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Exploring the Role of Teacher Self-Efficacy and Personal Environmental Practices in Integrating Sustainability into Teaching: A Network Analysis of German Teachers

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Abstract

Integrating sustainability into school curricula is increasingly important, with teachers seen as key "change agents". However, many lack specific preparation for Education for Sustainable Development (ESD), and there is considerable variability in how explicitly or implicitly they address these topics in their teaching. The purpose of this study was to investigate interpersonal and contextual factors related to ESD implementation, including self- and action-efficacy, personal attitudes, eco-anxiety, private engagement and knowledge, alongside perceived student interest and pressure, and school awareness. A total of 419 teachers from various German primary and secondary schools (M = 45 years, SD = 10.9; 68% female; teaching experience: M = 16 years, SD = 9.9) completed a cross-sectional online survey and knowledge test. Findings showed significant variation in how often teachers included sustainability in their teaching, unrelated to gender, school type, or training. Network analyses revealed that self-efficacy and private engagement—rather than teachers' knowledge—were central predictors of ESD integration. Notably, private engagement emerged as a key bridge in the network, while high self-efficacy was closely tied to frequent classroom implementation. These results suggest that fostering teachers' personal commitment and confidence may be more effective than focusing solely on knowledge to promote sustainability education.

Keywords: sustainability; self-efficacy; motivation; teacher; education for sustainable development

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1. Introduction

Climate change is one of the greatest challenges for society today, necessitating a response not only from a political perspective but also from collective and individual efforts. In this context, Education for Sustainable Development (ESD) is a transformative learning process aimed at equipping learners with the knowledge, skills, attitudes, and values necessary to address the complex challenges of sustainable development. These include climate change, biodiversity loss, poverty, and inequality. ESD empowers individuals to make informed decisions and take responsible actions for the environment, economic viability, and a fair society, both for present and future generations [1]. The global relevance of ESD is also visible in the United Nations' Sustainable Development Goals (SDGs), especially Goal 4, which aims to ensure inclusive and equitable quality education. Therein, it is also emphasized that ESD should be integrated into all levels of education by 2030. This is considered essential for fostering the competencies required to create a sustainable future,

such as critical thinking, problem-solving, and the ability to collaborate across cultural and disciplinary boundaries [2].

To this end, teachers are pivotal. As facilitators of learning, they are in a key position to influence students' understanding of and attitudes towards sustainability. Frequently, however, ESD is not yet embedded in common, national curricula. Besides implementing curricular content, teachers can act as "change agents" by integrating sustainability principles into their teaching practices, thereby fostering a culture of sustainability within their classrooms and broader school communities [3]. This exemplifies how ESD is a unique and complex approach, not just an implementation of new guidelines. As such, it requires comprehensive actions across the entire school, including teachers and students, whose lives and futures are directly affected by ESD issues. Therefore, while general models of how teachers implement change can help in grasping the issue of integrating ESD into teaching content and practice, specific insights are necessary to better understand the variability between teachers in their integration of ESD into their lessons [4]. Such variability between teachers is still little understood, including the surrounding nomological net. More specifically, the role of an ESD educator requires teachers to be well-prepared and confident in their ability to teach (complex and partly controversial) sustainability topics. In other words, they are likely to require high efficacy beliefs to address these topics in their teaching. In addition, following theories relating to competency models and educational psychology, many further factors can be considered as relevant for how teachers integrate ESD in their teaching, including personal factors such as attitudes, worries, private engagement, and knowledge, alongside perceived student interest and pressure, and school awareness.

Prior research has mostly examined these aspects separately, often with a focus on pre-service teachers and limited subsets of relevant constructs. There is a lack of more comprehensive investigations into how these factors interact in shaping ESD implementation among in-service teachers. Accordingly, the purpose of the present research was to investigate interindividual differences in teachers' implementation of ESD in a broad sample of German school teachers and explore its nomological net with the aforementioned factors. By exploring these questions, we aim to identify relevant levers for understanding and enhancing the effectiveness of sustainability education. This not only contributes to the academic understanding of ESD but also provides practical insights for policymakers and practitioners aiming to promote sustainable practices in schools.

2. ESD and Role of Teachers as "Change Agents"

ESD subsumes the addressing of critical global challenges such as climate change, biodiversity loss, environmental degradation, and economic instability. To this end, ESD seeks to foster a holistic understanding of sustainability. This is considered essential for developing the necessary attitudes and values that underpin sustainable living and for promoting behaviors that support environmental, economic, and social viability [5]. Accordingly, embedding ESD into school curricula transcends traditional disciplinary boundaries.

In practice, how ESD is embedded into school curricula varies significantly across different countries and educational systems [6]. Some nations have developed comprehensive national frameworks and policies that mandate the inclusion of ESD across all levels of education; most have not [6]. Many countries are still developing such frameworks, facing challenges like insufficient resources and limited policy support [7]. In Germany, ESD is not yet systematically formally anchored but is increasingly integrated into educational landscapes [8,9]. Accordingly, this provides a suitable foundation for investigating individual differences between teachers in ESD practices along with personal and school-related covariates.

The whole-institution approach advocated by UNESCO [1] emphasizes the need for ESD to stretch across all aspects of school life, including governance, operations, and community engagement. Specifically, this approach encourages schools to model sustainable practices, such as reducing energy consumption, promoting recycling, and engaging with local communities on sustainability initiatives, in a similar manner as universities [10]. By doing so, teachers and students can jointly create an environment that supports and reinforces the principles of sustainability, while providing a living example for students and staff.

This makes it clear that multiple, person- and institution-based factors matter for the incorporation of ESD in schools, and that individual teachers are central to the successful implementation of ESD [11]. The role of teachers as "change agents" seems to be particularly vital for the success of ESD, as they are responsible for translating educational policies and curricula into meaningful learning experiences for students. As facilitators of learning and role models, they are ideally positioned to shape students' understanding of and attitudes towards sustainability. Integrating sustainability principles into their teaching practices, teachers can further strengthen a culture of sustainability within their classrooms and extend it to the broader school community [12]. However, there is arguably substantial variability in how teachers incorporate ESD into their teaching in both the explicit and implicit integration of sustainability topics [13]. These interindividual differences in how teachers integrate sustainability and environmental conservation into their teaching, and the reasons for teachers (not) to do so, are still barely understood [13], despite their high relevance for the broader research desideratum of identifying how teachers successfully implement sustainability education—a goal that has been identified as a key research aim in the field [4] and to which end, particularly, quantitative insights are called for [14]. Teacher competence models and insights from educational psychology provide grounds to draw potential reasons and sources for interindividual differences.

Multiple theoretical models outline the competencies teachers need for effectively integrating Education for Sustainable Development (ESD) into their lessons. These models, including UNESCO's Competency Framework for ESD, UNECE's key competencies, and the European Competence Framework for Educators on ESD, were explicitly formulated regarding teacher competencies; others [15,16], have been adapted for educators. Common aspects across these models are teachers' sustainability knowledge, practical application skills, and fostering of positive attitudes and behaviors toward sustainability [16–18]. Accordingly, the models emphasize the importance of self- and action-efficacy and knowledge. For example, system thinking enhances self-efficacy by helping teachers understand and explain complex sustainability issues. In addition, personal aspects like attitudes and worries are also relevant to teaching sustainability, as a personal commitment to sustainability has been found to enable educators to promote value-based, future-oriented learning in line with ESD goals [15]. Moreover, teachers' private engagement with sustainability outside the classroom should reinforce behaviors aligned with ESD principles, strengthening authenticity and commitment in teaching. Further, from an educational psychology perspective, it is also important to consider aspects of the social context of teaching, such as perceived student interest and student pressure. Finally, as previously stated, school awareness of sustainability is expected to impact teaching [1]. This reflects the broader social and institutional context in which teachers operate. Perceived student interest and pressure can significantly drive a teacher's motivation to integrate ESD, while school awareness reflects the level of institutional support that can facilitate or hinder ESD.

In conclusion, self-and action-efficacy, personal attitudes, worries, private engagement, and knowledge, alongside perceived student interest, pressure, and school awareness, are

plausible elements of the nomological net of teachers' ESD integration that we investigated and elaborate on in what follows.

3. Teachers' Efficacy as Key Motivational Factor

To fulfill their role as change agents, teachers must be adequately prepared and supported. This involves not only the necessary content knowledge but also the pedagogical skills to engage students in critical discussions about sustainability and to inspire them to take action. Efficacy, encompassing both self-efficacy and action-efficacy beliefs, is a critical motivational factor in education, influencing teachers' enthusiasm, commitment, and instructional practices [19–24].

In general, efficacy refers to the belief in one's ability to execute actions necessary for specific performance attainments. It significantly impacts not only teachers' professional well-being but also their ability to foster student engagement and learning outcomes. Both theory and prior empirical evidence suggest that efficacy beliefs are key for teachers to address complex and sometimes controversial issues in their classrooms, such as sustainability [25,26]. Self-efficacy, specifically, is the belief in one's own capabilities to organize and execute the courses of action required to manage prospective situations [19]. Action efficacy (also termed action-outcome expectancy), in contrast, pertains to the belief that certain actions will produce desired outcomes [21,27]. Although empirically distinct, these constructs are often closely related. It is essential to distinguish between them to understand their individual effects accurately. To this end, multivariate analyses, like network analyses, are necessary.

High self-efficacy in teaching is associated with greater perseverance, openness to new teaching strategies, and inclusion of contextualized, called-for practices [24,28]. ESD-related self-efficacy, more specifically, has been found to be positively related to self-rated content knowledge of (typically, pre-service) teachers [29–33]. While there is little empirical evidence on teachers' action efficacy beliefs, the theoretical assumptions for their relevance for ESD implementation mirror those of self-efficacy. Highly efficacious teachers are more likely to adopt innovative and student-centered teaching methods conducive to ESD. They should also be more resilient in the face of challenges and more persistent in integrating sustainability into their teaching practices. Moreover, heightened efficacy should help teachers to overcome barriers such as limited resources or institutional constraints in incorporating sustainability topics into their curricula [25,26].

4. Personal Factors: Attitudes, Eco-Anxiety, Private Engagement, and Knowledge

As pointed out before, the successful implementation of ESD is likely to be associated not only with efficacy beliefs but also with further personal factors related to the teachers [34]. These personal factors include attitudes towards sustainability, worries about environmental issues (eco-anxiety), personal sustainable behaviors, and the knowledge they possess regarding sustainability topics. Understanding how these factors interact and relate to teaching practices can help elucidate variability in ESD implementation among teachers.

Teachers' attitudes towards sustainability education likely play a relevant role in shaping their teaching practices. Attitudes encompass beliefs, feelings, and behavioral intentions towards teaching sustainability and environmental issues [35]. Teachers who believe in the importance of sustainability and view it as a critical component of education are more inclined to incorporate relevant topics into their lessons [13]. Teachers with strong pro-environmental attitudes have been found to be more likely to adopt teaching practices that promote sustainability and encourage students to engage in sustainable behaviors [34,36].

Notably, teachers' attitudes towards environmental education are intertwined with their knowledge about environmental topics, pointing to a need to investigate both together when examining teachers' implementation of ESD [37].

Eco-anxiety, or environmental worries, refer to the feelings of concern and anxiety that individuals experience regarding environmental degradation and the potential future impacts of climate change [38]. Such worries can have both positive and negative effects on teaching practices. On the one hand, teachers who are highly concerned about environmental issues may feel more motivated to incorporate sustainability topics into their lessons to raise awareness and foster proactive behavior among students. On the other hand, excessive worry can lead to feelings of helplessness or eco-paralysis, where the magnitude of environmental problems seems so overwhelming that it inhibits action [38,39]. First research suggests that teachers who manage to channel their environmental concerns constructively are more likely to engage in ESD [40]. These teachers use their worries as a driving force to educate and inspire students, helping them understand the importance of sustainability and encouraging them to take action.

Teachers' private engagement regarding sustainable behaviors should also be closely connected to how they approach ESD. Sustainable behaviors refer to deliberate actions that individuals take to reduce their environmental impact, such as recycling, conserving energy, reducing waste, and using sustainable transportation [41,42]. Teachers who actively engage in these behaviors are more likely to integrate sustainability principles into their teaching practices [43]. Note that engagement is a multifaceted construct, including behavioral and affective tendencies [44,45]. Research indicates that teachers who practice and care about sustainable behaviors in their personal lives are more confident and motivated to teach these behaviors to their students [36]. Moreover, private engagement can enhance the authenticity and effectiveness of sustainability education, making it more relatable and impactful for students.

Finally, *knowledge* of sustainability topics should be essential for teachers to effectively incorporate ESD into their curricula. This includes understanding key concepts related to environmental science, climate change, resource management, and social equity, as well as being aware of current sustainability issues and potential solutions [46]. In part, such knowledge can already be generated by high private engagement regarding sustainability. Teachers who possess a strong knowledge base are better equipped to design and deliver lessons that get students to meaningfully engage with sustainability. However, from an empirical point of view, knowledge about sustainability does not necessarily directly lead to acting accordingly [47]. Attitudes towards environmental and sustainability issues and towards the effectiveness of possible solutions (i.e., their action efficacy), negative emotions as potential barriers, and teachers' personal approach to dealing with sustainability are arguably relevant personal factors to be considered besides teachers' knowledge regarding their integration of ESD into their teaching.

5. Student Interest and Pressure and School Awareness

Besides efficacy beliefs and personal factors, student- and institution-related factors matter for the successful implementation of ESD. As pointed out before, this is a key insight from educational psychology research, supplementing the insights on the more personal competence-related factors of teachers. Here, we focus on teachers' perceptions of their students' interest in sustainability topics and perceived pressure to engage with such topics, and school awareness of environmental issues appears as a relevant aspect of the nomological net surrounding teachers' ESD implementation.

Perceived interest of students in sustainability topics is a likely driver of effective ESD. When students are genuinely interested in and curious about environmental issues,

they can be expected to engage more deeply with the content and participate actively in learning activities [48,49]. The relevance of student interest for ESD extends beyond student outcomes; it also matters at the teacher's level. More perceived student interest in ESD topics should nudge teachers, in their professional role to pick up such topics in their lessons. Moreover, perceived student interest can serve as positive feedback for teachers, reinforcing their intention and motivation to teach sustainability topics.

At the same time, *perceived pressure* from students to address sustainability can, following the same rationale as before, act as an additional motivational factor, pushing teachers to integrate these topics more thoroughly into their lessons. In the light of the Fridays for Future movement, which is mainly led by school-aged students, pressure to cover sustainability topics from students might be a prevalent occurrence [49]. When students express a strong desire to learn about sustainability, it can validate and reinforce teachers' efforts, thereby boosting their motivation and confidence.

Finally, to close the circle back to the whole-institution approach [1], school *awareness of environmental issues* is another likely relevant aspect surrounding effective ESD. When a school collectively prioritizes and actively engages in sustainability practices, it creates an environment that values and supports ESD initiatives. Such heightened awareness can be inspiring in integrating ESD into teaching and lead to a more cohesive approach to ESD, as teachers feel supported and encouraged by their school's commitment to these principles. Moreover, schools that engage in sustainability initiatives help set a practical example that can reinforce teachers' efforts to incorporate sustainability topics into their lessons, by helping them see the tangible benefits and relevance of these practices within their own school environment [13].

6. The Present Research

With the present work, we investigate factors surrounding the incorporation of sustainability into teaching practices among in-service teachers in Germany. Doing so, we address the limitations of previous studies, which often focused solely on specific, isolated aspects and primarily considered perspectives of pre-service teachers or teacher education students rather than in-service teachers [34].

More specifically, our research questions were (1) to examine variability in teachers implementation of ESD practices in their lessons, (2) to study these for any notable differences regarding participants' demographics, and (3) to explore the nomological net of implementation of ESD practices in lessons regarding self- and action-efficacy beliefs, personal attitudes, eco-anxiety, private engagement, and knowledge, as well as perceptions of student interest and pressure alongside school awareness.

Regarding the latter, our main research aim, we employed network analyses. Network analyses (NAs) are a novel, and increasingly popular statistical approach that enable a multivariate modeling of the complex interplay between personal and contextual factors in shaping teachers' engagement with sustainability education [50–52]. NA serves in understanding the organization of constructs and their interrelations by treating variables (constructs or items) as nodes and their relationships as edges [53,54]. This approach is variable-centered, representing global relations between indicators using partial correlations, both graphically and numerically [55]. NA is particularly well-suited for examining complex and dense patterns of relationships, such as those in the present research, as it considers all nodes simultaneously, while avoiding issues of multicollinearity that often arise with large numbers of related variables in traditional factor-analytic approaches [56,57]. In NA, nodes form communities characterized by strong edges. Edges in NA, based on partial correlations, represent the unique relationship between two nodes while controlling for their relations with other nodes [58]. The visual and numerical representation of

these relationships informs influential nodes, with strong, close, and multiple edges to other nodes.

As such, NA complements traditional factor analysis methodologies in three notable ways. First, NA provides a comprehensive view of interconnected variables by analyzing multiple edges and expected influences simultaneously, which is ideal for studying the intricate relationships between factors related to ESD implementation. Second, NA visually represents networks, revealing whether groups of indicators form communities, facilitating the interpretation of relationships and network structure. Third, NA identifies influential nodes which is helpful in better understanding points of interest for interventions to support teachers' sustainability practices.

7. Method

To answer our research questions, we surveyed 419 teachers from various school types across Germany using established scales and a knowledge test to measure factors related to the implementation of sustainability education. We examined the relationships between teachers' incorporation of sustainability and their self- and action-efficacy, personal attitudes, eco-anxiety, private engagement, and knowledge, alongside perceived student interest and pressure, and school awareness, through network analyses. We provide all data and code underlying this investigation in an open repository: https://osf.io/dvgqc/ (accessed on 9 June 2025).

7.1. Participants and Procedure

The participating teachers were sampled from various types of school across Germany, resulting in a diverse representation of educational settings. On average, participants were 45 years (SD = 10.9) old and had 16 years of teaching experience (SD = 9.9). Two thirds (68%) were women, reflecting the gender distribution typical of the teaching profession in Germany; at the time of data collection, approximately 72% of teachers in Germany were women, with an average age of 44 years [59]. The teachers came from a range of school types and educational tracks. Specifically, 38% of the teachers worked at high schools ("Gymnasium"), 17% at intermediate schools ("Realschule"), 9% at primary schools ("Grundschule"), 5% at comprehensive schools ("Gesamtschule"), and 4% at middle schools ("Mittelschule"). Additionally, 20% of the participants worked within other school types, such as Waldorf schools and vocational schools ("Berufsschule"). Regarding their professional backgrounds, 79% were fully certified teachers, 14% were career changers, and 4% were teacher trainees.

The teachers participated in an online survey in October 2023, recruited through professional networks, educational associations, and social media platforms. Participants were informed about the study's purpose, assured of the confidentiality of their responses, and provided with instructions on how to complete the survey. Informed consent was obtained from all participants before they began the survey, and ethical standards for research involving human subjects by the American Psychology Association (APA) and the German Psychology Society (DGPs) were carefully followed. The University of Augsburg ethics committee declared this study exempt.

7.2. Measures

Before administering the survey, a pilot test was conducted with a small group of teachers to ensure clarity and suitability of the items. Based on the feedback, minor adjustments were made to the survey to improve comprehensibility. Although Likert-type response formats represent ordinal-level data, we followed common practice in psychological and educational research by treating aggregated multi-item scale

scores as approximately interval-scaled, thereby allowing the calculation of means and standard deviations.

7.2.1. ESD Implementation

To assess the extent to which teachers implemented ESD in their classrooms, we captured the frequency to which the teachers addressed sustainability-related themes into their teaching practices. We used the sum score of two items to reflect explicit and implicit consideration in their lessons (e.g., for explicit consideration: "How often in the course of the school year do you explicitly address sustainability and climate protection in your lessons?"), after providing examples of what explicit or implicit consideration entails. Teachers were instructed to refer their responses to the average across all their classes and subjects, and responded on a Likert scale ranging from 0 (*never*) to 5 (*almost each lesson*).

7.2.2. Self- and Action-Efficacy

Self-efficacy was measured using eight items adapted from [60]. This scale assesses teachers' confidence in their ability to effectively teach sustainability and climate protection topics (e.g., "To what extent can you provide alternative explanations in the area of sustainability and climate protection when your students do not understand something?"; internal reliability, McDonalds $\omega_h = 0.88$) Responses were recorded on a Likert-type scale ranging from 1 (*not at all confident*) to 9 (*completely confident*).

Action-efficacy was measured with three items adapted from [61]. This scale captures teachers' beliefs on the effects of teaching actions on students' sustainable behaviors (e.g., "Through school-based teaching of sustainability and climate protection, the sustainable behavior of students can be influenced"; $\omega_h = 0.62$). Responses were recorded on a 4-point Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*).

7.2.3. Personal Factors: Attitudes, Eco-Anxiety, Private Engagement, and Knowledge

Attitudes towards sustainability education were measured with a 5-item scale adapted from [62]. This scale captures teachers' beliefs about the necessity and importance of teaching sustainability and climate protection (e.g., "I believe that it is for teachers to convey sustainability and climate protection to students"; $\omega_h = 0.87$). Responses were recorded on a semantic differential scale from 1 (e.g., *unnecessary*) to 7 (e.g., *necessary*).

Eco-anxiety was assessed using a scale with 13 items adapted from [39]. It measures the frequency with which teachers experience anxiety or nervousness about climate change and other sustainability challenges (e.g., "When you think about climate change or other sustainability challenges, how often do you feel nervous, anxious, or tense?"; $\omega_h = 0.92$). Responses were recorded on a scale from 0 (*never*) to 4 (*almost every time*).

Teachers' private engagement in sustainable behaviors was assessed using a 9-item scale from [36]. This scale measures the frequency of personal practices such as recycling, conserving energy, and reducing waste, along with their affective–cognitive evaluation (e.g., "I use my bike, public transport or walk for my everyday journeys"; "It makes me angry when I see how Germany is missing its climate protection targets"; $\omega_h = 0.86$) Responses were recorded on a Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*).

Knowledge of sustainability was assessed using an 8-item single-choice test from [36]. This test evaluates teachers' understanding of key concepts related to sustainability and climate protection. A sample question is, "What does the carbon footprint of a product represent?", with answer options "The typical coloring of the sky caused by high CO_2 concentrations"; "The amount of all greenhouse gas emissions generated during the life cycle of a product" [correct]; "The amount of CO_2 that a product releases when it decomposes"; and "The chemical change caused by CO_2 in the atmosphere."

7.2.4. Student Interest and Pressure and School Awareness

Teachers' perceptions of student interest in sustainability topics was measured using a single item adapted from [63]: "How do you rate your students' interest in sustainability and climate protection compared to other subjects?" Responses were recorded on a scale from 1 (*less than other subjects*) to 4 (*higher than other subjects*).

Likewise, perceived pressure from students to include sustainability topics was measured with the following item: "How do you rate the pressure from your students to address sustainability and climate protection in your teaching?" Responses were recorded on a scale from 1 (*less than other subjects*) to 4 (*higher than other subjects*).

Finally, awareness of sustainability in the school environment was measured using a 4-item scale by [63]. This scale captures the extent to which sustainability and climate protection are prioritized and discussed within the school (e.g., "Sustainability and climate protection topics are important at our school"; $\omega_h = 0.74$). Responses were recorded on a 4-point Likert scale from 1 (*strongly disagree*) to 4 (*strongly agree*).

7.3. Analyses

All analyses were conducted in R, version 4.4.1 [64]. Regarding the first two research questions, we investigated descriptive statistics, including value distributions in violin plots, and multiple one-factorial analyses of variance to test for potential differences in ESD implementation between different subgroups of teachers.

As main analyses, we conducted network analyses to explore the relationships between the various constructs and identify key factors surrounding the implementation of ESD in classrooms [65]. Specifically, the network analysis was performed using the "network tools" package version 1.5.0 [66]. The graphical network was estimated using the Fruchterman–Reingold algorithm, which provides a layout for network visualization by treating edges as springs that can stretch and nodes as repulsive objects [67]. This helps in clearly displaying the structure of the network by minimizing edge crossings and evenly distributing nodes. To address potential issues concerning the representation of all edges, which can obscure meaningful connections, we applied the least absolute shrinkage and selection operator (LASSO) to the Gaussian graphical model. LASSO regularizes the partial correlations, shrinking smaller edges to zero, resulting in a sparser but more interpretable network. This helps in ensuring that the remaining edges are significant and meaningful [68].

Given the recommendations of Isvoranu and Epskamp [69] (low sample size; primary interest to discover a structure that resembles a true network and to discover the strongest edges), we used the Least Absolute Shrinkage and Selection Operator (LASSO), using the EBICglasso function that was applied to the Gaussian model to regularize partial correlations [70]. LASSO shrinks small correlations to zero, thereby eliminating potentially spurious relations and resulting in a network that contains fewer, but potentially more meaningful, edges. The LASSO graphical network exhibited multiple small edges, running danger of potentially false positive edges (dense network with $\lambda < 0.1 \times \lambda_{max}$). Accordingly, we applied a threshold to enforce higher specificity at the cost of sensitivity [71]. Edges meeting the minimum threshold were retained and those that did not were set to zero. The resultant network therefore contains fewer, but more genuine, edges. A similar reasoning was also reflected in our choice of hyperparameter values. Values closer to 0 accept models with a greater number of potentially false edges, and values closer to 0.5 accept models with fewer, but authentic, edges [53,55]. We chose $\gamma = 0.5$ to estimate a conservative model that contained the most meaningful edges. A non-parametric bootstrapping procedure using 1000 draws was used to estimate the edge weights. To draw the edges, we used the default fading rule of the qgraph package [53], as recommended by Isvoranu and Epskamp [69], considering our research questions. In the graphical networks, positive

edges are represented as green lines and negative edges as red lines, with thicker lines indicating stronger connections.

The number and strength of edges a node shares with others in the network were assessed through common centrality indices: (1) *betweenness* measures the extent to which a node lies on the shortest path between other nodes, indicating its role as an intermediary or bridge within the network, (2) *closeness* reflects the average distance from a node to all other nodes, highlighting how quickly information can spread from that node throughout the network, (3) *strength* represents the sum of the absolute values of all edges connected to a node, indicating its overall level of connectedness. Further, and accounting for the mix of positive and negative edges, we report one- and two-step expected influence (EI1 and EI2) values. These metrics provide estimates of node influence in networks with both positive and negative connections [72]. Note that the term "influence" is not intended to imply directionality or causality here; rather it is used to describe relations between nodes in terms of their number, strength, and distance. Specifically, *EI1* represents the direct influence of a node, calculated as the sum of its connections, and *EI2* represents the indirect influence of a node (i.e., its impact on other nodes through intermediate connections). Similarly, we calculated bridge centrality and expected influence values to understand the role of nodes in connecting different communities within the network.

We ran a series of robustness tests. Following [73], we used the bootnet package (version 1.5.5) to investigate the stability and accuracy of the network with 2500 nonparametric bootstrapped samples. The accuracy of the estimated network was checked following [73] threefold recommendations. First, bootstrapped Confidence Intervals (CIs) were used to assess the stability of the edge weights and centrality indices (see Figure S2). Second, we conducted stability checks across edge weights and expected influence indices on subsets of the data (see Figure S3). Third, bootstrapped difference tests were performed between pairs of nodes to evaluate the reliability of the centrality measures (see Figure S4).

8. Results

8.1. Variability Between Teachers in ESD Implementation in Their Teaching

Regarding our first research question on ESD implementation, we observed almost the full theoretical range, from participants reporting never explicitly and never implicitly implementing ESD in their lessons, to those doing so both explicitly and implicitly in almost every single lesson, across all their taught subjects and classes (see Table 1). The distribution of responses approximated a normal distribution, with most participants scoring in the mid-range. This is also illustrated by the dense clustering of scores around the central values (see violin plot, in Figure S1), indicating that many participants incorporated ESD topics on a monthly or weekly basis, while fewer participants were at the low or high ends of ESD integration. This central tendency highlights that most integrated ESD moderately, with room for more frequent inclusion of sustainability topics in education.

Regarding our second research question, we did not observe notable differences in this data distribution across different types of teachers (see Figure S1). Likewise, ANOVA results indicated no statistically significant differences in ESD implementation across different types of schools, with $F(5, 321) = 0.69$ and $p = 0.63$; gender, with $F(1, 273) = 0.01$ and $p = 0.93$; or professional status, with $F(1, 274) = 2.14$ and $p = 0.15$. We did observe that ESD implementation slightly covaried with teacher age ($r = 0.15$, $p = 0.01$). Further, there were small to medium correlations with assessed efficacy beliefs, personal, and student-related factors (see Table 1), strengthening the assumption that these were relevant aspects to be considered within the nomological net. The bivariate correlations among these factors also spoke to their intertwinement, paving the grounds for the subsequent network analysis that considered their interplay following a multivariate approach.

Table 1. Descriptive Statistics and Bivariate Correlations.

	Descriptive Statistics							Bivariate Correlations								
	M	*SD*	Min	Max	Range	Skew	Kurtosis	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
ESD implementation	5.70	2.21	0.00	10.00	0–10	−0.27	−0.21	0.45	0.22	0.12	0.09	0.33	0.14	0.14	0.17	0.23
[1] Self-efficacy	5.14	1.50	1.00	9.00	1–9	−0.29	0.32		0.35	0.25	−0.09	0.24	0.02	0.36	0.35	0.31
[2] Action-efficacy	2.65	0.68	1.00	4.00	1–4	−0.22	−0.66			0.13	0.05	0.25	−0.09	0.38	0.26	0.18
[3] Attitudes	6.19	1.07	1.00	7.00	1–7	−1.84	3.61				0.19	0.52	0.28	0.27	0.26	0.14
[4] Eco-anxiety	1.88	0.57	1.00	4.00	1–4	0.64	0.24					0.39	0.04	−0.02	0.01	−0.18
[5] Private engagement	5.72	1.08	1.67	7.00	1–7	−1.60	2.78						0.35	0.24	0.16	0.10
[6] Knowledge	0.88	0.16	0.00	1.00	0–1	−2.06	5.91							0.04	0.06	−0.02
[7] Student interest	2.32	0.73	1.00	4.00	1–4	−0.03	−0.42								0.56	0.19
[8] Student pressure	2.11	0.90	1.00	4.00	1–4	0.60	−0.31									0.24
[9] School awareness	4.81	0.85	2.75	6.50	1–7	−0.34	−0.79									

Note: $N = 419$. $|r| > 0.10$: $p < 0.05$, $|r| > 0.12$: $p < 0.01$, $|r| > 0.16$: $p < 0.001$.

8.2. Network Analysis on the Nomological Net of ESD Implementation

The purpose of the NA was to examine the nomological network along with centrality and influence statistics. In Figure 1, the measured constructs are presented as differently colored circles. Positive and negative edges are depicted as green and red lines, respectively. Following [73], bootstrapped CIs provided indications for the accuracy of the estimated edge weights, and the EI indices were relatively stable, with a stability coefficient of 0.52 (i.e., 52% of the data could be dropped to retain, with 95% certainty, a correlation of 0.70 with the original dataset). Additional details on the network stability and accuracy are provided in the Supporting Information.

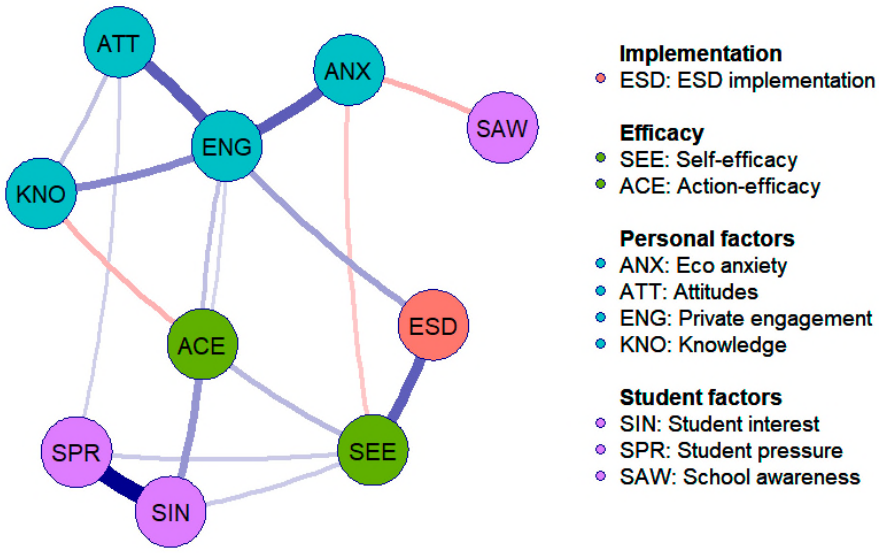

Figure 1. Graphical Network of ESD Implementation and its Nomological Net Based on Regularized Partial Correlations Between Nodes. *Note*: Blue and red edges represent positive and negative partial correlations, respectively. Edge weights ranged from −0.12 (ANX–SAW) to 0.41 (SIN–SPR).

The LASSO graphical network is shown in Figure 1 [69]. ESD implementation was located at the right of the network. In terms of statistically significant relations with the considered factors, ESD implementation was positively associated with self-efficacy (edge weight = 0.30) and private engagement (edge weight = 0.16). This suggests that teachers who felt more confident in their abilities and those who personally engaged in sustainable behaviors were more likely to integrate ESD into their lessons, considering all other factors.

Private engagement emerged as a central node that scored highly on all centrality and bridge indices (see Figure 2, and Supporting Information). Notably, private engagement served as a key bridge for the other three personal factors, attitudes, eco-anxiety, and knowledge, that clustered together in the upper part of the model. Knowledge was placed on the left of the model, and shared, beside the edge with private engagement, a negative

edge with action-efficacy, implying that teachers who have less knowledge of sustainability are more easily convinced as to how efficacious ESD actions can be, all other constructs considered.

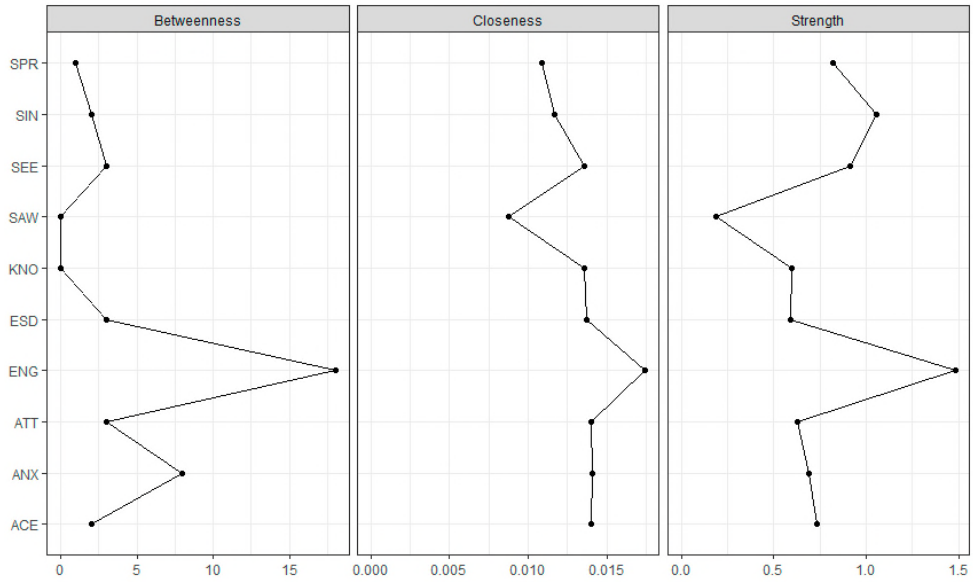

Figure 2. Centrality Indices. Note: ACE = Action-Efficacy, ANX = Eco-anxiety, ATT = Attitudes, ENG = Private Engagement, ESD = ESD Implementation, KNO = Knowledge, SAW = School Awareness, SEE = Self-Efficacy, SIN = Student Interest, SPR = Student Pressure.

Self-efficacy, while closely related to ESD implementation, did not stand out as a key bridge, like private engagement. Instead, we observed only weak edges, with student interest and pressure that closely clustered together at the bottom left of the model. While primarily operating as a bridge towards perceived student interest and pressure, self-efficacy shared one statistically significant edge with the personal factors, namely a negative edge with personal anxiety. This implies that highly self-efficacious teachers also tended to feel less eco-anxiety than other teachers, all other factors considered. Action-efficacy was placed to the left of self-efficacy, bridging it towards private engagement, with which the latter shared no direct edge. This emphasizes different roles of private engagement and self-efficacy in the model.

Notably, while student pressure and interest were closely grouped, school awareness was not part of this community, but placed on the other end of the model. This was also the least relevant node in the model in terms of observed influence (see Figure S6).

9. Discussion

Given its global significance, particularly highlighted in the United Nations' Sustainable Development Goals (SDGs), understanding how teachers implement ESD in their classrooms is crucial to address challenges regarding sustainable futures. In this study with a broad sample of practicing teachers from Germany, we discovered large differences in ESD implementation. Demographic variables like age, gender, and school type were not significant predictors. Instead, psychological and potentially malleable aspects emerged as explanatory and shaped the nomological net surrounding ESD implementation, which we investigated through network analyses—a novel statistical approach that proved suitable to investigate the complex interplay of personal and institutional factors surrounding ESD. Taken together, these findings suggest actionable pathways for enhancing ESD implementation, focusing on bolstering teachers' self-efficacy and considering their private engagement in sustainable practices.

More specifically, our findings for Research Question 1 revealed significant variability in how frequently teachers incorporate ESD into their lessons. Most teachers reported incorporating sustainability topics on a monthly or weekly basis. This suggests that, while teachers are somewhat engaged with sustainability topics, there is still a meaningful opportunity to deepen their engagement, thus strengthening the frequently articulated necessity of initiatives aimed at encouraging more frequent inclusion of sustainability topics in education [74,75], while generally supporting the need for better understanding of this variability that we followed in the present work.

To this end, and addressing Research Question 2, we found no significant differences in the implementation of ESD based on demographic factors, such as age, gender, or school type. This conclusion was supported by both visual inspection of value distributions and explicit statistical tests. These findings challenge commonly held ideas that older teachers would be less capable of integrating ESD into their lessons, or that only younger teachers, who might have received more recent training in sustainability education, would be more likely to implement ESD effectively. This aligns with findings from previous research that suggest that the personal factors that we considered in our network analysis, rather than immutable demographic characteristics, are more relevant in influencing ESD practices [6,7].

For Research Question 3, our findings highlight self-efficacy and private engagement as the primary factors relevant to ESD implementation. Interestingly, these two constructs emerged as quite distinct, with no direct relationships between them and belonging to different communities within the network analysis. Private engagement, in particular, functioned as a key bridge among other personal factors, in line with its broader theoretical influence encompassing cognitive and affective–behavioral aspects [44,45]. Reflecting both personal commitment and practical actions toward sustainability makes private engagement a valuable proxy for identifying teachers who could benefit most from targeted support. For instance, teachers who are already engaged in sustainable behaviors in their private lives may be more receptive to engaging in practical initiatives focused on ESD and could serve as starting points to get the ball rolling by initiating sustainability practices in their schools. Conversely, teachers with low private engagement might especially benefit from participating in professional development in ESD. On a more general note, the identified relevance of private engagement aligns with the mission carved out in our introduction, suggesting that an isolated approach may not be as effective as a whole-school approach that integrates personal, professional, and institutional support [1,5]. This also reflects ideas from identity development theory, according to which sustained engagement in personally meaningful practices (here environmental behavior) can contribute to the integration of such values into one's professional identity [76]. Accordingly, for ESD, teachers are not merely conveyors of knowledge but also role models and catalysts for change within their school communities.

Self-efficacy, while empirically most critical for ESD implementation, was not related to these personal factors, but rather to perceived student interest and pressure and, negatively, to eco-anxiety. While self-reported by teachers, this aligns well with the rationale that students' positive feedback concerning sustainability topics makes teachers feel more efficacious about teaching these topics. As our results are cross-sectional, however, this could also illustrate that teachers who are confident about teaching ESD in the first place are better equipped to spark students' interest. Such a phenomenon has been observed in mathematics education before [77], suggesting that fostering teachers' self-efficacy to teach ESD might trickle through, here additionally fostering students' interest in sustainability topics. At the same time, the negative link between self-efficacy and eco-anxiety reinforces

the notion that high self-efficacy can protect against the anxiety-inducing uncertainty regarding environmental issues [38].

Moreover, the overall sparse relations between self-efficacy and other aspects considered in our model suggest that additional factors beyond our current scope may play a significant role in fostering self-efficacy. One such aspect is collective self-efficacy, the shared belief in the group's capabilities to achieve goals, which has been shown to impact individual self-efficacy and instruction [78]. Another related factor is principals' leadership [79]. In particular, drawing on ecological systems theory [80], such factors may be situated more at the meso- and macro-levels (reflecting institutional norms, leadership culture, or broader educational policies) that interact with individual beliefs and behaviors. While the present research focused on individual teachers' perspectives, an inclusion of such broader institutional factors could help to better understand and enhance teacher self-efficacy in the context of ESD.

The negative edge between action-efficacy and knowledge (i.e., teachers holding less knowledge of sustainability being more easily convinced of the efficacy of ESD actions) highlights another noteworthy area for intervention. One possible explanation is that teachers with more knowledge may be more aware of the complexity and challenges of fostering behavioral change, leading to more reserved expectations about the outcomes of ESD practices. In contrast, those with less knowledge may hold more optimistic (or simplified) assumptions about the effectiveness of sustainability teaching. This could therefore involve a cognitive bias like that of the Dunning-Kruger effect [81], in which limited knowledge is associated with overconfidence in related judgments. While classically framed in terms of competence misjudgment, here, limited knowledge could foster overconfidence in how impactful certain ESD behaviors are. This implies that following up on action efficacy as a potential intermediary belief might offer additional room for practical interventions, particularly among teachers with little knowledge.

In summary, our findings emphasize that both self-efficacy (work-related) and private engagement (largely outside work) are necessary for effective ESD implementation. Accordingly, we encourage both constructs for practical consideration; while private engagement might be particularly relevant for fitting interventions to teachers, self-efficacy is likely more feasible to be addressed through direct and broad intervention (also justified by the strongest relationship identified with ESD integration). We outline ideas for practical implications based on these insights later.

Generally, while highlighting these two aspects within the nomological network surrounding teachers' ESD integration, our study also emphasizes the importance of a multivariate approach in exploring the complex landscape of the nomological net of ESD implementation. By employing the novel concept of network analysis, we were able to capture the intricate interrelations among various factors, demonstrating the merits not only of focusing on single constructs, but also of broadly involving cognitive, behavioral, and emotional–affective aspects. Further, our approach underscores the significance of educational psychology in contributing to this line of research, particularly regarding the understanding of how different personal and contextual factors contribute to teachers' implementation of ESD practices. By integrating insights from educational psychology, environmental education, and sustainability studies, we can develop more holistic strategies to support teachers in incorporating sustainability into their teaching. This aligns with the recommendations of [82] who advocate for an interdisciplinary approach to teaching and research in ESD—another encouraging take-away from the present research.

9.1. Limitations

This study has several limitations that need to be borne in mind when interpreting the results. First, the broad sample from various types of schools across Germany and the inclusion of practicing teachers that match well with the general population of teachers in Germany is a notable strength, but the findings' international generalizability may be limited to similar contexts. Given that Germany's formal incorporation of ESD into curricula is moderate by international standards, our results may be generally applicable to other contexts. However, one must consider that Germany, being part of the WEIRD (Western, Educated, Industrialized, Rich, and Democratic) countries, differs significantly from many other countries, underscoring the need for more international studies [83].

Second, while having an actual knowledge test is an important asset, all other constructs are based on self-reports. Most of the considered constructs, such as anxiety, engagement, and efficacy beliefs, are inherently cognitive and affective, and cannot be readily assessed through other means than self-report. Yet it would be insightful to supplement these self-reports with additional data, such as actual behavior, which could be approximated using a diary approach [62]. Note that the measures of student interest and pressure reflect teachers' perceptions rather than students' actual experiences. This introduces additional bias, as they could be influenced by teachers' own enthusiasm or efficacy beliefs. The edges with student interest and pressure may thus partly reflect projection, warranting further investigation, ideally facilitated through multi-informant designs (including student reports). Moreover, both were assessed using single-item measures. Despite a reliance on established items with high face validity and clarity, this underscores the need for cautious interpretation.

Third, the cross-sectional nature of the data limits our ability to draw causal interpretations. While our research helped identify two possible focal leverage points of interest (self-efficacy and private engagement), future studies using longitudinal designs are necessary to follow up on the underlying mechanisms and validate these findings over time. This study can contribute to the identification of constructs to include in such longitudinal studies.

Fourth, action efficacy yielded a somewhat modest internal consistency ($\omega_h = 0.62$). While this still falls within acceptable limits for short, applied scales with non-redundant items [84,85], findings involving this node should be interpreted with particular caution.

Fifth, while we conducted multiple robustness tests to ensure the reliability of our findings, the insights, and particularly the network structure generated through this study, require further confirmation. Future research should replicate and extend these findings to follow up on their stability and applicability in different contexts and with diverse populations.

9.2. Practical Implications

Paralleling empirical results for higher education teachers [10], our findings can provide first ideas on how to enrich practical implications on how to foster schoolteachers' ESD integration into their teaching. Courses in sustainable development within pre-service teacher training have been found to be capable of effectively modifying students' beliefs, attitudes, and norms [86]. As noted before, our results imply the need also to focus on enhancing teachers' self-efficacy and to consider their private engagement. While content-specific courses are often advocated [37] and might be warranted for teachers teaching in certain subjects or school types [87], it seems equally important to specifically target self-efficacy for teaching practice. Given that subject knowledge continuously evolves, teachers must also develop the confidence and skills to independently acquire and update their knowledge of sustainability and climate protection.

To this end, teacher training programs could incorporate strategies that build teachers' confidence in their abilities to teach sustainability. This can be achieved through practical workshops, collaborative projects, and opportunities for reflective practice. For instance, integrating self-efficacy building activities into content-specific professional development can create a dual focus on both knowledge acquisition and personal confidence. Practical examples include role-playing exercises, peer teaching sessions, and scenario-based learning, which allow teachers to practice and refine their skills in a supportive environment.

Moreover, a strong sense of efficacy may help mitigate the negative effects of eco-anxiety [38], a challenge that was also observable in our sample. Training programs could additionally bolster self-efficacy beliefs (that were negatively associated with eco-anxiety in the present research) by addressing eco-anxiety directly by providing coping strategies and fostering a sense of empowerment among teachers. This can include discussions on managing environmental concerns, resilience-building activities, and creating a community of practice where teachers can share experiences and support each other.

Finally, we have seen that ESD-related teaching does not occur in isolation but is embedded in teachers' personal and professional spheres. Our findings on self-efficacy and private engagement thus imply that didactic approaches aiming to foster ESD could profit from integrating teachers' own sustainability engagement into their teaching. In this context, our findings may even resonate with more holistic pedagogical models, such as the socioformation approach [88,89], which emphasizes the formation of socially responsible competencies through contextualized, collaborative, and ethically grounded learning processes. While our study did not examine collective self-efficacy, the socioformation approach emphasizes collaborative and ethically grounded learning processes through which a shared sense of agency can emerge [90]. In working together as a group, teachers may develop collective self-efficacy, which in turn can strengthen their individual confidence and motivation to integrate sustainability into their teaching.

9.3. Conclusions

In the quest to better understand differences in teachers' integration of ESD in their teaching, we observed large variability between teachers that was not attributable to demographic factors. A network analysis illuminated the nomological net surrounding ESD implementation, highlighting self-efficacy and private engagement as two key aspects with functionally different roles. Our findings imply that, by understanding and addressing these factors, we can create more engaging and supportive learning environments. This, we hope, will contribute to developing informed and proactive global citizens capable of addressing the complex challenges of climate change and sustainable development.

Supplementary Materials: The following supporting information can be downloaded at https://www.mdpi.com/article/10.3390/su17167533/s1: Figure S1: Violin Plots of ESD Implementations Across Different Subgroups of the Sample; Figure S2: Bootstrapped Confidence Intervals of Edge-Weights for the Estimated Network; Figure S3: Average Correlations of Edges and Expected influence Statistics Sampled with Persons Dropped and the Original Sample; Figure S4: Edge Bootstrapped Difference Test for all Non-Zero Edges in the Network Structure; Figure S5: Bridge Centrality Indices; Figure S6: Indices for One- and Two-Step Expected Influence and Bridge Expected Influence.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and waived by the Institutional Review Board (or Ethics Committee) of the University of Augsburg. According to the ethical guidelines of the German Psychological Society (Deutsche Gesellschaft für Psychologie, DGPs), as well as the prevailing practices at German universities at the time of data collection, anonymous, non-invasive self-report studies (e.g., questionnaires on motivational beliefs and practices) do not often require formal ethics approval. The study was conducted in accordance with the ethical standards of the DGPs and the American Psychological Association (APA). No identifying information was collected, and participation was entirely voluntary.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: We provide all materials underlying the presented findings in an open repository at https://osf.io/dvgqc/ (accessed on 9 June 2025).

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