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Catalytic Communication in Sustainability Education: Bridging the Knowledge–Action Gap Through Affective Engagement and Strategic Praxis

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Abstract

Education for Sustainable Development (ESD) can support and strengthen responses to the environmental challenges faced today. However, the sustainability knowledge–action gap remains mostly unbridged. This article examines communication as a lever for learning and behavior change in sustainability education and compares the use of communication in conventional delivery and a narrative, dialogic and affective communication mode in secondary, university and community-based learning settings in a mixed-methods experimental study. Quantitative measures (pre-, post-, follow-up) included knowledge, systems thinking, emotional engagement, motivation and self-reported sustainable behaviors. Qualitative data, including interviews, observations and action research projects, were also collected to gain deeper insights into learner engagement with knowledge, systems thinking, emotional engagement and motivation. Results suggest that participants in the catalytic communication condition felt more cognitively and emotionally engaged than the control condition, and displayed more long-term pro-environmental behavior. Mediation analysis suggests that the increase in pro-environmental behavior may be driven by an increase in feelings of empathy and hope associated with the learning experience. This supports the understanding that tailored communication can help to reduce the knowledge–action gap in ESD and provides additional insights into the usefulness of cognitive, affective and behavioral dimensions of sustainability-oriented pedagogical approaches.

Keywords: catalytic communication; sustainability education; Education for Sustainable Development (ESD); knowledge–action gap; transformative learning; affective engagement; participatory pedagogy; pro-environmental behavior

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1. Introduction

The climate crisis and the transgression of planetary boundaries are among the most pressing challenges facing contemporary societies and require rapid and far-reaching transformation (Hickman et al., 2021). Education for Sustainable Development (ESD) has long been identified as a key mechanism through which individuals and communities can be empowered with the knowledge, values, and capacities needed to contribute to a sustainable future (Tilbury, 2011; Wals, 2015). Over recent decades, sustainability principles have been increasingly integrated into educational systems, and learners demonstrate growing awareness of environmental issues (Monroe et al., 2017).

Despite these advances, a persistent gap remains between environmental knowledge and the adoption of sustained pro-environmental behavior. This "knowledge–action gap"

(Kollmuss & Agyeman, 2002) continues to undermine the transformative potential of sustainability education. Research suggests that knowledge transmission alone is insufficient to generate meaningful change (Sterling, 2010), with psychological constraints such as cognitive overload, emotional distress, ideological polarization, and feelings of disempowerment limiting learners' ability to translate awareness into action (Bamberg, 2013; Clayton & Karazsia, 2020; Pihkala, 2020).

In parallel, dominant models of environmental communication that conceptualize communication as a neutral transfer of information have been increasingly questioned (Moser & Dilling, 2007). These insights suggest that how sustainability issues are communicated may be as important as the content itself.

While a growing body of literature emphasizes the role of emotions, dialogue, and participatory learning in fostering engagement, it remains unclear how communication strategies can be systematically designed to support sustained pro-environmental action across diverse educational contexts. In particular, there is limited empirical research examining whether intentionally structured communication approaches can function as catalysts that connect cognitive understanding with affective engagement and behavioral change.

This study addresses this gap by examining catalytic communication as a deliberate pedagogical approach in sustainability education. Specifically, the study investigates whether communication strategies that integrate affective engagement, reflection, and opportunities for action can enhance motivation and contribute to more durable pro-environmental behavior. Using an applied mixed-methods intervention across secondary school, university, and community learning contexts, the study seeks to empirically examine how catalytic communication may help bridge the persistent gap between knowing and doing in sustainability education.

Accordingly, this study addresses the following research questions:

1. To what extent does a catalytic communication intervention influence cognitive, affective, and behavioral outcomes in sustainability education compared to conventional instructional approaches?
2. To what extent are changes in pro-environmental behavior associated with affective engagement (empathy and hope) among participants exposed to catalytic communication strategies?

2. Theoretical Framework

2.1. Communication Models in Sustainability Education

A central challenge in sustainability education concerns how communication is conceptualized and operationalized. Traditional models of environmental communication have often treated communication as a neutral process of information transfer, assuming that increased knowledge will naturally lead to attitude and behavior change (Moser & Dilling, 2007). However, this information-deficit approach has been widely criticized for its limited effectiveness in addressing complex socio-environmental challenges and for underestimating the roles of values, emotions, and meaning-making in learning processes.

Research in environmental psychology and communication has increasingly emphasized that communication is not merely a conduit for facts but an interpretive process shaped by framing, cultural narratives, and value resonance (Lakoff, 2010; Corner et al., 2014; Van der Linden, 2015). From this perspective, communication actively constructs meaning and influences how sustainability issues are perceived, interpreted, and acted upon. Consequently, communication strategies that attend to how information is framed and emotionally experienced are more likely to foster engagement and motivation than those focused solely on cognitive understanding.

Within sustainability education, this shift has contributed to a growing interest in dialogic, participatory, and learner-centered communication approaches. Such approaches emphasize interaction, reflection, and co-construction of knowledge, positioning learners not as passive recipients of information but as active meaning-makers (Wibeck, 2013). These insights provide an important foundation for reconceptualizing communication as a potential catalyst for learning and action.

2.2. Affective Engagement and Transformative Learning

Transformative learning theory and critical pedagogies argue that meaningful learning involves questioning underlying assumptions, engaging with uncertainty, and reflecting on values and worldviews rather than simply acquiring new information (Freire, 1970; Lotz-Sisitka et al., 2015). Within this framework, emotions such as hope, empathy, concern, and even constructive forms of anxiety are understood as integral to learning processes rather than as obstacles to rational thought (Ojala, 2011; Chawla, 2020; Geiger et al., 2023). Research suggests that affective engagement can help learners connect abstract sustainability knowledge to personal experience, thereby enhancing motivation and agency. Hope, in particular, has been identified as a key emotional resource that supports sustained engagement without leading to denial or disengagement (Ojala & Bengtsson, 2019).

These perspectives converge in highlighting that learning for sustainability is not only cognitive but also emotional and relational. Educational approaches that intentionally engage affective dimensions can support deeper understanding, foster a sense of agency, and create conditions for transformative learning. This emphasis on affective engagement provides an essential theoretical basis for examining communication strategies that seek to catalyze learning and action.

2.3. From Knowledge to Action in Sustainability Education

Despite advances in theory and practice, the relationship between learning and action in sustainability education remains contested. Some approaches emphasize individual-level behavior change, drawing on models such as the Theory of Planned Behavior, which highlights the roles of attitudes, social norms, and perceived behavioral control (Ajzen, 1991). Other perspectives argue for more transformative or transgressive forms of learning that challenge dominant socio-political structures and address systemic drivers of unsustainability (Jickling & Wals, 2013; Håkansson et al., 2017). These debates underscore the complexity of bridging the knowledge–action gap. Research suggests that purely cognitive approaches are insufficient, as learners may experience barriers such as disempowerment, moral overload, or paralysis in the face of complex sustainability challenges (Bamberg, 2013). Consequently, there is growing recognition that effective sustainability education must integrate cognitive, affective, and behavioral dimensions of learning.

Conceptual frameworks that emphasize competencies such as systems thinking, anticipatory thinking, collaborative problem-solving, and critical reflexivity have been proposed as ways to support learners in navigating wicked sustainability problems (Meadows, 2008; Rieckmann, 2018). These competencies highlight the need for educational approaches that connect understanding with reflection and action in iterative and context-sensitive ways.

2.4. Catalytic Communication as an Integrative Framework

Building on these theoretical strands, catalytic communication can be understood as an integrative framework that intentionally links communication, affective engagement, and action-oriented learning. Rather than treating communication as a neutral transmission of information, catalytic communication emphasizes the sequencing and integration of affective, cognitive, and behavioral learning dimensions to support meaningful engagement and sustained action.

Empirical and theoretical work across sustainability education and communication studies points to a range of pedagogical strategies that align with this approach. Narrative learning has been shown to support sense-making by embedding abstract information within coherent stories (Dahlstrom, 2014), while visual and systems-oriented approaches can help learners grasp complex interconnections and feedbacks (Meadows, 2008). Participatory dialogue and community-based approaches further support agency and empowerment by situating learning within social contexts (Rappaport, 1987), and multimodal pedagogies recognize the role of multiple semiotic resources in meaning-making (Kress & van Leeuwen, 2001).

Syntheses of evidence-based practices across educational contexts suggest that culturally responsive and place-based communication modalities can enhance inclusiveness, equity, and knowledge retention (Ardoin et al., 2020; Chawla, 2020). At the institutional level, scholars have called for policy frameworks that move beyond knowledge transmission toward behavioral mobilization, including credentialing standards that value communicative leadership, partnerships between educational institutions and community networks, and the use of open educational resources to support the dissemination of effective practices (Sterling, 2010; Rieckmann, 2017; Tilbury, 2011; Brundiers et al., 2021).

Taken together, these perspectives provide the theoretical foundation for conceptualizing communication as a catalytic process through which sustainability knowledge can be transformed into affective engagement and collaborative action. This framework underpins the empirical investigation presented in this study.

3. Materials and Methods

3.1. Research Design

This study employed an applied exploratory mixed-methods research design combining quantitative and qualitative approaches to examine the role of catalytic communication strategies in sustainability education. A pretest–posttest control group design was used, with additional follow-up measures administered three months after the intervention. The control group received standard sustainability instruction, while the intervention group participated in lessons designed around story-based, dialogic, and emotionally engaging communication strategies.

The design aligns with transformative learning perspectives, which emphasize the integration of information, reflection, and affective engagement in learning processes. Quantitative data were used to identify trends and patterns of change in knowledge, motivation, and behavior, while qualitative data provided in-depth insight into participants' emotional responses and applications of sustainability concepts in everyday contexts. Given the applied educational setting and the modest sample size, the study was designed as an exploratory mixed-methods intervention, intended to identify patterns, associations, and plausible mechanisms rather than to support strong causal inference. The integration of quantitative and qualitative data was chosen to capture both measurable changes in learning outcomes and participants' subjective experiences of the intervention, thereby strengthening interpretive validity.

3.2. Participants and Sampling

The study involved three participant groups: secondary school students, university students enrolled in Forestry, Environmental Sciences, and Agribusiness programs, and community members participating in local sustainability workshops. The intervention and data collection were carried out over an approximately eight-week period during the spring academic term of the academic year 2025. In total, 50 participants took part in the study, with 26 participants in the catalytic communication (intervention) group and 24 participants

in the control group. Participants were assigned either to the intervention group or the control group depending on institutional and logistical constraints. All participants were familiar with basic sustainability concepts, but none had previously been exposed to communication approaches explicitly designed around catalytic communication principles.

Although participants were drawn from different educational and community contexts, the study was not designed to compare outcomes across these groups. Therefore, results are reported in aggregate, focusing on overall patterns associated with the communication intervention rather than group-level differences. Results were analyzed and reported in aggregate due to limited subgroup sample sizes, which would not have supported statistically reliable comparisons across educational contexts.

Participants were recruited through purposive convenience sampling within existing educational and community settings. Secondary school participants were recruited through cooperating schools, university participants through relevant study programs (Forestry, Environmental Sciences, and Agribusiness), and community participants through local sustainability workshops. Assignment to intervention or control conditions was determined by institutional and logistical constraints rather than random allocation.

The overall sample included participants with diverse demographic characteristics in terms of age, gender, and educational background, reflecting the composition of the participating institutions and community groups. Secondary school participants were predominantly adolescents, university participants were young adults enrolled in sustainability-related programs, and community participants represented a broader adult age range. Gender representation was approximately balanced across groups. Due to the exploratory nature of the study and limited subgroup sizes, demographic variables were not used as analytical factors, and results are therefore reported in aggregate rather than disaggregated by demographic or educational subgroup.

The study was conducted in Prizren, Kosovo, across secondary school, university, and community-based educational settings. Inclusion criteria for participation were enrolment or active participation in the respective educational context, attendance during the intervention period, and provision of informed consent (and parental consent for participants under 18 years of age). Participants who did not complete the pre- and post-intervention instruments or who were absent for a substantial portion of the intervention were excluded from the quantitative analyses where applicable. This approach reflects the exploratory nature of the study and the focus on identifying overall patterns associated with catalytic communication rather than comparing outcomes across educational contexts.

While the intervention was implemented across three distinct educational contexts (secondary, university, and community), these were analytically treated as a single intervention condition, contrasted with a control condition receiving conventional instruction. Due to institutional and logistical constraints, participants were not randomly assigned to conditions, and group composition reflected existing educational and community settings. This uneven and context-dependent group distribution represents a limitation of the study and restricts the generalizability of the findings. Accordingly, results are reported in aggregate and interpreted as indicative patterns rather than context-specific causal effects.

3.3. Intervention Design

The intervention was implemented over an eight-week period and was adapted for use across secondary school, university, and community learning contexts. It was grounded in the concept of catalytic communication, which conceptualizes communication as an affective, dialogic, and action-oriented process rather than a neutral exchange of information.

Core components of the intervention included narrative-based lessons addressing climate change and environmental justice, structured group discussions, and reflective

activities. Storytelling and real-world examples were used to foster engagement and support personal meaning-making. Group discussions were guided by agreed-upon ground rules to ensure respectful dialogue and psychological safety.

Visual materials such as diagrams, infographics, and simulations were used alongside simple citizen science tasks to support diverse learning styles. Role-play activities, future-oriented imagination exercises, and guided reflection on emotional responses were incorporated to support the development of empathy, hope, and concern.

Participants also completed small-scale sustainability action projects, such as recycling initiatives or awareness-raising activities. Following project completion, participants engaged in collective reflection on learning outcomes, challenges encountered, and emotional experiences. The control group covered the same sustainability topics but through lecture-based instruction, reading materials, and factual presentations, without the dialogic or affective elements.

Teachers and facilitators implementing the intervention received preparatory training, and fidelity checklists were used throughout the program to ensure consistent application of the communication strategies. While activities were adapted to suit each educational context, the core catalytic communication framework remained consistent across all settings.

3.4. Data Collection, Instruments and Procedures

Data were collected using a combination of surveys, interviews, observations, and behavioral records. Surveys were administered before the intervention, immediately after its completion, and three months later to assess changes in knowledge, attitudes, motivation, and self-reported pro-environmental behavior.

Qualitative data were collected through semi-structured interviews and focus groups. Fifteen participants from each context were interviewed about their experiences of the program, perceived self-efficacy, and the applicability of communication strategies in everyday life. Focus groups were used with younger participants to create a less intimidating research setting. All interviews were audio-recorded, anonymized, and transcribed.

Classroom and workshop sessions were observed by trained researchers using structured checklists to document participation, questions asked, and affective responses. Additional behavioral data included records of energy use, recycling activities, participation in voluntary environmental events, and reflective diaries maintained by community participants. Outputs from action projects (e.g., posters and videos) were collected and analyzed for evidence of empathy, hope, and systems thinking. All instruments and procedures were pilot-tested for clarity and cultural sensitivity, and surveys were completed anonymously to reduce potential response bias.

3.5. Measures and Variables

Cognitive, affective, and behavioral outcomes were assessed using multiple instruments. Cognitive outcomes were measured using a researcher-developed knowledge test consisting of multiple-choice and open-ended items aligned with the intervention content. Systems thinking and critical reflection were assessed through scenario-based tasks, reflective journals, and interview responses.

Affective outcomes included environmental empathy, hope, and motivation. Environmental empathy was measured using an adapted version of an environmental empathy scale originally developed by Ojala (2011) and further operationalized in educational research by Li and Monroe (2017). The scale captures both emotional and cognitive dimensions of empathy toward environmental and social sustainability issues. Hope related to climate and sustainability was assessed using selected items adapted from climate-related hope scales developed by Ojala (2011) and later extended by Ojala et al. (2021),

focusing on agency, collective efficacy, and positive future orientation. Motivation toward sustainability was measured using the Motivation Toward the Environment Scale (MTES), which assesses intrinsic motivation, extrinsic motivation, and amotivation in environmental contexts (Pelletier et al., 1998). Behavioral outcomes were assessed using self-reported items adapted from the General Ecological Behavior (GEB) scale, a widely used measure of pro-environmental behavior (Kaiser & Wilson, 2004). Follow-up measures examined the continuity of reported pro-environmental behaviors three months after the intervention. All multi-item scales demonstrated acceptable reliability for exploratory research purposes. Although established multi-item instruments were employed, numerical internal consistency indices such as Cronbach's alpha were not calculated in this study. Given the exploratory mixed-methods design and the modest sample size, reliability was instead supported through pilot testing, the use of previously validated instruments, and triangulation across quantitative and qualitative data sources. This approach is consistent with accepted practices in exploratory educational research. Pilot testing was conducted with a small group of participants who did not take part in the intervention or the main study. Where necessary, item wording was minimally adapted for educational level and setting without altering the underlying constructs or intended meaning of the original scales.

3.6. Data Analysis

Quantitative data were analyzed using statistical software. Exploratory mixed analyses of variance (ANOVA) were conducted to examine patterns of change across measurement points. Effect size estimates and correlations were explored to support interpretation of observed trends. Exploratory mediation analyses were performed to examine whether changes in affective engagement (empathy and hope) were associated with changes in reported pro-environmental behavior.

Qualitative data from interviews, journals, and open-ended survey responses were analyzed thematically. Two researchers independently coded a subset of the data to establish credibility and refine the coding framework. Coding differences were discussed and resolved through consensus, and formal interrater reliability statistics (e.g., percentage agreement or Cohen's κ) were not calculated, as the qualitative analysis followed an exploratory, interpretive thematic approach. Themes focused on emotional responses, perspective change, perceived challenges, and real-life applications of sustainability learning. Quantitative and qualitative findings were subsequently integrated to identify areas of convergence and divergence. Due to the exploratory design and the applied nature of the intervention, statistical analyses focused on identifying patterns of change rather than on confirmatory hypothesis testing.

Assumptions underlying repeated-measures analyses (including normality and sphericity) were examined prior to analysis. Where violations were identified, appropriate corrections (e.g., Greenhouse–Geisser adjustments) were applied during analysis. Missing data were minimal and handled using listwise deletion.

3.7. Validity, Bias and Ethics

The study was reviewed and approved by the Scientific Committee of the Faculty of Philology at the University of Prizren. Participation was voluntary, and all participants were informed about the study's aims and their right to withdraw at any time. For participants under 18 years of age, parental consent was obtained.

Potential sources of bias were addressed through anonymized data collection, pilot-testing of instruments, and triangulation of data sources. Facilitators were trained to handle emotionally sensitive sustainability topics and to provide appropriate support when needed.

Validity was addressed through multiple strategies appropriate for an exploratory mixed-methods design. Content validity was supported by aligning all instruments and learning tasks with the conceptual framework of catalytic communication and the objectives of the intervention. Construct validity was strengthened through the use of previously validated instruments reported in the literature and through convergence across quantitative measures, qualitative interviews, classroom observations, and action project artefacts. Pilot testing further supported clarity and contextual appropriateness of the instruments. Given the exploratory nature of the study and the modest sample size, formal statistical validity coefficients were not calculated.

4. Results

This section presents the quantitative and qualitative findings of the study. Considering the exploratory nature of the research and the sample size, results are reported in aggregate across participant groups rather than disaggregated by educational context. Quantitative results describe changes in cognitive, affective, and behavioral measures, followed by qualitative findings that provide contextual insight into participants' experiences of the intervention. Assumptions of normality and sphericity were examined prior to analysis. Where violations were detected, Greenhouse–Geisser corrections were applied. Missing data were minimal and handled using listwise deletion.

Given the exploratory nature of the study and the applied educational context, quantitative results are presented using group means to illustrate overall patterns of change across conditions. Full variance estimates (e.g., standard deviations) and detailed inferential statistics were not retained from the original analyses and are therefore not reported. The quantitative findings should be interpreted as indicative rather than confirmatory and are complemented by qualitative analyses that provide contextual depth and explanatory insight.

4.1. Cognitive Results

Baseline knowledge scores were comparable between the intervention and control groups. Following the intervention, participants in the intervention group demonstrated larger increases in knowledge scores compared to the control group. These gains remained largely stable at the three-month follow-up assessment. Mixed ANOVA results indicated a greater increase in knowledge scores over time for the intervention group relative to the control group.

As shown in Table 1, performance on the Systems Thinking Task followed a similar pattern. Participants in the intervention group demonstrated greater increases in identifying causal relationships, feedback loops, and system interconnections compared to the control group. Improvements observed in the control group were smaller and showed less evidence of increased complexity.

Table 1. Knowledge test scores (0 to 30 points).

Group	Pre-Test Mean	Post-Test Mean	Follow-Up Mean
Intervention	14.8	24.6	23.9
Control	15.1	18.3	17.5

Table 2 illustrates that comparative analyses across measurement points indicated a differential pattern of change between the intervention and control groups, with the intervention group demonstrating consistently larger improvements over time.

Table 2. Systems Thinking Task Scores (0 to 10).

Group	Pre-Test Mean	Post-Test Mean	Follow-Up Mean
Intervention	3.1	7.6	7.4
Control	3.0	4.8	4.6

4.2. Affective Outcomes

Affective outcomes were assessed using the Environmental Empathy Scale, the Climate Change Hope Scale, and the Motivation Toward the Environment Scale (MTES).

4.2.1. Empathy

Scores on the Environmental Empathy Scale increased for both emotional and cognitive empathy in the intervention group, while changes in the control group were comparatively small.

Findings presented in Table 3 indicate that participants frequently described moments during storytelling and role-play activities in which they reported a shift toward viewing sustainability challenges as personally and socially relevant.

Table 3. Environmental Empathy Scale Scores (1 to 5).

Emotional Empathy			
Group	Pre-test mean	Post-test mean	Follow-up mean
Intervention	2.96	4.21	4.08
Control	2.91	3.12	3.05
Cognitive Empathy			
Group	Pre-test mean	Post-test mean	Follow-up mean
Intervention	3.04	4.18	4.10
Control	3.01	3.29	3.22

4.2.2. Hope

On the Climate Change Hope Scale (Table 4), the intervention group showed increases across individual and collective hope dimensions, which were maintained at follow-up. Scores for the control group showed minimal change across measurement points.

Table 4. Climate change hope scale (1–5).

Group	Pre-Test Mean	Post-Test Mean	Follow-Up Mean
Intervention	2.78	4.03	3.96
Control	2.73	3.01	2.95

4.2.3. Motivation (MTES)

Motivation toward sustainability, measured using the MTES (Table 5), showed increases in intrinsic motivation and decreases in amotivation for participants in the intervention group. Changes in the control group were smaller across all motivational dimensions.

Table 5. MTES Scores (1–5).

Intrinsic Motivation			
Group	Pre-test mean	Post-test mean	Follow-up mean
Intervention	3.14	4.30	4.20
Control	3.12	3.39	3.32
Amotivation			
Group	Pre-test mean	Post-test mean	Follow-up mean
Intervention	2.61	1.42	1.55
Control	2.59	2.43	2.48

4.3. Behavioral Outcomes

Self-reported pro-environmental behavior, measured using the General Ecological Behavior (GEB) scale (Table 6), increased more substantially in the intervention group than in the control group. These changes were maintained at follow-up.

Table 6. GEB Behavioral Scores (0 to 38).

Group	**Pre-Test Mean**	**Post-Test Mean**	**Follow Up**
Intervention	12.4	24.1	22.9
Control	12.6	16.2	15.5

Reported behaviors included recycling practices, reductions in electricity consumption, participation in environmental clean-up activities, and involvement in collective sustainability initiatives.

4.4. Observed Engagement

Observer-coded measures indicated higher levels of engagement in sessions involving the intervention group compared to the control group (Table 7).

Table 7. Observed Engagement During Sessions (indicators measured using different metrics and reported descriptively).

Indicator	**Intervention**	**Control**
Active participation	74%	41%
Student-initiated questions per session	3.8	1.2
Emotional expressions noted (interest, concern, enthusiasm)	62%	23%

4.5. Action Projects

Action project outputs differed between groups in terms of depth and quality, with higher average rubric scores observed in the intervention group (Table 8).

Table 8. Action Project Rubric Scores (0 to 10).

Group	**Average Score**
Intervention	8.4
Control	5.7

Several project initiatives continued beyond the intervention period.

4.6. Follow-Up Behavior

At the three-month follow-up, a higher proportion of participants in the intervention group reported engaging in new environmental actions compared to participants in the control group (Table 9).

Table 9. Follow-Up Behavioral Actions.

Indicator	Intervention	Control
Joined or started an environmental activity	43%	14%

4.7. Mediation Analysis

Exploratory mediation analyses indicated that increases in empathy and hope were associated with changes in reported pro-environmental behavior. When considered jointly, these affective variables accounted for a substantial proportion of the observed behavior change (Table 10).

Table 10. Mediation Effects.

Mediator	Percentage of Behavior Change Explained
Empathy	28%
Hope	21%
Combined emotional engagement	49%

These mediation findings should be interpreted cautiously, as the analyses were exploratory and based on a limited sample size.

4.8. Qualitative Insights

Qualitative data were derived from 15 semi-structured interviews and three focus groups conducted across the intervention contexts. Thematic analysis identified four recurring themes: (1) emotional engagement and perspective change, (2) increased sense of agency, (3) application of sustainability practices in everyday contexts, and (4) development of collective purpose.

Participants frequently described emotionally salient moments during storytelling and role-play activities that altered how they related to sustainability challenges "*It stopped feeling abstract and started feeling personal.*" (University student, P12). Many reported increased confidence in discussing and acting on sustainability issues "I felt more capable of actually doing something" (Community participant, P3). Participants also described applying learning in home, school, and community contexts, such as initiating recycling activities or discussing sustainability with peers and family members. Finally, several participants emphasized the importance of shared dialogue in fostering a sense of collective engagement "It felt like we were part of something together" (Secondary school student, P7). These qualitative findings complement the quantitative results by illustrating how affective and dialogic elements of catalytic communication supported cognitive understanding and sustained behavioral engagement.

5. Discussion

Building on the empirical findings, this discussion interprets how catalytic communication may have contributed to the cognitive, affective, and behavioral patterns observed across intervention contexts. Overall, the results provide evidence suggesting that catalytic communication functions as a meaningful contributing process in sustainability education, supporting learning and engagement beyond what is typically achieved through

information-focused instruction. In line with theoretical perspectives that conceptualize communication not merely as a channel for information transfer but as a mediator of learning, the findings indicate that narrative, dialogic, and affectively engaging strategies were associated with stronger outcomes across multiple learning dimensions.

Improvements in knowledge retention and systems thinking observed among intervention participants align with Meadows' (2008) argument that sustainability challenges require learning designs that make complex systems visible. The use of narratives and visual tools appears to have supported learners in organizing and interpreting sustainability knowledge as relational and systemic rather than fragmented. In this sense, the findings are consistent with research suggesting that stories can function as a form of cognitive scaffolding (Dahlstrom, 2014), supporting the integration of abstract scientific information into coherent mental models.

While the study reports descriptive trends and comparative patterns rather than detailed inferential statistics, the observed differences between intervention and control groups were consistent across multiple cognitive, affective, and behavioral indicators. Given the exploratory design and modest sample size, emphasis was placed on identifying convergent patterns and practical relevance rather than on formal hypothesis testing using p-values or large effect size estimation. This approach aligns with prior exploratory research in sustainability education, where mixed-methods evidence is used to identify promising pedagogical directions rather than confirm causal effects.

At the same time, the relatively modest gains observed in the control group challenge the information-deficit model of communication (Moser & Dilling, 2007; Van der Linden, 2015). This reinforces broader critiques that emphasize the limitations of fact-based approaches to climate and sustainability communication (Moser, 2016). Learning factual information in isolation, even when accurate, appears insufficient for developing higher-order sustainability competencies or sustained engagement.

A central contribution of this study lies in its empirical attention to affective engagement as a key dimension of sustainability learning. The observed increases in empathy, hope, and intrinsic motivation among intervention participants are consistent with prior research identifying hope as an important psychological factor in motivating engagement with sustainability issues (Li & Monroe, 2017). These patterns also resonate with Ojala's (2011) work on constructive hope, suggesting that emotional engagement characterized by concern combined with perceived agency may be particularly relevant for sustaining action.

In this regard, the findings are consistent with Geiger et al.'s (2023) concept of empowering hope, in which emotional responses support engagement rather than disengagement or paralysis. Qualitative accounts of emotional "turning points" during storytelling and role-play activities further indicate that learning processes involved not only cognitive change but also emotional reorientation toward sustainability challenges. This interpretation aligns with transformative learning theory, which emphasizes the role of emotional disturbance and critical reflection in challenging existing mental models (Lotz-Sisitka et al., 2015).

Sustained changes in reported pro-environmental behavior observed at the three-month follow-up suggest that catalytic communication may contribute to participants' motivation to act. This finding is consistent with Bamberg's (2013) view of behavior change as a recursive process involving motivation, self-efficacy, and social support. The action–reflection cycles embedded in the intervention appear to have supported collective engagement and reduced feelings of isolation, reflecting Rappaport's (1987) understanding of empowerment as a socially situated process. Furthermore, exploratory mediation analyses indicated that empathy and hope accounted for a substantial proportion of observed behavior change, supporting Ajzen's (1991) assertion that attitudes are unlikely to trans-

late into action without sufficient motivation and perceived control. Aggregating results across educational contexts limits conclusions about context-specific effects and should be considered when interpreting the findings.

These findings have implications for multiple educational agents. For educators and facilitators, the results highlight the importance of designing communication that intentionally integrates emotional engagement, dialogue, and opportunities for action. For curriculum designers and institutions, the study suggests that sustainability education frameworks should move beyond content coverage toward pedagogies that support agency and collective engagement. At a policy level, the findings support calls for Education for Sustainable Development approaches that recognize communication as a lever for behavioral mobilization rather than information transmission alone.

In general, these findings support calls for Education for Sustainable Development pedagogies that are learner-centered, participatory, and affectively relevant (Tilbury, 2011; Wals, 2015). They also highlight the importance of supporting educators not only as content experts but as communicators and facilitators capable of fostering dialogue, emotional engagement, and collective action. This has implications for teacher education, curriculum design, and accreditation standards that continue to prioritize content coverage over the activation of agency and behavior (Sterling, 2010).

More broadly, the study reinforces the theoretical position that communication can be understood as a deliberately designed, catalytic mediator of learning rather than a neutral instructional context. When communication integrates cognitive, affective, and behavioral dimensions in a coherent sequence, it may function as a meaningful lever for sustainability-oriented learning and action. These interpretations should be considered in light of the exploratory design and modest sample size, which limit generalizability and point to the need for further research across diverse cultural and institutional contexts.

6. Conclusions

This study provides evidence suggesting the potential efficacy of catalytic communication for addressing the knowledge–action gap in sustainability education. By deliberately integrating affective engagement with opportunities for reflection and action, communication processes may support the enactment and persistence of pro-environmental behavior. The findings reinforce the view that sustainability education must extend beyond the transmission of knowledge toward processes of becoming and acting. By combining a theoretically informed framework with empirical evidence from an applied intervention, this study contributes to ongoing debates on how communication can function as a catalytic mediator of learning and action. Future research should further examine how catalytic communication strategies operate across diverse cultural, institutional, and educational contexts.

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Informed Consent Statement: Informed consent was obtained from all participants involved in the study. For participants under 18 years of age, informed consent was obtained from parents.

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Abbreviations

The following abbreviations are used in this manuscript:

ANOVA	Analysis of Variance
ESD	Education for Sustainable Development
GEB	General Ecological Behavior

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