the Technical Knowledge Paradox as part of broader challenges in environmental behavior change.

5.3 Student Perspectives

The qualitative responses provide systematic validation for the quantitative patterns documented in Section 4, revealing the cognitive mechanisms behind statistical differences:

Policy Frustration validates Q4 findings (Technical $M=6.10$ vs Business $M=4.68$, $p<0.001$): Technical students' anger about missed climate goals manifests as critique rather than compliance: "Environmental protection is very important - but unfortunately completely incorrectly implemented by politics." This sophisticated policy skepticism represents a previously unidentified dimension of the Technical Knowledge Paradox—where deeper understanding leads to criticism of solutions rather than behavioral implementation.

Analytical Paralysis validates Q13 findings (Technical $M=6.34$ vs Business $M=3.70$, $p<0.001$): Despite higher willingness to adjust lifestyles, technical students' comprehensive cost-benefit reasoning reveals decision complexity: "A wooden toothbrush that costs five times as much... can hardly be more environmentally friendly." Technical knowledge enables sophisticated analysis that paradoxically complicates rather than clarifies behavioral choices.

Alternative Pathways validate Q19 findings (Technical $M=3.51$ vs Business $M=2.26$, $p<0.001$): When technical students do act, they demonstrate creative problem-solving: "I focus on used items... a contribution to sustainability." This suggests the paradox is not absolute—technical students can translate knowledge into action when clear, systematic pathways exist. These qualitative-quantitative convergences confirm that the Technical Knowledge Paradox operates through sophisticated environmental reasoning rather than indifference or ignorance.

Sophisticated Economic Integration: Technical students demonstrate complex approaches to sustainability: "Sustainability must also be viewed economically. Money is ultimately always in relation to labor invested or the consumption of limited resources. A wooden toothbrush that costs five times as much as a plastic one can hardly be more environmentally friendly." The Technical Knowledge Paradox does not reflect simplistic thinking, but rather comprehensive consideration of multiple factors that can complicate decision-making.

Alternative Action Pathways: Some responses reveal that technical students do translate knowledge into action, but through creative approaches: "I focus on used items. For example, I find eBay […] a successful exchange and a contribution to sustainability so that not everything needs to be bought new." Technical students can effectively act when clear, practical pathways exist that align with their systematic thinking.

Systemic Awareness and Responsibility: Students emphasize the need for comprehensive approaches: "It's not enough to just take small steps like recycling. We must also advocate for larger systematic changes, such as in politics and economics." Technical understanding creates both awareness of complexity and motivation for systemic rather than purely individual solutions.

Personal Responsibility and Barriers: Students also acknowledged individual limitations in environmental engagement: "It's a trend where one feels compelled to agree, even though one is personally occupied with so many other private problems that one actually has no time for it." Competing priorities and the psychological burden of environmental responsibility may reinforce the Technical Knowledge Paradox, even among environmentally conscious students.

Policy Frustration and Implementation Critique: Students express frustration with current policy approaches to environmental challenges: "Environmental protection is very important - but unfortunately completely incorrectly implemented by politics." Students also express concerns about disproportionate regulatory burden: "Germany approaches it too strictly, while others abroad pay 0.0% attention to it." Some students advocate for different policy mechanisms: "I am more in favor of subsidies and creating incentives instead of more bans or laws, since the response of consumers varies."

Policy skepticism represents another dimension of the Technical Knowledge Paradox, where students' sophisticated understanding of environmental challenges leads to criticism of existing solutions rather than increased compliance.

5.4 Gender Patterns

The selective gender differences identified in 5.1.2 show how the academic environment moderates traditional gender patterns in environmental behavior, creating unexpected deviations from established research findings.

Recent cross-cultural research by Grossmann et al. (2025) provides important context for these findings. Their study finds that German students often demonstrate more self-critical assessment of their sustainability practices, which they attribute to intense media coverage of sustainability gaps in German society. Their research highlights how several factors influence this self-critical stance: First, extensive media coverage of sustainability challenges in German society may lead students to assess their own efforts more stringently. Second, geographic factors, such as limited public transportation access for students from rural areas, can significantly impact both actual sustainability behaviors and self-reporting. Additionally, their qualitative findings reveal that German students frequently express skepticism about individual sustainability efforts, often viewing them as insufficient compared to needed systematic changes.

The self-critical tendency is also reflected in the qualitative responses of this study. When asked about barriers to sustainable behavior, German respondents frequently emphasize societal factors and systemic limitations rather than individual efforts. Typical responses included critiques of current institutional approaches and expressions of doubt about the impact of individual actions. As one student noted: 'Environmental protection is very important - but unfortunately completely incorrectly implemented by politics.' A broader trend in German sustainability discourse emerges, where heightened awareness of systemic challenges may lead to more reserved self-assessment of individual contributions.

The findings show significant parallels to previous surveys conducted by Germany's Federal Environmental Agency / Umweltbundesamt (BMU & UBA (2019)) on environmental consciousness, while revealing important deviations that highlight the unique characteristics of the university context. Female students in the sample show higher sensitivity to sustainability topics and more frequent implementation of sustainable behaviors in everyday life, particularly in cognitive aspects like resource consumption awareness. These results mirror the Umweltbundesamt's findings that women consistently evaluate environmental problems as more severe and are more likely to implement sustainable practices than men. However, the finding of higher green electricity usage among male students (29.20% vs 13.64%, $p=0.004$) represents a notable departure from established patterns, suggesting that university contexts may alter traditional gender-based environmental behaviors.

The similarities with established Germany's Federal Environmental Agency / Umweltbundesamt research patterns validate the methodology, while the identification of unexpected gender patterns in specific behaviors offers new insights for sustainability education and highlights the complex interactions between academic environment, gender, and environmental behavior.

5.5 Implications for Higher Education

The Technical Knowledge Paradox and policy frustration identified in previous sections necessitate fundamental reconsideration of how environmental education is approached in higher education. Current educational approaches need substantial revision, particularly in light of disciplinary socialization theory (Becher & Trowler, 2001), which explains how academic disciplines shape students' ways of thinking and professional identities. While technical education successfully raises environmental awareness, it may inadvertently create barriers to action through its emphasis on problem complexity and systematic analysis. Kollmuss and Agyeman's (2002) framework identifies how comprehensive environmental knowledge can become a barrier when it overwhelms individuals' sense of agency and efficacy.

Universities need to develop strategies that bridge the gap between technical knowledge and practical action, potentially through integrating more action-oriented learning experiences. Simpler environmental behaviors can provide a model for scaffolding more complex environmental actions, while the sophisticated economic thinking demonstrated by students suggests opportunities for integrating sustainability economics into technical curricula.

However, this recommendation requires careful consideration of a potential paradox: teaching techno-economic optimization could either exacerbate or alleviate analytical paralysis. On one hand, additional cost-benefit analysis frameworks might further entrench the analytical mindset that contributes to decision paralysis. On the other hand, structured economic analysis could channel students' analytical capabilities toward identifying viable pathways for systemic change, transforming critique into constructive solution design. The effectiveness likely depends on pedagogical framing: economics education focused solely on identifying trade-offs and constraints may reinforce paralysis, while economics education emphasizing opportunity identification, innovation potential, and viable implementation pathways could help students translate their technical understanding into actionable strategies. This pedagogical distinction merits empirical investigation in future research.

Educational interventions should systematically address the analytical paralysis that may emerge from deep technical understanding. Breaking down complex environmental challenges into manageable actions while maintaining awareness of their systemic nature could be particularly effective, given the significant difference in adoption rates between simple and complex behaviors. Additionally, the policy frustration expressed by students indicates a need for curricula that not only identify environmental problems but also engage students in developing and evaluating potential solutions.

This approach must address a critical tension: breaking down complex challenges into smaller actions could reinforce the drop-in-the-ocean perception that contributes to analytical paralysis. Effective scaffolding must explicitly connect individual behaviors to collective impact, maintaining students' sense of meaningful agency while acknowledging the systemic complexity they recognize.

The reduced influence of gender on environmental behavior suggests that universities should focus on developing targeted interventions based on disciplinary background rather than demographic categories. The Technical Knowledge Paradox appears to be a more significant factor in determining environmental behavior than traditional demographic variables. Effective environmental education must go beyond simply transmitting technical knowledge about environmental problems, instead focusing on developing students' capacity to translate their understanding into action while addressing their legitimate concerns about policy implementation and systemic barriers.

5.6 Limitations

Several limitations of this study should be considered when interpreting the results and the identification of the Technical Knowledge Paradox.

First, the sample composition requires careful consideration. With 318 participants (technical students n=174, business students n=144), while sufficient for statistical analysis, represents a relatively small portion of the German university student population. The distribution between technical (54.72%) and business students (45.28%) may affect the generalizability of these comparisons. The stark differences between the findings regarding the Technical Knowledge Paradox and previous international studies might partly be explained by cultural factors specific to the German context, as highlighted in the gender patterns analysis.

Second, the cross-sectional design captures only a snapshot of student attitudes and behaviors. While the statistical analyses reveal significant differences between groups at this single point in time, the study cannot track how these differences develop over time. The observed gap between knowledge and action may persist or change as students progress in their studies and careers, and policy frustration might evolve with increased exposure to environmental challenges.

Third, while the quantitative approach revealed clear patterns in the consciousness-behavior gap and helped identify the Technical Knowledge Paradox, it provided limited insight into the underlying psychological and social mechanisms. The statistical analyses demonstrate significant differences in behavior adoption with varying rates across different environmental actions - but cannot fully explain the cognitive and social processes that create these variations. Although the qualitative insights provided valuable context for understanding student perspectives on economic integration, policy frustration, and systemic barriers, a more comprehensive mixed-methods approach would be needed to fully understand the mechanisms underlying the Technical Knowledge Paradox.

Finally, the cultural specificity of the findings, particularly the self-critical tendencies observed among German students and their policy frustration, may limit transferability to other educational and cultural contexts. Future research should examine whether the Technical Knowledge Paradox manifests similarly across different institutional and national contexts.

6. Conclusion and Recommendations

6.1 Key Findings

Technical and business students demonstrate significant differences in environmental consciousness (M = 5.82, SD = 2.15 vs M = 5.03, SD = 2.38) (see table 9 in Attachment C) while showing unexpected patterns in behavioral engagement . The data particularly highlights the Technical Knowledge Paradox, where deeper technical understanding appears to inhibit rather than promote environmental action. Evidence includes varying adoption rates of sustainable practices, with notably lower engagement in more complex actions (active engagement: 10.4%).

The qualitative analysis revealed five key dimensions underlying the Technical Knowledge Paradox: (1) sophisticated economic integration, where students demonstrate complex cost-benefit thinking about sustainability; (2) alternative action pathways, including creative approaches like using second-hand platforms; (3) systemic awareness and responsibility that emphasizes large-scale changes over individual actions; (4) personal responsibility barriers due to competing life priorities; and notably, (5) policy frustration and implementation critique. Students express significant dissatisfaction with current environmental policies, with responses like "Germany approaches it too strictly, while others abroad pay 0.0% attention to it" and advocacy for "subsidies and creating incentives instead of more bans or laws." Policy skepticism represents a previously unidentified dimension where technical knowledge leads to criticism of existing solutions rather than increased compliance.

The results also reveal important cultural context specific to German students, who demonstrate more self-critical assessment of their sustainability practices compared to international patterns. Self-critical tendencies, attributed to intense media coverage of sustainability gaps in German society, may moderate both behavioral reporting and actual environmental engagement, contributing to the observed knowledge-action gap.

Gender-related patterns proved more nuanced than previous research suggested, with significant differences in some behaviors (male students showing higher green electricity usage: 29.20% vs 13.64%, $p=0.004$) but not others (sustainable transportation behaviors showing no significant differences). The results indicate a shift in traditional gender-based environmental behavior patterns, particularly within academic settings, where the university environment appears to moderate established gender differences in environmental consciousness and behavior.

6.2 Recommendations for Universities

The knowledge-action gap identified in this study aligns with Kollmuss and Agyeman's (2002) framework for understanding barriers to pro-environmental behavior. Universities need to develop comprehensive strategies that address the technical knowledge paradox while fostering practical implementation of environmental awareness.

Universities should systematically advance sustainability education by integrating practical implementation into core academic work. Awarding credit points for sustainable initiatives or requiring participation in service-learning programs can bridge the gap between knowledge and action. Simpler environmental behaviors can provide a model for scaffolding more complex environmental actions through structured skill-building approaches.

Institutions should create targeted interventions based on disciplinary background rather than demographic categories. The Technical Knowledge Paradox appears to be a more significant factor than traditional demographic variables. Technical students require educational approaches that address potential analytical paralysis, while business students need stronger foundational environmental awareness. The sophisticated economic thinking demonstrated by students suggests opportunities for integrating sustainability economics into technical curricula.

Universities should address the policy frustration expressed by students by developing curricula that not only identify environmental problems but also engage students in developing and evaluating potential solutions. Students' advocacy for "subsidies and creating incentives instead of more bans or laws" indicates a need for education that bridges technical knowledge with practical policy implementation and addresses their legitimate concerns about systemic barriers.

Educational approaches should break down complex environmental challenges into manageable actions while maintaining awareness of their systemic nature. Scaffolding approaches can help overcome the paralysis that arises from deep technical understanding of environmental complexity, allowing students to maintain agency while appreciating the full scope of environmental challenges.

Sustainability should become mandatory components across all degree programs rather than remaining elective options. Universities should establish practical advisory and implementation centers for sustainable campus projects, providing students with direct opportunities to translate their environmental knowledge into concrete action.

6.3 Future Research Directions

The Technical Knowledge Paradox identified in this study warrants further investigation, particularly regarding its manifestation across different cultural and institutional contexts. Cross-cultural validation studies are essential to determine whether this paradox—where comprehensive technical understanding creates action barriers—represents a universal phenomenon or is specific to German educational contexts. Replication studies in diverse national settings could examine whether the relationship between technical knowledge and analytical paralysis manifests consistently across different educational systems, cultural values, and institutional structures. Various educational approaches might help bridge the gap between technical knowledge and environmental action and require systematic evaluation. Policy frustration emerged as a previously unidentified dimension where technical knowledge leads to criticism rather than compliance with environmental solutions. Investigation of how policy skepticism manifests in different political and educational contexts could inform pedagogical approaches that channel critical analysis into constructive policy development. Cross-cultural studies could examine whether the preference for "subsidies and incentives instead of bans or laws" reflects broader patterns in technically-oriented disciplines or represents German educational culture specifically.

Gender patterns in academic settings revealed unexpected deviations from traditional environmental behavior research, with male students showing higher green electricity usage despite females demonstrating stronger cognitive sustainability frameworks. Academic environments may permanently moderate traditional gender differences in environmental behavior and warrant longitudinal investigation.

Methodologically, combining quantitative measurements with qualitative insights would better illuminate the mechanisms behind the technical knowledge paradox. Mixed-methods research should particularly focus on testing scaffolding approaches that build from simpler environmental behaviors to more complex environmental actions, evaluating which educational interventions effectively address analytical paralysis while maintaining technical rigor.

Implementation research is needed to test the educational recommendations emerging from this study, particularly the effectiveness of discipline-specific approaches, policy evaluation curricula, and sustainability economics integration in technical programs. Addressing the Technical Knowledge Paradox through targeted educational design may improve both environmental consciousness and behavioral implementation in technically-oriented disciplines and requires empirical validation.

The results of this study contribute to theoretical insights as it highlighted change factors in interorganisational contexts, such as structures and processes that enable cooperation on sustainability goals or the consideration of sustainability aspects in early phases of the cooperation (formulation of strategic goals, consideration of sustainability in contracts). The case study character also allowed identifying factors that are particularly relevant for the health sector (e.g. patient-centred organizational culture driven by double securing hygienic aspects). At the same time, there are a number of practical implications that can be derived from the study and that have been discussed with practice partners of the project (representatives from hospitals, service companies and other stakeholders such as the German Association for Facility Management (GEFMA)).

These implications encompass for example the need to involve stakeholders (among others employees, patients, service providers at different levels of the value chain) in the development of sustainability-related policies and measures. This would be reflected in a change of understanding of internal and external service providers as strategic allies in favour of sustainability, with appropriate (contractual) conditions and appropriate communication. Furthermore, results indicate that hospitals and service providers should establish appropriate governance structures and focus more on the formulation and measurement of clear sustainability related objectives. Finally, target group-oriented communication needs to be enhanced that accompanies well-designed bottom-up and top-down change processes.

There are certainly a number of limitations of the study. Firstly, the process of deriving impact factors form literature could be enhanced by extending the literature basis and grouping context factors by means of a content analysis. Besides, because of its qualitative-explorative character, the national focus and the limited number of interviews, theoretical and practical implications have a case study character and need to be validated for other contexts. As explained in chapter 2.3 change management is influenced by a number of factors (e.g. regulatory context, culture), which vary not only between countries, but also - as in Germany - between Federal states and potentially between hospitals. These differences refer for example to the size (from small hospitals with primary care services to big hospitals providing maximum care), the agency (public, private, ecclesial), the link to an university (university hospitals) or the focus (hospitals providing a broad range of treatments versus hospitals with a focus in specific medical disciplines). Within the study, we covered some, but not all of these peculiarities, and further research would be necessary to uncover potential differences in the collaboration between hospital and service provider based on hospital characteristics or region of activity. The qualitative results of this study therefore need to be understood a basis for further quantitative and / or trigonometrical research approaches in other national or an international context to validate and confirm its results and or uncover geographical or other differences.

Declarations

Ethics Statement

This study involved minimal-risk survey research with adult university students. The research was conducted under faculty supervision at a German university of applied sciences as part of a Bachelor thesis program (2023-2024). Participation was voluntary and anonymous, with no collection of personally identifiable information. Informed consent was obtained through participants' voluntary completion and submission of the online survey after being informed about the study's purpose, data handling, and their right to withdraw. All data handling complied with EU GDPR regulations. At the time of data collection, formal ethics committee review was not required for this type of minimal-risk educational research at our institution, as confirmed by institutional guidelines.

Consent to Participate

Informed consent was obtained from all participants prior to survey participation. Participants were informed of the study's purpose, voluntary nature of participation, their right to withdraw at any time, and data handling procedures.

Consent to Publish

Not applicable. The study does not include any identifiable images or personal data of individual participants.

Final remark (Declaration of AI Usage)

During the preparation of this work the author(s) used [Elicit / ChatGPT / Grafiati / Claude] in order to [search for more literature / sometimes rephrase texts / manage literature properly / interpretation of statistical values & working on revisions]. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Data Availability Statement

The data that support the findings of this study are available on reasonable request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions, as they contain information that could compromise the confidentiality of research participants under GDPR regulations.

References

Adomßent, M., Fischer, D., Godemann, J., Herzig, C., Otte, I., Rieckmann, M., & Timm, J. (2014). Emerging areas in research on higher education for sustainable development – management education, sustainable consumption and perspectives from Central and Eastern Europe. *Journal of Cleaner Production*, *62*, 1–7. https://doi.org/10.1016/j.jclepro.2013.09.045

Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, *27*(1), 14–25. https://doi.org/10.1016/j.jenvp.2006.12.002

Becher, T., & Trowler, P. R. (2001). *Academic tribes and territories. intellectual enquiry and the culture of disciplines*. Open University Press. (Original veröffentlicht im Jahr 1989)

BMU & UBA. (2019). *Umweltbewusstsein in Deutschland 2018: Ergebnisse einer repräsentativen Bevölkerungsumfrage / Environmental awareness in Germany 2018: results of a representative population survey*.

Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU) & Umweltbundesamt (UBA). https://www.umweltbundesamt.de/publikationen/umweltbewusstsein-in-deutschland-2018

Elkington, J. (1997). *Cannibals with forks: The triple bottom line of 21st century business*. Capstone.

Elkington, J. (2018). *25 years ago I coined the phrase "triple bottom line." here's why it's time to rethink it.* Harvard Business Review. https://hbr.org/2018/06/25-years-ago-i-coined-the-phrase-triple-bottom-line-heres-why-im-giving-up-on-it

Grossmann, A. G., Tran, M. D., Liu, X., & Kriehn, T. (2025). Similarities and contrasts: A comparative study of student perceptions of sustainability in the USA and Germany. *Cleaner Engineering and Technology*, *24*, 100889. https://doi.org/10.1016/j.clet.2025.100889

Kollmuss, A., & Agyeman, J. (2002). Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, *8*(3), 239–260. https://doi.org/10.1080/13504620220145401

Leal Filho, W., Shiel, C., Paço, A., Mifsud, M., Ávila, L. V., Brandli, L. L., Molthan-Hill, P., Pace, P., Azeiteiro, U. M., Vargas, V. R., & Caeiro, S. (2019). Sustainable Development Goals and sustainability teaching at universities: Falling behind or getting ahead of the pack? *Journal of Cleaner Production*, *232*, 285–294. https://doi.org/10.1016/j.jclepro.2019.05.309

Lozano, R., Lukman, R., Lozano, F. J., Huisingh, D., & Lambrechts, W. (2013). Declarations for sustainability in higher education: Becoming better leaders, through addressing the university system. *Journal of Cleaner Production*, *48*, 10–19. https://doi.org/10.1016/j.jclepro.2011.10.006

Sammalisto, K., Sundström, A., & Holm, T. (2015). Implementation of sustainability in universities as perceived by faculty and staff – a model from a Swedish university. *Journal of Cleaner Production*, *106*, 45–54. https://doi.org/10.1016/j.jclepro.2014.10.015

Stephens, J. C., Hernandez, M. E., Román, M., Graham, A. C., & Scholz, R. W. (2008). Higher education as a change agent for sustainability in different cultures and contexts. *International Journal of Sustainability in Higher Education*, *9*(3), 317–338. https://doi.org/10.1108/14676370810885916

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, 12(2), 257–285. https://doi.org/10.1207/s15516709cog1202_4

Vicente-Molina, M. A., Fernández-Sáinz, A., & Izagirre-Olaizola, J. (2013). Environmental knowledge and other variables affecting pro-environmental behaviour: Comparison of university students from emerging and advanced countries. *Journal of Cleaner Production*, *61*, 130–138. https://doi.org/10.1016/j.jclepro.2013.05.015

World Commission on Environment and Development. (Hrsg.). (1987). *Our common future*. Oxford University Press.

Zelezny, L. C., Chua, P.-P., & Aldrich, C. (2000). New ways of thinking about environmentalism: Elaborating on gender differences in environmentalism. *Journal of Social Issues*, 56(3), 443–457. https://doi.org/10.1111/0022-4537.00177

Appendix A: Study Program Classification

Sample and Data Cleaning

Initial dataset: 328 students. Final sample: 318 students (96.95% retention).

Exclusions (n=10, 3.0%): Unclear gender entries (n=8), unclear study program (n=1), program outside scope (n=1, Early Childhood Education).

Classification Criteria

Programs were classified into two categories based on core disciplinary focus:

- **Technical Studies (n=174, 54.72%):** Programs with engineering, technology, informatics, or natural science components (technical problem-solving, technological innovation, scientific methodology).

- **Business Studies (n=144, 45.28%):** Business administration, trade, logistics, management, and social science programs without significant technical components.

Classification Rules

- Interdisciplinary programs (e.g., Industrial Engineering, Business Engineering Logistics) → Technical Studies (due to engineering methodology foundation)
- Abbreviations resolved by institutional context (WI=Industrial Engineering→Technical; TM=Tourism Management→Business)

Program Distribution

- Top Technical Programs: Mechatronics (25), Industrial Engineering (23), Business Engineering Logistics (18), Mechanical Engineering (11), Other Technical (53 distributed across 13 additional programs)
- Top Business Programs: Business Admin - Consumer Goods Trade (55), Trade Logistics (21), Tourism Management (10), Business Administration (10), Other Business (26 distributed across 11 additional programs)
- Gender Distribution: Female n=173 (54.40%), Male n=145 (45.60%)

Note

Complete program listing and detailed classification rationale available from corresponding author upon request. Binary classification *approach and its methodological justification are discussed in Section 3.1 and Section 5.6 (Limitations).*

Appendix B: Questionnaire

Table 8: Survey Questions Organized by Type and Category (Source: (BMU & UBA (2019)).

No.	Question (German)	Question (English)	Question Type	Category
-	Wie alt bist du?	How old are you?	Open-ended Question	Demographic Question
-	Was ist dein Geschlecht?	What is your gender?	Closed-ended Question	Demographic Question
-	An welcher Hochschule/Universität studierst du?	Which university/college are you studying?	Open-ended Question	Demographic Question
-	Was studierst du?	What is your field of study?	Open-ended Question	Demographic Question
-	Welchen Hochschulabschluss strebst du an?	What academic degree are you pursuing?	Closed-ended Question	Demographic Question
-	In welchem Semester bist du?	In which semester are you?	Open-ended Question	Demographic Question
1	Menschengemachte Umweltprobleme wie die Abholzung der Wälder oder	Human-made environmental problems like deforestation or	Likert Scale	Environmental Affect

	das Plastik in den Weltmeeren empören mich.	plastic in the oceans make me angry.		
2	Der Klimawandel bedroht auch unsere Lebensgrundlagen hier in Deutschland.	Climate change also threatens the living conditions here in Germany.	Likert Scale	Environmental Affect
3	Es beunruhigt mich, wenn ich daran denke, in welchen Umweltverhältnissen zukünftige Generationen wahrscheinlich leben müssen.	It worries me to think about the environmental conditions future generations will likely live in.	Likert Scale	Environmental Affect
4	Es macht mich wütend, wenn ich sehe, dass Deutschland seine Klimaschutzziele verfehlt.	It makes me angry to see that Germany is missing its climate protection goals.	Likert Scale	Environmental Affect
5	Ich freue mich über Initiativen, die nachhaltige Lebensweisen einfach ausprobieren, zum Beispiel Ökodörfer, Slow-Food-Bewegung.	I'm happy about initiatives that simply try out sustainable lifestyles, for example eco-villages, Slow Food movement.	Likert Scale	Environmental Affect
6	Ich ärgere mich, wenn mir andere vorschreiben wollen, dass ich umweltbewusst leben soll.	I'm annoyed when others want to prescribe how I should live environmentally consciously.	Likert Scale	Environmental Affect
7	Die Umweltproblematik wird von vielen Umweltschützerinnen und Umweltschützern stark übertrieben.	The environmental issue is greatly exaggerated by many environmentalists.	Likert Scale	Environmental Affect
8	Jede und jeder Einzelne trägt Verantwortung dafür, dass wir nachfolgenden Generationen eine lebenswerte Umwelt hinterlassen.	Each individual is responsible for leaving a livable environment for future generations.	Likert Scale	Environmental Affect
9	Wir sollten nicht mehr Rohstoffe verbrauchen, als nachwachsen können.	We should not consume more raw materials than can regenerate.	Likert Scale	Environmental Cognition
10	Mehr Umweltschutz bedeutet auch mehr Lebensqualität und Gesundheit für alle.	More environmental protection also means more quality of life and health for everyone.	Likert Scale	Environmental Cognition
11	Wir müssen Wege finden, wie wir unabhängig vom Wirtschaftswachstum gut leben können.	We must find ways to live well independently of economic growth.	Likert Scale	Environmental Cognition
12	Es gibt natürliche Grenzen des Wachstums, die unsere industrialisierte Welt längst erreicht hat.	There are natural growth limits that the industrialized world has long since reached.	Likert Scale	Environmental Cognition
13	Zugunsten der Umwelt sollten wir alle bereit sein, unseren derzeitigen Lebensstandard einzuschränken.	For the sake of the environment, we should all be willing to restrict the current standard of living.	Likert Scale	Environmental Cognition

14	Für ein gutes Leben sind andere Dinge wichtig als Umwelt und Natur.	Other things are important for a good life besides environment and nature.	Likert Scale	Environmental Cognition
15	Wir brauchen in Zukunft mehr Wirtschaftswachstum, auch wenn das die Umwelt belastet.	We need more economic growth in the future, even if it burdens the environment.	Likert Scale	Environmental Cognition
16	Beim Kauf von Haushaltsgeräten wähle ich besonders energieeffiziente Geräte (A+++ oder A++ Energieeffizienzsiegel).	When buying household appliances, I choose particularly energy-efficient devices (A+++ or A++ energy efficiency label).	Likert Scale	Environmental Behavior
17	Für meine alltäglichen Wege benutze ich das Fahrrad, öffentliche Verkehrsmittel oder gehe zu Fuß.	For my daily routes, I use bicycle, public transportation, or walk.	Likert Scale	Environmental Behavior
18	Beim Einkaufen wähle ich Produkte mit Umweltsiegel, zum Blauer Engel, EU-Biosiegel oder EU-Ecolabel.	When shopping, I choose products with environmental labels, such as Blue Angel, EU Organic Label, or EU Ecolabel.	Likert Scale	Environmental Behavior
19	Ich kaufe Lebensmittel aus kontrolliert-biologischem Anbau.	I buy food from controlled organic cultivation.	Likert Scale	Environmental Behavior
20	Zu den Hauptmahlzeiten esse ich Fleisch.	I eat meat during main meals.	Likert Scale	Environmental Behavior
21	Beziehen Sie derzeit Ökostrom?	Are you currently using green electricity?	Dichotomous Question	Environmental Behavior
22	Ich spende Geld für den Umwelt und Klimaschutz.	I donate money for environmental and climate protection.	Dichotomous Question	Environmental Behavior
23	Ich engagiere mich aktiv für den Umwelt- und Klimaschutz.	I actively engage in environmental and climate protection.	Dichotomous Question	Environmental Behavior
24	Wenn ja, wie engagierst du dich?	If yes, how do you engage?	Open-ended Question	Environmental Behavior
25	Was ist deine generelle Meinung zum Thema Nachhaltigkeit? Gibt es etwas, das du zu diesem Thema noch hinzufügen oder loswerden möchtest?	What is yThe general opinion on the topic of sustainability? Is there anything you would like to add or express about this topic?	Open-ended Question	Opinion

Appendix C: Complete Statistical Results and Boxplot Analyses

C.1 Complete Mann-Whitney U Test Results (Technical vs Business Students)

Table 9 presents the comprehensive statistical analysis of all 20 Likert-scale questions comparing technical and business students. This complete documentation supplements the selected key findings presented in the main text.

Table 9: Differences between Technical and Business Students (Mann Whitney U test, SD = Standard Deviation) n=318 (10-point Likert scale: 1 = strongly disagree, 10 = strongly agree)

Category	Question	Mean Technical	SD Technical	Mean Business	SD Business	z-value	p-value	Conclusion
Environmental Affect	1	7,80	1,86	5,02	3,07	7,71	0,00000000	Technical students show significantly higher environmental concern.
Environmental Affect	2	7,62	2,24	5,12	3,02	7,12	0,00000000	Technical students show significantly higher climate change awareness.
Environmental Affect	3	7,42	2,33	5,02	2,9	7,04	0,00000000	Technical students are significantly more concerned about future generations.
Environmental Affect	4	6,10	2,57	4,68	2,56	4,8	0,00000157	Technical students are significantly angrier about missed climate goals.
Environmental Affect	5	6,39	2,37	5,15	2,42	4,68	0,00000288	Technical students derive significantly more pleasure from sustainable lifestyles.
Environmental Affect	6	5,49	2,68	7,49	2,81	-6,26	0,00000000	Business students are significantly more annoyed by environmental demands.
Environmental Affect	7	4,59	2,74	7,02	2,97	-6,89	0,00000000	Business students believe significantly environmental issues are more exaggerated.
Environmental Affect	8	8,12	2,09	6,59	2,96	4,44	0,00000909	Technical students feel significantly more responsible for sustainability.
Environmental Cognition	9	7,79	2,25	7,73	2,27	0,12	0,90068862	No significant difference.
Environmental Cognition	10	7,37	2,38	5,37	3,01	5,82	0,00000001	Technical students significantly link more environmental protection to quality of life.
Environmental Cognition	11	7,20	2,46	7,5	2,25	-0,9	0,36687546	No significant difference.

Environ mental Cognition	12	6,23	2,73	5,81	2,45	1,89	0,05820 233	No significant difference (borderline significance).
Environ mental Cognition	13	6,34	2,48	3,7	3,2	7,48	0,00000 000	Technical students are significantly more willing to adjust lifestyles.
Environ mental Cognition	14	5,27	2,16	5,73	1,95	-2,34	0,01924 077	Business students prioritize non-environmental factors significantly more.
Environ mental Cognition	15	3,92	2,2	4,26	1,89	-1,93	0,05391 238	No significant difference (borderline significance).
Environ mental Behavior	16	3,93	1,48	2,93	1,56	5,56	0,00000 003	Technical students prioritize energy efficiency significantly more.
Environ mental Behavior	17	4,18	1,67	3,46	1,76	3,65	0,00025 829	Technical students use eco-friendly transport significantly more.
Environ mental Behavior	18	3,21	1,51	2,32	1,49	5,23	0,00000 017	Technical students choose eco-labeled products significantly more.
Environ mental Behavior	19	3,51	1,43	2,26	1,43	7,36	0,00000 000	Technical students buy organic food significantly more.
Environ mental Behavior	20	3,84	1,45	3,4	1,67	2,33	0,01993 273	Technical students eat meat slightly more frequently.

C.2 Overview of Boxplot Presentations

The following boxplots visualize all statistically significant differences identified in the Mann-Whitney U tests between different study groups. While the main results in the text are presented through selected, particularly meaningful visualizations, this appendix provides complete graphical documentation of all significant findings for comprehensive traceability of research results.

C.3 Interpretation of Boxplot Elements

Each boxplot contains the following statistical information:

- **Median** (middle line): The value that divides responses into two equal halves
- **Quartiles** (box boundaries): 25th percentile (Q1) and 75th percentile (Q3), corresponding to the middle 50% of responses
- **Whiskers** (lines extending from box): Show the range of data within 1.5 times the interquartile range
- **Outliers** (red dots): Extreme values outside the normal distribution
- **Box overlap**: Less overlap indicates stronger group differences

C.4 Discipline-based Differences (Technical vs. Business)

The boxplots for Technical-Business differences (Questions 1-20) consistently show the pattern of the "Technical Knowledge Paradox": Technical students exhibit consistently higher median values in environmental consciousness and behavior, albeit with sometimes greater variability in responses. Particularly notable are:

- **Questions 1-8 (Environmental Affect)**: Technical students show significantly higher emotional concern for environmental issues
- **Questions 9-15 (Environmental Cognition)**: Recognizable but less pronounced differences in cognitive assessment
- **Questions 16-20 (Environmental Behavior)**: Moderate differences in reported behavior that illustrate the theoretical-practical gap

C.5 Gender-based Differences (Male vs. Female)

The gender-specific boxplots reveal a more nuanced picture than traditional studies might suggest. The visualizations show:

- **Selective significance**: Only few questions show statistically meaningful gender differences
- **Reversed expectations**: For some behaviors (e.g., green electricity usage) males show higher adoption
- **Consistent patterns**: Females tend toward higher ratings for cognitive sustainability aspects
- **Overlapping distributions**: Most boxplots show considerable overlap, indicating similar basic attitudes

C.6 Methodological Transparency

All presented boxplots are based on original Likert scale data (1-10) without transformation. The graphical representations allow evaluation of the statistical significances reported in tables within their practical context. In particular, the following aspects can be assessed:

- **Effect sizes**: Magnitude of practical differences beyond statistical significance
- **Distribution characteristics**: Normality, skewness, and outlier patterns in the data
- **Group overlaps**: Extent of shared response ranges between comparison groups

C.7 Limitations of Visualizations

When interpreting the boxplots, the following limitations should be considered:

- The representations show only univariate distributions and no interaction effects
- Ordinal Likert data are treated as continuous, which can be problematic with extreme distributions
- Missing values and response biases are not explicitly visible in the graphical representations
- The cross-sectional survey design does not allow statements about developmental trajectories

This complete documentation of all significant findings supports transparency and traceability of research results and enables further analyses by other research groups.

For additional information on questions 1–20, see the following figures with boxplots (which have not been shown in the main article and have $p < 0.05$)

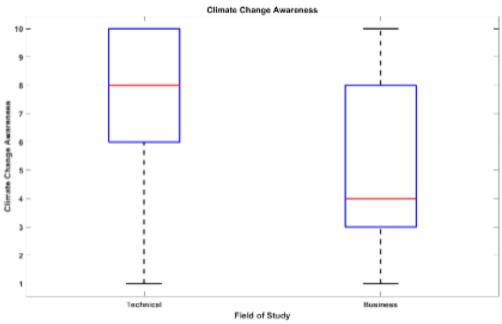

Figure 9: Q2 Climate change also threatens our living conditions here in Germany. Interpretation: Technical students show significantly higher climate change awareness than business students (M=7.62, SD=2.24 vs M=5.12, SD=3.02, p<0.001), reflecting deeper understanding of climate risks and local environmental threats.

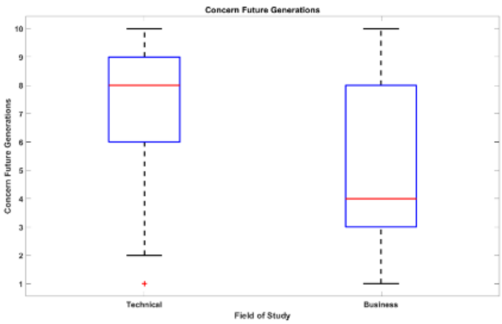

Figure 10: Q3 It worries me to think about the environmental conditions future generations will likely live in. Interpretation: Technical students are significantly more concerned about future generations than business students (M=7.42, SD=2.33 vs M=5.02, SD=2.90, p<0.001), showing greater intergenerational environmental responsibility.

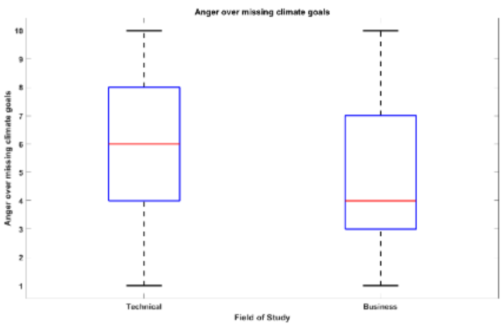

Figure 11: Q4 It makes me angry to see that Germany is missing its climate protection goals. Interpretation: Technical students are significantly more frustrated about missed climate goals than business students (M=6.10, SD=2.57 vs M=4.68, SD=2.56, p<0.001), indicating stronger expectations for environmental policy performance.

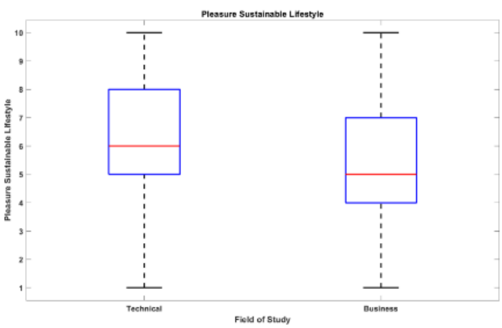

Figure 12: Q5 I'm happy about initiatives that simply try out sustainable lifestyles, for example eco-villages, Slow Food movement. Interpretation: Technical students derive significantly more pleasure from sustainable lifestyle initiatives than business students (M=6.39, SD=2.37 vs M=5.15, SD=2.42, p<0.001), showing greater appreciation for alternative environmental approaches.

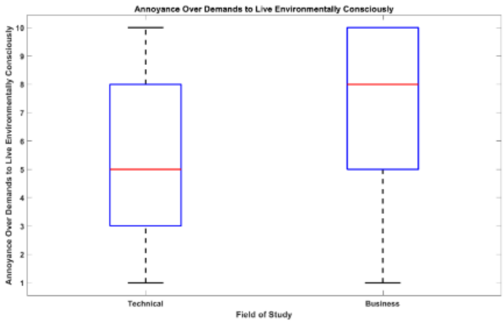

Figure 13: Q6 I'm annoyed when others want to prescribe how I should live environmentally consciously. Interpretation: Business students are significantly more annoyed by environmental demands than technical students (M=7.49, SD=2.81 vs M=5.49, SD=2.68, $p<0.001$), revealing resistance to external environmental pressure and contrasting sharply with technical students' environmental openness.

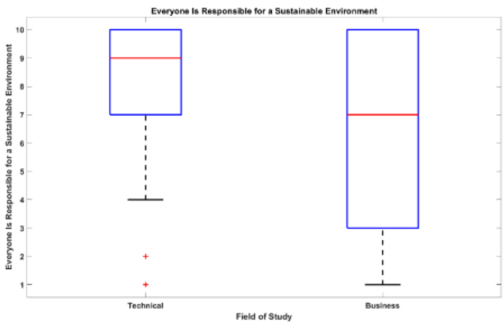

Figure 15: Q8 Each individual is responsible for leaving a livable environment for future generations. Interpretation: Technical students feel significantly more individual responsibility for environmental stewardship than business students (M=8.12, SD=2.09 vs M=6.59, SD=2.96, $p<0.001$), demonstrating stronger personal environmental accountability.

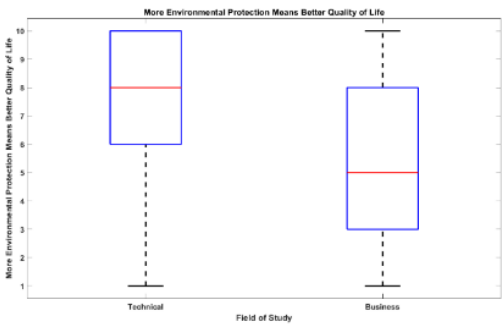

Figure 16: Q10 More environmental protection also means more quality of life and health for everyone. Interpretation: Technical students significantly link environmental protection to quality of life more than business students (M=7.37, SD=2.38 vs M=5.37, SD=3.01, $p<0.001$), showing stronger understanding of environmental-health connections and co-benefits.

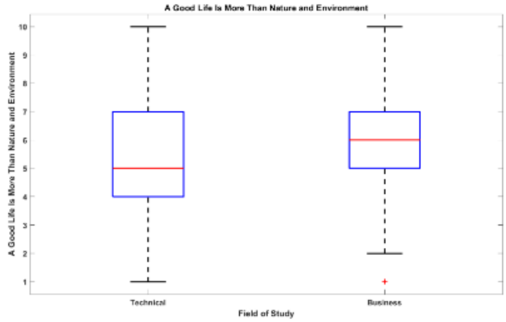

Figure 18: Q14 Other things are important for a good life besides environment and nature. Interpretation: Business students prioritize non-environmental factors significantly more than technical students (M=5.73, SD=1.95 vs M=5.27, SD=2.16, p=0.019), demonstrating different value hierarchies and life priorities.

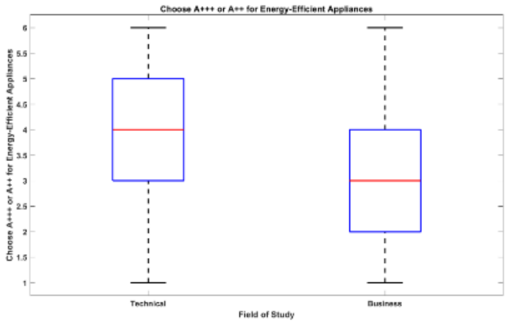

Figure 19: Q16 When buying household appliances, I choose particularly energy-efficient devices (A+++ or A++ energy efficiency label). Interpretation: Technical students prioritize energy efficiency significantly more than business students (M=3.93, SD=1.48 vs M=2.93, SD=1.56, p<0.001), demonstrating translation of environmental consciousness into specific purchasing decisions.

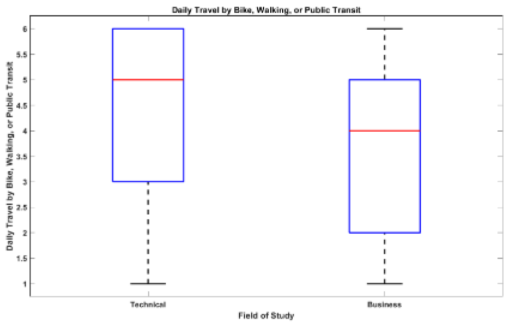

Figure 20: Q17 For my daily routes, I use bicycle, public transportation, or walk. Interpretation: Technical students use eco-friendly transportation significantly more than business students (M=4.18, SD=1.67 vs M=3.46, SD=1.76, p<0.001), showing behavioral implementation of environmental awareness in mobility choices.

Figure 21: Q18 When shopping, I choose products with environmental labels, such as Blue Angel, EU Organic Label, or EU Ecolabel. Interpretation: Technical students choose eco-labeled products significantly more than business students (M=3.21, SD=1.51 vs M=2.32, SD=1.49, p<0.001), indicating greater attention to environmental certification and labeling.

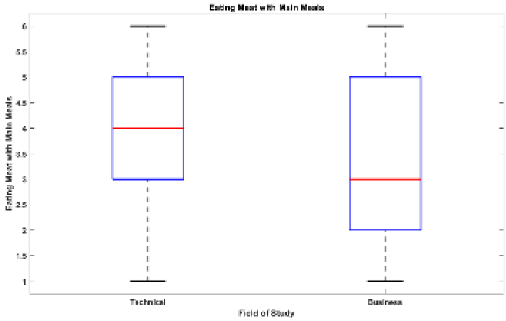

Figure 23: Q20 I eat meat during main meals. Interpretation: Technical students eat meat slightly more frequently than business students (M=3.84, SD=1.45 vs M=3.40, SD=1.67, p=0.020), representing a moderate difference that shows technical environmental consciousness doesn't automatically translate to all dietary behaviors.

Remark: Questions Q9 (resource consumption), Q11 (growth-independent living), Q12 (natural growth limits), and Q15 (economic growth vs. environment) showed no statistically significant differences between technical and business students ($p>0.05$). These findings suggest that both groups share similar cognitive frameworks regarding fundamental sustainability principles and resource constraints, despite their pronounced differences in emotional engagement and behavioral implementation documented above.

Appendix D: Complete Gender Statistical Results and Boxplot Analyses

D.1 Complete Mann-Whitney U Test Results (Male vs Female Students)

Table 10 presents the comprehensive statistical analysis of all 20 Likert-scale questions comparing male and female students. This complete documentation supplements the selected key findings presented in the main text.

Table 10: Complete Differences between Male and Female Students (Mann Whitney U test, SD = Standard Deviation) n=318 (10-point Likert scale: 1 = strongly disagree, 10 = strongly agree)

Category	Question	Mean Male	SD Male	Mean Female	SD Female	z-value	p-value	Conclusion
Environmental Affect	1	6,90	2,64	6,37	2,91	1,5	0,1334	No significant difference.
Environmental Affect	2	6,63	2,95	6,57	2,76	0,34	0,7310	No significant difference.
Environmental Affect	3	6,42	2,77	6,42	2,87	-0,18	0,8610	No significant difference.
Environmental Affect	4	5,24	2,81	5,74	2,46	-1,65	0,0984	No significant difference.
Environmental Affect	5	5,72	2,51	5,94	2,4	-0,99	0,3219	No significant difference.
Environmental Affect	6	6,35	2,87	6,22	2,94	0,3	0,7665	No significant difference.

Environmental Affect	7	5,43	3,02	5,73	3,11	-0,93	0,3524	No significant difference.
Environmental Affect	8	7,22	2,61	7,73	2,54	-1,94	0,0529	No significant difference.
Environmental Cognition	9	7,36	2,43	8,13	1,97	-2,76	0,0058	Female participants show significantly higher agreement.
Environmental Cognition	10	6,19	2,71	6,85	2,87	-2,27	0,0235	Female participants link environmental protection to quality of life significantly stronger.
Environmental Cognition	11..	6,91	2,67	7,7	2,01	-2,31	0,0210	Female participants support lifestyle adjustments significantly more.
Environmental Cognition	12	5,74	2,93	6,31	2,32	-1,53	0,1262	No significant difference.
Environmental Cognition	13	5,06	2,87	5,41	3,26	-1,05	0,2920	No significant difference.
Environmental Cognition	14	5,62	2,1	5,25	2,08	1,61	0,1076	No significant difference.
Environmental Cognition	15	4,29	2,16	3,84	1,96	1,43	0,1523	No significant difference.
Environmental Behavior	16	3,54	1,51	3,45	1,65	0,51	0,6106	No significant difference.
Environmental Behavior	17	3,86	1,8	3,97	1,67	-0,33	0,7452	No significant difference.
Environmental Behavior	18	2,81	1,49	2,83	1,61	0,09	0,9257	No significant difference.
Environmental Behavior	19	3,12	1,54	2,83	1,56	1,78	0,0754	No significant difference.
Environmental Behavior	20	4,03	1,51	3,33	1,53	4,01	0,0001	Male participants consume meat significantly more frequently.

This complete table supplements the selected key findings presented in Section 4.2 of the main text and provides comprehensive documentation of all statistical comparisons between male and female students.

D.2 Overview of Gender-based Visualizations

The following boxplots visualize the statistically significant differences between male and female students identified through Mann-Whitney U tests. In contrast to the pronounced disciplinary differences between Technical and Business students, the gender analyses reveal a considerably more nuanced picture with selective yet meaningful differences.

D.3 Interpretation of Gender-specific Patterns

Each boxplot documents the following statistical information:

- **Median** (middle line): The value that divides responses into two equal halves
- **Quartiles** (box boundaries): 25th percentile (Q1) and 75th percentile (Q3), representing the middle 50% of responses
- **Whiskers** (lines extending from box): Show the data range within 1.5 times the interquartile range
- **Outliers** (red dots): Extreme values outside the normal distribution
- **Box overlap**: Less overlap indicates stronger group differences

D.4 Characteristic Gender Differences

The gender-based boxplots reveal a more complex pattern than traditional studies might suggest:

Environmental Cognition

- **Questions 9-11**: Female students show significantly higher agreement on questions regarding resource consumption, environmental protection, and growth-independent living
- **Consistent patterns**: Females tend toward higher cognitive sustainability assessments

Environmental Behavior

- **Meat consumption (Q20)**: Male students show significantly higher meat consumption (M = 4.03 vs F = 3.33)
- **Green electricity usage (Q21)**: Surprisingly higher adoption among male students (29.20% vs 13.64%)

D.5 Deviations from Traditional Gender Patterns

The visualizations document notable deviations from established gender stereotypes:

- **Reversed expectations**: For some behaviors (e.g., green electricity usage), males show higher adoption rates
- **Selective significance**: Only few questions show statistically meaningful gender differences

Overlapping distributions: Most boxplots show considerable overlap, indicating similar basic attitudes

D.6 Methodological Characteristics of Gender Analysis

Compared to Technical-Business differences, the gender analyses show:

- **Smaller effect sizes**: Practical differences are often smaller despite statistical significance
- **Inconsistent patterns**: No consistent directional differences across all categories
- **Cultural context**: Possible deviations from international gender patterns in the German university context

D.7 Interpretation in Context of the "Technical Knowledge Paradox"

Gender differences are significantly less pronounced than disciplinary differences and demonstrate:

- **Secondary importance**: Gender plays a subordinate role compared to study discipline
- **Situational relevance**: Gender effects manifest only in specific areas
- **Complex interactions**: Possible interactions between gender and study discipline

D.8 Limitations of Gender Visualizations

When interpreting gender boxplots, the following limitations should be considered:

- **Binary classification**: The reduction to Male/Female does not capture the diversity of gender identities
- **Sample size**: With n=145 (Male) and n=173 (Female), groups are limited for subgroup analyses
- **Cultural bias**: Results reflect specifically German university contexts
- **Temporal effects**: Cross-sectional design does not capture developmental gender differences

D.9 Contribution to Overall Analysis

The gender-specific boxplots complement the main findings through:

- **Nuancing**: Demonstrating that not all demographic factors are equally influential
- **Contrasting**: Highlighting the particular importance of disciplinary differences
- **Validation**: Confirming that the "Technical Knowledge Paradox" is primarily disciplinary rather than gender-related

This complete documentation of gender-specific findings supports transparency of research results and enables differentiated interpretations of the complex relationships between demographic factors and environmental consciousness.

For additional information on questions 1–20, see the following figure with boxplot (which has not been shown in the main article and has $p < 0.05$)

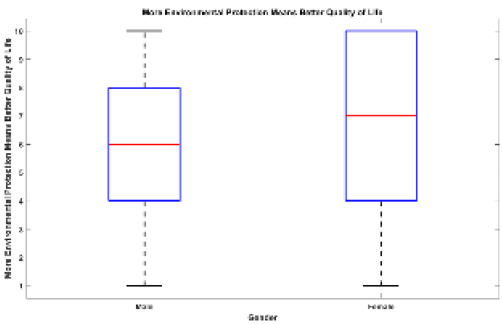

Figure 25: Q10 More environmental protection also means more quality of life and health for everyone. Interpretation: Female participants link environmental protection to quality of life significantly stronger (M=6.85, SD=2.87 vs M=6.19, SD=2.71, p=0.0235), showing enhanced understanding of environmental-health connections.

The majority of questions showed no statistically significant gender differences (p>0.05), including Q1-Q2, Q4-Q8 (environmental affect), Q12-Q15 (environmental cognition), and Q16-Q19 (environmental behavior). This pattern contrasts sharply with the systematic disciplinary differences documented in Appendix C, confirming that gender plays a subordinate role compared to academic discipline in shaping environmental consciousness among German university students. Only four questions revealed significant gender differences, which are visualized in the boxplots. Complete statistical details for all non-significant comparisons are available from the corresponding author upon request.