

Active Hydroponic Plant Care, Nature Connection, and Perceived Stress among Adolescents: A Mixed-Methods Pilot Study

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ABSTRACT

Adolescents today report unprecedented levels of academic stress and growing disconnection from the natural world, yet remain underrepresented in nature-based wellbeing interventions, and school-based mental health resources remain stretched thin. This mixed-methods pilot study examines whether sustained active engagement with a living system is associated with reduced perceived stress, stronger ecological identity (how people perceive themselves as living beings connected to nature), and social connection in high-pressure academic environments. We hypothesized that a 3-week hydroponic herb-growing project would be associated with reduced perceived stress, increased nature connection, heightened environmental responsibility, and strengthened peer collaboration among high school students. Three participants (two juniors and one freshman) completed pre- and post-intervention Perceived Stress Scale (PSS-10) assessments, weekly Likert-scale surveys, and reflection journals, while the researcher independently recorded observational field notes. Data were analyzed using descriptive statistics and qualitative thematic coding. Results indicated a 38.0% reduction in mean PSS-10 scores among the three participants (pre: 29.7; post: 18.3). Post-intervention surveys showed strong endorsement of stress management ($M = 4.00$) and peer collaboration ($M = 4.67$ – 5.00), moderate nature connection ($M = 4.67$), and variable environmental responsibility ($M = 3.33$ – 4.00). Qualitative analysis most frequently reflected sensory engagement, environmental stewardship, and nature connection, with journal entries demonstrating a progression from procedural task completion to integrated moral responsibility. These findings suggest that structured plant stewardship may offer a cost-effective, accessible approach worth investigating for reducing adolescent stress while fostering ecological identity and social bonds. Future research employing larger samples, control groups, and longitudinal designs is needed to confirm generalizability across diverse populations and contexts.

Keywords: Adolescents, biophilia, hydroponics, wellbeing, collaboration

INTRODUCTION

Adolescence involves substantial physical, social, and psychological changes (World Health Organization, n.d.). When compounded with external stressors—particularly academic stress—adolescents may experience increased anxiety, depression, and declining academic performance (McGorry et al., 2025). While college students face similar stress patterns, research on nature-based interventions remains limited for adolescents. This gap motivated our focus on high school students, who experience comparable academic pressure but fewer structured nature engagement opportunities. Our study investigates whether structured hydroponic plant cultivation—requiring daily care, nurturing, and witnessing plant growth—influences adolescent stress, attention, and environmental connection differently versus passive nature exposure.

We grounded our intervention in biophilia theory, which describes humans' innate tendency to affiliate with nature and other forms of life, one theoretical explanation for why nature contact may support wellbeing (Wilson, 1984). Wilson (1984) proposed that this tendency arose because humans evolved in close association with living systems. Rather than providing mere aesthetic enjoyment, interactions with nature may satisfy fundamental psychological needs, including stress reduction, attention restoration, and enhanced connection and purpose (Bratman et al., 2019; Kaplan, 1995). Biophilia has been used to explain people's attraction to gardens, forests, wildlife viewing, and indoor plants (Wilson, 1984). If humans are naturally drawn toward living systems, then caring for plants may be a particularly meaningful way of supporting adolescent wellbeing.

Attention Restoration Theory (ART), as proposed by Kaplan (1995), explains how nature counteracts cognitive fatigue from prolonged directed attention, the effortful focus required for academic work. When depleted through demanding tasks, this cognitive capacity leads to reduced performance and diminished concentration. Recovery requires a restorative environment with four components: fascination (soft, effortless engagement like watching leaves), being away (psychological distance from daily demands), extent (immersion in a coherent environment), and compatibility (alignment with human inclinations). Experimental work has tested ART's predictions, with mixed results across measures (Hartig et al., 1996); however, exposure to natural environments has been shown to improve directed-attention performance compared to urban conditions (Berman et al., 2008), with individuals reporting restored focus and reflection capacity (Kaplan & Kaplan, 1989). For academically pressured adolescents, plant engagement could offer these restorative benefits through fascination, compatibility, and psychological distance, and thus support stress management and cognitive restoration.

Recent research increasingly recognizes nature contact as vital for mental health (Bratman et al., 2019). Universities have responded by implementing programs like Campus Nature Rx, which increase student nature exposure through green spaces and outdoor activities (Rakow & Ibes, 2022). However, these programs emphasize passive exposure—visiting green spaces or viewing nature—rather than active

engagement. Few studies evaluate whether actively cultivating and caring for plants produces stronger psychological benefits than passive exposure. If biophilia and ART both suggest that meaningful engagement with living systems facilitates wellbeing, does the active responsibility of plant stewardship produce greater benefits than passive nature time? Whether the active responsibility of plant stewardship confers benefits beyond those of passive nature exposure remains an open question, and one this pilot was not designed to resolve.

We hypothesized that sustained, hands-on responsibility for the herb tower would be associated with reduced perceived stress, increased connection to nature, and heightened environmental responsibility, as well as strengthened peer collaboration through shared caretaking. Because the hydroponic system required participants to coordinate and troubleshoot together, shared responsibility for a stressful task may itself have reduced stress, independent of the plant care itself. Hydroponic systems represent a distinct form of active engagement with living systems, fundamentally different from traditional classroom plants. Hydroponics is a method of growing plants in a nutrient-rich water solution without soil, using controlled systems that deliver precise amounts of water, nutrients, and light directly to plant roots (Savvas & Gruda, 2018). Unlike potted plants that require occasional watering and minimal monitoring, hydroponic systems demand routine, systematic responsibility: participants must monitor nutrient concentrations (measured as electrical conductivity, EC), pH levels, water quality, and lighting cycles while troubleshooting system malfunctions and adjusting growing conditions based on plant responses.

This technical engagement transforms plant cultivation from passive observation into active problem-solving. The systems also foster collaboration: students must coordinate monitoring schedules, troubleshoot system issues collectively, and share responsibility for plant health outcomes. Critically, hydroponics may make plant stewardship visible and quantifiable in ways traditional gardening may not: daily monitoring logs, weekly data collection, and observable system responses create accountability and emotional investment. For adolescents, this technical sophistication and tangible responsibility may support psychological benefits that passive nature observation alone is less likely to provide, engaging the agency, ecological identity, and resilience theorized through "positive dependency" (Chawla, 2022; Tidball & Stedman, 2013). This comparison, however, remains untested. Taken together, these features suggest that active plant stewardship, even in an indoor setting, could serve as a meaningful wellbeing intervention for adolescents, and that a sense of responsibility developed through caretaking may be a key mechanism underlying that effect.

Despite evidence that nature contact supports mental health, most research examines passive exposure: window views of greenery (Ulrich, 1984) and proximity to green space (de Vries et al., 2003; Twohig-Bennett & Jones, 2018). Ulrich's foundational study showed hospital patients with tree views recovered faster, required fewer painkillers, and received fewer negative nurse evaluations than those viewing a brick wall (Ulrich, 1984), demonstrating that passive visual exposure produces measurable benefits. However, active engagement with nature may support agency, ecological identity, and resilience in ways passive exposure may not (Chawla, 2022; Tidball & Stedman, 2013). Few studies have examined indoor hydroponic systems as a wellbeing intervention, particularly with adolescents rather than college

or adult samples, and fewer still have used mixed-methods approaches to examine both psychological outcomes and the mechanisms behind them.

The present study begins to address this gap through a three-week mixed-methods pilot in which high school students assumed daily responsibility for a vertical hydroponic herb tower installed in their school atrium. Pre- and post-intervention PSS-10 scores, a final Likert-scale survey, reflection journals, and researcher observation notes were used to characterize both psychological outcomes and participants' accounts of the experience.

MATERIALS AND METHODS

Participants

Participants were recruited from the gardening club at Seoul International School. Seven club members were contacted, and four declined due to a lack of interest, yielding a final sample of three. None of the three participants had experience with hydroponics, although two had experience caring for small succulents at home. Two participants were in 11th grade and one was in 9th grade. Recruitment criteria included informal self-reported interest in plants and self-reported high stress; PSS-10 scores were then collected as a baseline measure to formally characterize participants' stress levels. Because participants were drawn from an existing gardening club and were additionally required to report an interest in plants, the final sample was doubly selected for prior affinity with plant care, and may therefore have been especially likely to engage with and benefit from the intervention independent of any general effect of hydroponic care. The four declines, all attributed to a lack of interest, further concentrated the sample toward plant-enthusiastic adolescents, which may inflate engagement and self-reported benefit relative to a general adolescent population (see Limitations). On the first day of the study, the participants were taught how to manage the pH and EC levels using the FreeLife FB-99 Multi-Parameters Water Quality Analyzer. All participants remained in the study through the final data collection point and spent approximately 15–20 minutes per session tending the seedlings as a group.

System Setup



Figure 1. The SpaceTree Vertical Hydroponic System Installed in the School Atrium.

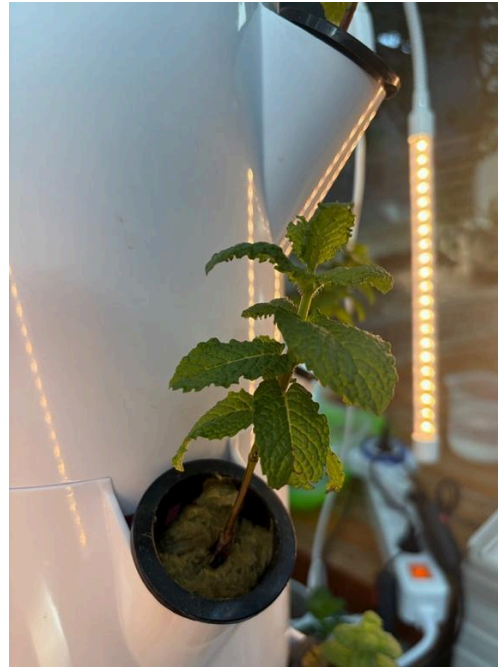


Figure 2. Mint seedling growing in a rockwool cube within a hydroponic pod.

A total of 24 *Mentha suaveolens* and *Mentha spicata* seedlings were purchased from Daerim Nursery. The seedlings were then placed in net cups of the SpaceTree Vertical Hydroponics Tower (Figure 1). Before placing the seedlings in the net cups, their roots were washed to remove any soil remnants and then were wrapped with small pieces of rockwool (Figure 2). Liquid nutrients of N-P-K were diluted at a 1:125 ratio with a total of 20 L of water to ensure an EC of approximately 1.45 dS/m and pH ranging from 5.8 to 6.2. The hydroponics tower was placed in the school's atrium for the three weeks the study was conducted.

Procedure

Starting from May 19th, 2026, participants recorded EC and pH levels at 9 a.m. A 1:100 citric acid solution was used to lower pH when readings exceeded the target range, and 5 g of baking soda was used to raise pH when needed. An analogue timer was used to ensure 2 cycles of 15 minutes during the day. The pump was turned off during non-daylight hours to reduce the risk of excessive root moisture. Full-spectrum LED lights were used to provide twelve hours of additional lighting to the natural light coming through the ceiling windows in the atrium.

Ethical Considerations

Because all participants were minors, written parental/guardian consent and written participant assent were obtained from each participant before any data collection began. Participants were informed of the study's purpose, procedures, and their right to withdraw at any time without penalty. No identifying

information was collected, and all data were anonymized and stored on a password-protected device accessible only to the researcher. Prior to data collection, the study protocol was reviewed and approved using the Society for Science Human Participants Form — the standard ethics review pathway for pre-college research of this kind, used in lieu of a university Institutional Review Board (IRB) — and was signed by a licensed clinical psychologist, a certified educator, and a school administrator. The project was conducted under the supervision of Dale Fiess (Science Teacher, Seoul International School).

Data Collection

Student participants were given journal templates to record their stress levels and sense of connection with the seedlings (Appendix B). No researcher self-report data were included in the participant dataset; the researcher's role was limited to recording independent observational field notes. Journals were initially planned to be collected daily, but journal templates were collected 3 times per week. This was due to participants' opinions that daily journaling was not favored. Although primarily the participants worked as a group to tend to the seedlings, schedule conflicts occasionally required some participants to fill out their journal template individually. Students were also asked to fill out PSS-10 forms at the start of the first week and on the last day of the experiment. PSS-10 is a questionnaire that is widely used to measure subjective stress levels over the past month (Cohen et al., 1983). This questionnaire was used because it provides quantitative evaluations of how unpredictable, uncontrollable, and stressful individuals perceive their experiences.

Data Analysis

After collecting journals, students were kept anonymous, and their responses were coded into 5 themes: sensory/active engagement; environmental responsibility and stewardship; nature connection; peer collaboration and learning; and wellbeing and stress management (Table 3). The codes were collected into a codebook with explicit inclusion and exclusion criteria for each theme (Appendix C). Coding followed a combined deductive-inductive approach: an initial set of codes was drawn from the constructs guiding the study's research question (e.g., nature connection, environmental responsibility, wellbeing), and additional codes were added inductively as new patterns emerged from a first full pass through the data. For each code, inclusion and exclusion criteria were written to define what qualified as an instance of that theme. Once these criteria were finalized, all previously coded entries were reviewed again against them to check coding consistency, and discrepancies were resolved by refining the criteria or reclassifying the entry. Researcher observation notes were coded using the same codebook and thematic framework and were triangulated with survey and journal data. Each entry could receive more than one thematic code, so the total number of codes (53) exceeds the number of entries collected. Given the small sample size ($n = 3$), inferential statistical tests were not conducted; all quantitative findings are reported descriptively.

RESULTS

All three high school participants completed pre- and post-intervention PSS-10 surveys, final surveys, and journal entries across 3 weeks. Compared to pre-intervention PSS-10 scores, the group mean PSS-10 score decreased across the three participants from 29.7 to 18.3 (an 11.3-point decrease and 38.0%

reduction; Table 2). Although individual score reductions varied, Participant 2 showed the greatest reduction (-17 points, Table 2).

Table 1. Final survey responses by participant (1 = Strongly Disagree, 5 = Strongly Agree).

The full final survey instrument is provided in Appendix A.

Survey Questions	P1	P2	P3	Mean (±SD)
Q1: Caring for plants helped me feel calmer	4	4	4	4.00 (±0.00)
Q2: Hydroponic system gave me a mental break	3	5	4	4.00 (±1.00)
Q3: Collaborating brought us closer together	4	5	5	4.67 (±0.58)
Q4: Sharing solutions helped me learn new things	5	5	5	5.00 (±0.00)
Q5: Project made me think about where food comes from	2	4	3	3.00 (±1.00)
Q6: Caring for plants made me feel connected to nature	4	5	5	4.67 (±0.58)
Q7: Project helped me understand hydroponic sustainability	2	5	5	4.00 (±1.73)
Q8: I feel more responsible for my environmental choices	2	4	4	3.33 (±1.15)
Q9: More likely to support sustainable agriculture	3	5	4	4.00 (±1.00)
Open-ended questions				

Q10: What was the most meaningful or memorable part of the hydroponic project for you? Why?	P1: The very first day when we all got rid of the dirt was the most memorable because it was a lot of fun. It was very painful, yet it had a sense of accomplishment after we were done. And this moment was the reason why I wanted to continuously visit the plants during the three-week period. P2: I think the most memorable part of the hydroponic project was collabing with other people. It made the whole process much more enjoyable as there were people right next to me doing the same things in order to support the mints. P3: When we all got together to set up the tower was the most memorable for me. Everyone was working together, talking, laughing, and enjoying the scent of the mints. It was a great experience and the people made it even better.
Q11: Did participating in this project change how you think about or handle academic stress? If yes, how? If no, why not?	P1: Personally, it didn't really change anything because it's not something I do every time I'm stressed. I have my ways of handling academic stress and although it did open up some options, it ultimately just wasn't my way of venting out my stress. P2: Yes because it allowed for me to take my mind off of incoming tests, therefore giving me more time for myself and to just cool down. P3: Yes. I tend to bottle up my stress but with this project I felt much more relaxed. It didn't feel like I was holding back any pent up stress and it helped me feel much better compared to when I wasn't actively in the project.

Table 2. Pre- and post-project PSS-10 scores for the three participants.

Higher scores indicate greater perceived stress (possible range: 0–40).

Participant	Pre-Score	Post-Score	Change	% Decrease
1	29	20	-9	31.0%
2	31	14	-17	54.8%
3	29	21	-8	27.6%
Group Mean	29.7	18.3	-11.3	38.0%

Table 3. Number of journal entries and researcher observation notes coded per theme.

Theme	Journal Entries Coded	Researcher Observation Notes Coded
Sensory / Active Engagement	18	6

Environmental Responsibility and Stewardship	15	6
Nature Connection	11	1
Peer Collaboration and Learning	5	4
Wellbeing and Stress Management	4	2
Total	53	19

Discussion of Themes in Table 3

Wellbeing and Stress Management

To assess changes in perceived stress, the PSS-10 was administered at the start of Week 1 and again at the end of Week 3. PSS-10 scores declined for all three participants (Table 2). Group mean PSS-10 score decreased from 29.7 to 18.3, a mean reduction of 11.3 points (38.0%). Individual reductions were -9 for P1, -17 for P2, and -8 for P3. Given the very small sample and the absence of a comparison condition, this consistent decline is best read as a promising descriptive pattern within this pilot rather than as a generalizable effect. On the final survey, both wellbeing items received a group mean of 4.0 out of 5 (Table 1). Two of three participants reported in their open-ended response (Q11) that the project changed how they handled academic stress: P2 noted it allowed them to "take my mind off of incoming tests," while P3 reported feeling "much more relaxed" and no longer "holding back pent-up stress." P1 reported that the project introduced new options for stress management but did not replace existing coping strategies. Wellbeing and Stress Management was the least frequently coded journal theme, appearing in 4 entries (Table 3), though those entries described states of calm, tranquility, and emotional relief explicitly linked to plant-care sessions.

Environmental Responsibility and Stewardship

Participants' survey and journal responses were consistent with a growing sense of environmental responsibility and stewardship over the course of the project. To measure whether participants developed a sense of personal responsibility for a living system, three survey items assessed environmental responsibility alongside journal and observation coding. Survey responses showed moderate to strong agreement with environmental responsibility items. Participants averaged 4.00/5 on understanding hydroponic sustainability (Q7), 3.33/5 on daily environmental responsibility (Q8), and 4.00/5 on future support for sustainable agriculture (Q9). Environmental Responsibility was the second most frequently coded journal theme at 15 entries and was also coded in 6 researcher observation notes — the highest observation count of any theme (Table 3). Journal entries included explicit duty language: one participant wrote that caring for the plants "felt more like a choice — I don't actually need to but I choose to since I'm responsible for the plants," while another reflected that their "responsibility towards the plants increased as more time and energy was put into caring for the plants." A third noted that "the mints would be in a worse living condition if none of us showed up." Researcher observations during Week 3 recorded that all participants voluntarily checked on the seedlings during the school's twenty-five-minute midday break and communicated independently about plant health issues, including root rot.

Sensory and Active Engagement

Sensory and Active Engagement was the most frequently coded journal theme, appearing in 18 of 53 journal entries (34%) and was also coded in 6 researcher observation notes (Table 3). Journal entries recorded detailed hands-on and sensory descriptions of the care activity: one participant described that "the leaves feel kind of fuzzy" during physical handling; another noted that "the air seemed cleaner in the atrium — I could smell the mints; it had a fresh smell"; a third described the activity as having "been engraved into my routine." This quote was coded as active engagement because it reflects repeated integration into daily routine. Researcher observation notes from Week 2 suggested that one participant independently measured pH and EC levels and was first to identify abnormalities in one of the mint plants, demonstrating attentive, self-directed engagement with the system.

Nature Connection

Participants reported stronger connection to nature after caring for the hydroponic mint tower. On Q6, participants scored 4, 5, and 5, with a mean of 4.67 (± 0.58). This was one of the highest survey means in the study. In contrast, the food-origins item was more variable and averaged neutral. On Q5, scores were 2, 4, and 3, with a mean of 3.00 (± 1.00) (Table 1). Nature Connection was coded in 11 journal entries and 1 researcher observation note (Table 3). Journal responses described a notable before-and-after shift: one participant wrote that they "used to barely notice the trees, plants, flowers, or any kind of nature" but now noticed how plants flourish and wilt in the surrounding environment. Furthermore, another described the experience as the following: "caring for the plants helped make me more attuned to nature and its importance to me."

Peer Collaboration and Learning

Coded journal entries and observation notes were consistent with noticeable patterns of collaborative engagement in shared plant stewardship. To assess whether shared plant care fostered peer learning and social connection, two survey items measured collaboration outcomes alongside journal and observation coding. On Q4 ("Sharing solutions and ideas with my teammates helped me learn new things"), all three participants scored 5 out of 5, for a mean of 5.00 (± 0.00). This was the only survey item with unanimous strong agreement. On Q3 ("Collaborating on plant care brought us closer together"), scores were 4, 5, and 5, with a mean of 4.67 (± 0.58) (Table 1). All three participants independently identified collaborative experiences as the most meaningful part of the project in their open-ended response (Q10). P2 described how collaborating "made the whole process much more enjoyable"; P3 recalled, "everyone working together, talking, laughing, and enjoying the scent of the mints." Peer Collaboration was coded in 5 journal entries and 4 researcher observation notes (Table 3). Although peer collaboration appeared less frequently in weekly journal coding than sensory engagement or responsibility, final survey responses showed strong agreement across all participants. Researcher observation notes corroborated these quantitative findings. Week 2 field notes documented peer-to-peer interaction around the tower, with participants sharing troubleshooting strategies and plant health observations. By Week 3, all three participants were independently checking seedlings during free periods and communicating unprompted about plant health concerns, including wilting leaves and the progression of root rot identified at the end of Week 2. This pattern of self-initiated collaboration on system maintenance is consistent with a deepening shared responsibility for the living system.

DISCUSSION

The 3-week mixed-methods pilot study suggests that sustained active care for herbs through a hydroponic tower may be associated with reduced perceived stress, stronger nature connection, and increased environmental responsibility among high school students. The decrease in PSS-10 scores provides preliminary quantitative support for the possibility that the intervention was associated with reduced perceived stress. Together with post-intervention wellbeing ratings, these findings suggest that participants experienced the activity as a calming break from academic stress.

These findings are in line with Rakow and Ibes (2022), who examined short nature-based interventions among college students, although the present study differed by focusing on active plant care among high school students. One plausible explanation for the decline in PSS-10 scores could be that active engagement with the hydroponic herb tower provided psychological restoration by creating temporary distance from academic stress. The Attention Restoration Theory states that natural environments, particularly those requiring sensory engagement and soft fascination, allow depleted attentional resources to recover, lowering perceived stress. Beyond immediate stress relief, however, the structured daily engagement with living plants may have cultivated what Tidball and Stedman term "positive dependency"—a constructive reliance on and trust in natural systems that strengthens ecological identity and contributes to individual and system resilience (Tidball & Stedman, 2013). Rather than viewing dependency as inherently problematic, Tidball and Stedman reframe it as a beneficial psychological and relational condition: when individuals actively interact with living systems through care, stewardship, and responsibility, they develop enhanced ecological selfhood and a deeper sense of place, both of which support personal resilience and wellbeing. In their work on urban resilience, Tidball and Stedman argue that active stewardship of natural systems, particularly in resource-constrained environments, enhances individuals' sense of ecological agency and connection. The journal data align with this framework: 15 coded instances of environmental responsibility and stewardship language suggest that participants may have developed an awareness of their role as caretakers. Participant 2's notation that "adjusting the pH was like learning the plant's language" exemplifies how tactile, ongoing engagement may deepen perceived interdependence with the system—moving beyond passive observation to active relational awareness.

While passive exposure to nature offers measurable benefits, research distinguishes between the restorative effects of viewing nature and the deeper psychological and behavioral outcomes associated with active engagement. Ulrich's (1984) seminal work demonstrated that even passive observation—surgical patients viewing trees through windows—required fewer pain medications and experienced shorter postoperative recovery periods (7.96 vs. 8.70 days) compared to those viewing built structures. Additionally, patients with tree views received significantly fewer negative evaluative comments in nursing notes (1.13 vs. 3.96 per patient), suggesting improvements in mood and behavioral recovery alongside reduced analgesic use. Chawla (2022) argues that framing nature's benefits through a "medical model" of passive reception misses a crucial dimension: humans are active agents whose wellbeing deepens when they exercise autonomy, competence, and relatedness within natural settings. Research on school gardening supports the benefits of active plant engagement. Blair's comprehensive

review of school gardening programs found that qualitative studies documented broader behavioral, social, and environmental learning outcomes among children who participated in hands-on cultivation (Blair, 2009). Though Blair's review focuses on documenting gardening program benefits rather than explicitly comparing active versus passive nature exposure, the evidence suggests that structured plant engagement may support benefits across multiple developmental domains. In our pilot study, participants moved beyond passive viewing—they monitored pH, harvested plants, and troubleshooted system problems. This active stewardship, grounded in Chawla's transactional framework and supported by Blair's evidence, may have contributed to the strong nature-connection ratings (Q6: 4.67). However, environmental responsibility outcomes were more variable across items (Q7 showed stronger agreement than Q8), suggesting that while the intervention supported connection to nature, the development of sustained environmental commitment may require longer timeframes or additional supports. The patterns observed across quantitative and qualitative data suggest that active plant stewardship may support ecological awareness, though caution is warranted in attributing all responsibility gains directly to the intervention without further investigation.

A central limitation of this design bears directly on the question that motivated it. Although this study is framed around the distinction between active stewardship and passive nature exposure, it included no passive-nature comparison condition: participants were not compared against peers who viewed plants without caring for them, kept uncared-for indoor plants, or spent an equivalent amount of time in outdoor green space. The changes observed here therefore cannot be attributed specifically to the active, caregiving dimension of the intervention, as opposed to nature contact of any kind, time away from academic work, or the social contact that accompanied each session. Establishing whether active care confers benefits beyond passive exposure would require a design with at least one passive-nature control arm — passive plant viewing, indoor plants without care duties, or outdoor green-space time — matched on duration and setting.

By week three, the participants demonstrated a stronger sense of responsibility and stewardship. For instance, Participant 2 wrote in their journal: "The mints would be in a worse living condition if none of us showed up. While the pod is easy to manage, it doesn't mean we can just neglect it." This statement moves beyond technical competence to acknowledge interdependence—the recognition that the plants depend on human care and that abandoning this responsibility would cause harm. This sense of stewardship was reflected in environmental responsibility survey items (Q7–Q9), where participants reported moderate to strong agreement with statements about hydroponic sustainability, environmental responsibility, and sustainable agriculture support. While variation existed (particularly P1's lower Q8 rating of 2), the general trend suggests that sustained engagement with a living system involves not just task competence, but a moral dimension—a felt duty to care.

Beyond the reduction in perceived stress (38.0% PSS-10 decrease), qualitative and quantitative data suggest that regular engagement with the hydroponic system may have supported a sense of wellbeing that extended beyond immediate stress relief. In this pilot, participants engaged with the hydroponic system for 15–20 minutes during the midday break. Post-intervention survey responses supported

participants' experience of plant care as calming and mentally restorative. All three participants agreed that caring for plants helped them feel calmer (Q1), suggesting that the intervention may have offered psychological benefit across the group. This finding supports Rakow and Ibes's (2022) argument that structured nature engagement offers cost-effective, accessible mental health support. However, the variation in Q2 (± 1.00) suggests that the perceived "break" from academic work was experienced differently: some participants may have viewed plant care as a genuine escape from schoolwork, while others integrated it more seamlessly into their academic routine. This nuance underscores that while participants in this study experienced plant care as stress-relieving, the subjective experience of mental restoration varied by individual. Future research could examine this variation more directly—for instance, whether individual differences in baseline stress, coping style, or personality shape which specific psychological mechanism (escape from routine, sensory engagement, social distraction) drives the restorative effect for a given person.

Peer collaboration emerged as an unexpectedly strong finding, despite receiving the least attention in journal entries. Participants rated Q3 ("Collaborating brought us closer together") at 4.67 and Q4 ("Sharing solutions helped me learn new things") unanimously at 5.00, the highest quantitative ratings across all survey domains. This discrepancy between journal frequency and survey enthusiasm suggests that collaborative learning, though less explicitly reflected upon in writing, was deeply valued. The unanimous agreement on Q4 suggests that all three participants experienced peer learning as valuable—troubleshooting pH imbalances together, sharing observations about plant growth patterns, and collectively problem-solving system failures created opportunities for social bonding alongside practical skill-building. This finding aligns with research showing that structured group activities in nature foster social cohesion and cooperative learning (Blair, 2009). The peer collaboration dimension of this hydroponic project may have been particularly significant because it framed learning as a collective responsibility rather than individual achievement: participants were not competing for grades but working toward a shared goal of plant health. This cooperative framing may have created an environment where participants felt comfortable asking questions, admitting confusion, and learning from one another—conditions that support both academic and social-emotional growth in high-stress settings.

LIMITATIONS

This pilot study, while demonstrating promising preliminary findings, is subject to several important limitations that constrain generalizability and require cautious interpretation. The sample size ($n=3$ participants) is small, providing rich qualitative data but limited statistical power and restricted representativeness. As described in Participants, all three were self-selected members of the gardening club at a single private international school, introducing potential selection bias that limits applicability to less environmentally motivated populations. The study lacked a control group, preventing definitive causal claims about whether observed improvements resulted from hydroponic engagement specifically versus other concurrent stressors, academic supports, or seasonal factors (the three-week pilot occurred during a single term). Additionally, the self-report nature of survey and journal data introduces social desirability bias—participants may have inflated positive ratings or emphasized stewardship language to

align with perceived researcher expectations or peer group norms. Journal and observation coding was also conducted by a single researcher; although inclusion and exclusion criteria were defined for each code and all entries were reviewed a second time against the finalized criteria, no second, independent coder verified the thematic categorization, so formal inter-rater reliability could not be established. The data collection schedule further deviated from the original protocol: journals were planned to be collected daily but were instead collected three times per week after participants reported that daily journaling was burdensome, which may have reduced the granularity of the qualitative data relative to what was originally intended.

The brief intervention window (three weeks of data collection plus reflections) limits assessment of long-term retention or behavioral change; it remains unknown whether the psychological and environmental benefits observed would persist months or years after the pilot ended. Finally, quantitative measures relied on single-item constructs (Q1–Q9) rather than validated psychometric instruments beyond the PSS-10, reducing confidence in the reliability and construct validity of findings across wellbeing, nature connection, and environmental responsibility domains. Future research employing longitudinal designs, larger and more diverse samples, control/comparison conditions, and validated measurement tools will be essential to confirm whether this pilot's promising results generalize to other populations and settings.

CONCLUSION

Despite these limitations, this pilot study opens several productive directions for future research on nature-based wellbeing interventions in high-pressure academic settings. First, a larger, randomized controlled trial comparing hydroponic gardening with other nature-based activities (passive plant viewing, indoor plants without care duties, and outdoor green-space time) would clarify which dimensions of engagement—active stewardship, tactile sensory contact, or social cooperation—drive the observed benefits. Second, longitudinal follow-up with current participants and expanded cohorts would reveal whether the psychological gains and environmental responsibility patterns documented here persist into future academic years and whether they predict real-world environmental behaviors (e.g., sustainable food choices, conservation activism). Third, examining the role of structure versus autonomy in garden-based learning merits investigation: does teacher-directed instruction about hydroponic systems dampen the self-directed engagement observed here, or does it scaffold learning for less experienced gardeners? Fourth, adapting this model to diverse school contexts—rural schools, under-resourced urban schools, schools serving students with lower baseline nature exposure—would test whether the benefits observed in this privileged sample generalize and whether gardening programs can meaningfully reduce disparities in nature access and mental health support. Finally, investigating the mechanisms linking active plant stewardship to ecological identity development could clarify whether brief hydroponic engagement contributes to lasting shifts in how adolescents understand their relationship to the natural world—a question with implications for environmental education policy and funding. While this small pilot cannot yet position nature-based interventions as established components of school mental health support, the

findings suggest they are worth investigating further as potentially accessible and cost-effective tools for supporting adolescent wellbeing.

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REFERENCES

- Berman, M. G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychological Science*, 19(12), 1207–1212. <https://doi.org/10.1111/j.1467-9280.2008.02225.x>
- Blair, D. (2009). The child in the garden: An evaluative review of the benefits of school gardening. *The Journal of Environmental Education*, 40(2), 15–38. <https://doi.org/10.3200/JOEE.40.2.15-38>
- Bratman, G. N., Anderson, C. B., Berman, M. G., Cochran, B., de Vries, S., Flanders, J., Folke, C., Frumkin, H., Gross, J. J., Hartig, T., Kahn, P. H., Jr., Kuo, M., Lawler, J. J., Levin, P. S., Lindahl, T., Meyer-Lindenberg, A., Mitchell, R., Ouyang, Z., Roe, J., ... Daily, G. C. (2019). Nature and mental health: An ecosystem service perspective. *Science Advances*, 5(7), eaax0903. <https://doi.org/10.1126/sciadv.aax0903>
- Chawla, L. (2022). Passive patient or active agent? An under-explored perspective on the benefits of time in nature for learning and wellbeing. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.942744>
- Cohen, S., Kamarck, T., & Mermelstein, R. (1983). A global measure of perceived stress. *Journal of Health and Social Behavior*, 24(4), 385–396. <https://doi.org/10.2307/2136404>
- de Vries, S., Verheij, R. A., Groenewegen, P. P., & Spreeuwenberg, P. (2003). Natural environments—healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A*, 35(10), 1717–1731. <https://doi.org/10.1068/a35111>
- Hartig, T., Bökk, A., Garvill, J., Olsson, T., & Gärling, T. (1996). Environmental influences on psychological restoration. *Scandinavian Journal of Psychology*, 37(4), 378–393. <https://doi.org/10.1111/j.1467-9450.1996.tb00670.x>
- Kaplan, S. (1995). The restorative benefits of nature: Toward an integrative framework. *Journal of Environmental Psychology*, 15(3), 169–182. [https://doi.org/10.1016/0272-4944\(95\)90001-2](https://doi.org/10.1016/0272-4944(95)90001-2)
- Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge University Press.
- McGorry, P., Gunasiri, H., Mei, C., Rice, S., & Gao, C. X. (2025). The youth mental health crisis: Analysis and solutions. *Frontiers in Psychiatry*, 15, 1517533. <https://doi.org/10.3389/fpsyg.2024.1517533>

- Rakow, D. A., & Ibes, D. C. (2022). Campus Nature Rx: How investing in nature interventions benefits college students. *Frontiers in Psychology*, 13. <https://doi.org/10.3389/fpsyg.2022.960370>
- Savvas, D., & Gruda, N. (2018). Application of soilless culture technologies in the modern greenhouse industry—A review. *European Journal of Horticultural Science*, 83(5), 280–293. <https://doi.org/10.17660/eJHS.2018/83.5.2>
- Tidball, K. G., & Stedman, R. C. (2013). Positive dependency and virtuous cycles: From resource dependence to resilience in urban social-ecological systems. *Ecological Economics*, 86, 292–299. <https://doi.org/10.1016/j.ecolecon.2012.10.004>
- Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research*, 166, 628–637. <https://doi.org/10.1016/j.envres.2018.06.030>
- Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science*, 224(4647), 420–421. <https://doi.org/10.1126/science.6143402>
- Wilson, E. O. (1984). *Biophilia*. Harvard University Press.
- World Health Organization. (n.d.). Adolescent health. Retrieved June 26, 2026, from <https://www.who.int/health-topics/adolescent-health>

APPENDIX A

Final Survey Instrument (Hydroponic Herb Project)

The survey below was administered to all three participants on the final day of the study via Google Forms. Items 1–9 used a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). Items 10–11 were open-ended. Items marked with an asterisk (*) were required.

Wellbeing and Stress Management

How did working on the project affect your mood and stress levels? This section is all about whether caring for the plants helped you feel better or gave you a break from the pressure of school.

1. Caring for the plants helped me feel calmer during stressful periods. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

2. Working with the hydroponic system gave me a mental break from my academic work. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

Peer Collaboration and Learning

Did working together on the project bring you closer to your teammates and help you learn from each other? We're curious whether teamwork made the experience more enjoyable and if you picked up useful skills from your classmates.

3. Collaborating with other students on plant care and troubleshooting brought us closer together. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

4. Sharing solutions and ideas with my teammates helped me learn new things. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

Nature Connection

Did the project change how you think about nature and where your food comes from? We want to know if watching plants grow made you feel more connected to the natural world.

5. This project made me think more about where my food comes from and how it grows. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

6. Caring for living plants made me feel more connected to nature and living things. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

Environmental Responsibility

Did the project make you think differently about the environment and your impact on it? This section is about whether you learned something new about sustainable farming and whether it's changed how you think about your choices.

7. This project helped me understand how hydroponic systems reduce water waste and environmental impact compared to traditional farming. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

8. I feel more responsible for considering the environmental impact of my daily choices (e.g., food consumption, water use, waste) because of this project. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

9. After this experience, I'm more likely to support or participate in sustainable agriculture and environmental conservation efforts in the future. *

Strongly Disagree 1 2 3 4 5 Strongly Agree

Changes Since the Project

Thinking back to before the project started, do you feel differently now? These questions compare your stress levels, connection to nature, and teamwork abilities before versus after the project.

10. What was the most meaningful or memorable part of the hydroponic project for you? Why?

11. Did participating in this project change how you think about or handle academic stress? If yes, how? If no, why not? *

APPENDIX B

Journal Reflection Templates

Participants recorded reflections using five thematic journal templates across the three-week study period. Each entry included fields for name, date, and day number, followed by four guided reflection prompts. Prompts are reproduced below exactly as presented to participants; italicized text beneath each prompt is the guiding sub-text shown to help participants develop their responses.

01 — General Observations

What did the plants reveal to you today?

Q1. Walk through exactly what you did with the plants today — and describe what you noticed while doing it.

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Don't just list tasks. What did the leaves feel like? What did the water smell like? What made you stop and look closer?

Q2. Something looked, smelled, or felt different from yesterday. What was it, and what do you think caused the change?

Even tiny shifts count — a slightly different color, a new root poking through, a stronger scent.

Q3. Describe a moment today where you had to make a decision about the plants. What did you decide, and why?

Could be adjusting the water, trimming something, or just choosing where to focus your attention.

Q4. How did spending time with the plants affect how you felt — and did that surprise you at all?

Try to trace the feeling: when did it shift, and what specifically caused it?

02 — Responsibility and Care

What does keeping something alive demand of you?

Q1. If you hadn't shown up today, what would have been different for the plants by tomorrow?

Think through it seriously — what depends on your presence, and what would survive without you?

Q2. Describe a moment this week when you felt genuinely responsible for the plants — not just going through the motions.

What made it feel real? Was it something you saw, something that worried you, or something you fixed?

Q3. Did caring for the plants today feel like a chore, a choice, or something harder to name? Explain what made it feel that way.

Try to go beyond "I enjoyed it" or "it was fine" — what was the actual texture of the experience?

Q4. How has your sense of responsibility toward the plants shifted from Week 1 to now — and what do you think caused that shift?

Think about how you approached them on Day 1 versus today. What's different in how you show up?

03 — Midpoint Reflection

Q1. Think back to the very first day of this project. How did you relate to the plants then compared to now — and what do you think produced that change?

Be specific: what moment or experience marks the clearest before-and-after for you?

Q2. Was there a point during these three weeks when you felt genuinely worried about or attached to the plants? Describe what happened and why it affected you.

If there wasn't, explore that too — what kept emotional distance from forming?

Q3. Looking at the full three weeks, what do you think drove any wellbeing changes you experienced — the plants themselves, the routine, being outside, working with others, or something else?

Try to isolate the specific element that mattered most, rather than crediting "the whole experience."

Q4. If someone asked you to argue — using only your own experience — that growing plants changes how a person thinks and feels, what would you say?

You're building the case from scratch. What's your evidence, and where does it fall short?

04 — Nature Connection

Has something shifted in how you see the living world?

Q1. Before this project, how present was nature in your daily awareness — and has that changed? Walk through what your relationship with the natural world looked like before, and what it looks like now. *Think about your commute, your phone habits, what you notice on the way to school. Has any of that shifted?*

Q2. Did growing something make you feel genuinely connected to the environment, or did it mostly feel like a contained classroom activity? What created that feeling — or prevented it? *There's no right answer. Push past the surface — what did the experience give you access to, or not?*

Q3. Describe a specific moment when the plants made you aware of something larger than just the task — a system, a cycle, something you don't usually think about. *Could be the water cycle, where food comes from, what "alive" means — any moment of wider awareness.*

Q4. How do you think this experience will — or won't — stay with you? What would have to be true for it to change how you live going forward? *Be honest about what's likely to stick versus what fades once the project ends.*

05 — Final Week

Before we say goodbye to the plants — a closing reflection on wellbeing, connection, and what growing something taught you.

Q1. Three weeks ago, you started caring for something alive. What is the most honest thing you can say about how that changed you — even slightly?

Don't reach for the "right" answer. What shifted — in how you think, feel, or notice things?

Q2. Looking back, which part of this experience had the biggest effect on your wellbeing — the plants themselves, the routine, working alongside others, or something else entirely?

Try to isolate the one thing that mattered most and explain why you think it was that specific thing.

Q3. Did growing something in a school atrium — indoors, in water, without soil — feel like a real connection to nature, or did it feel like a simulation of one? What made it feel that way?

Your honest answer here is exactly what this research needs. There's no version that weakens the study.

Q4. What do you want to say about this project that no survey question has asked you?

This space is yours. Anything — an observation, a frustration, a small thing you loved, a question the plants made you think about.

APPENDIX C

Journal and Observation Coding Criteria

Journal entries and researcher observation notes were coded into five themes, each defined by explicit inclusion and exclusion criteria to guide consistent application. A sixth category, Unexpected Findings, was defined during codebook development to capture responses that did not fit the five primary themes, but no journal entries or observation notes were ultimately coded to it.

Theme 1: Wellbeing and Stress Management

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Inclusion criteria: Include a response if the participant explicitly describes feeling calmer, more relaxed, or emotionally better as a direct result of the plant-care activity. This includes words like peaceful, tranquil, refreshed, or relieved, as well as phrases that describe the activity as mentally restorative or therapeutic. The emotional improvement must be tied to the act of caring for the plants, not just to being in a good mood generally.

Exclusion criteria: Do not include a response if the positive emotion comes from socializing with peers rather than from the plant-care activity itself. Do not include a response if the participant feels stressed, worried, or guilty because of the plants — those responses indicate a negative emotional reaction and belong under Unexpected Findings. Do not include a response if the participant describes the activity as enjoyable or interesting without mentioning any change in their emotional or mental state.

Theme 2: Peer Collaboration and Learning

Inclusion criteria: Include a response if the participant explicitly describes working with, learning from, or helping other group members as part of the plant-care activity. This includes making decisions together, discussing plant issues as a group, teaching or explaining something to a peer, or describing the group dynamic in a way that shows active participation from multiple people.

Exclusion criteria: Do not include a response if the participant mentions other people but does not describe any collaborative interaction. Do not include a response if the social interaction described is unrelated to the plant-care activity. Do not include a response if only one person is doing the work while others are present but uninvolved.

Theme 3: Nature Connection

Inclusion criteria: Include a response if the participant describes a shift in how they relate to, notice, or feel about living things or nature as a result of caring for the plants. This includes expressing emotional attachment to the plants as living things, noticing nature in their surroundings in a new way, or describing a sense of curiosity, awe, or appreciation toward plant life or the natural world.

Exclusion criteria: Do not include a response if the participant is simply describing the physical condition of the plants to decide what action to take — that is task-based observation and belongs under Sensory/Active Engagement. Do not include a response if the participant notices something about the plants but does not express any emotional reaction or sense of meaning attached to that observation. Do not include a response if the curiosity or interest is directed at the hydroponic equipment rather than at the plants as living things.

Theme 4: Environmental Responsibility and Stewardship

Inclusion criteria: Include a response if the participant expresses that they feel personally responsible for

the plants' survival or wellbeing or describes taking action because they felt it was their duty to care for them. This includes ownership language such as describing the plants as something they are accountable for, describing the consequences of neglecting them, or noting that their sense of responsibility grew over the course of the project. The participant does not need to use the word "responsibility" — look for the underlying meaning.

Exclusion criteria: Do not include a response if the participant feels worried or guilty about the plants but does not describe any action taken or intention to act — worry without a sense of duty or ownership belongs under Unexpected Findings. Do not include a response if the participant describes a care task as part of a habit or routine without expressing any sense of personal obligation toward the plants — that belongs under Sensory/Active Engagement. Do not include a response if the participant makes a general statement about environmental importance without connecting it to their own behavior or sense of duty.

Theme 5: Sensory and Active Engagement

Inclusion criteria: Include a response if the participant describes physically interacting with the plants or the hydroponic system or uses sensory language to describe what they experienced during the activity. This includes describing touch, smell, or visual observations made during hands-on care, naming specific actions performed such as pruning, adjusting water levels, or checking plant health, or describing the activity as a recurring habit or embodied routine.

Exclusion criteria: Do not include a response if the physical observation of the plants leads the participant to express emotional connection or attachment to them as living things — that belongs under Nature Connection. Do not include a response if the hands-on action is described alongside clear ownership or duty language — in that case, code primarily under Environmental Responsibility. Do not include a response if the emphasis is on a group decision made during the activity rather than on the physical or sensory experience itself — that belongs under Peer Collaboration.