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How a marine debris environmental education program plays to strengths of linguistically diverse learners

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Although environmental education (EE) has increased focus on how to best serve diverse populations, one understudied area is how linguistically diverse learners may engage with EE programming. Linguistic diversity is on the rise across the United States; for instance, nearly one-third of all children between the ages of 0 and 8 have at least one parent who speaks a language other than English in the home. This study evaluated impacts of an EE curriculum designed to promote pro-environmental behavior change with a pre-post, treatment-control experimental design among students from linguistically diverse households. In partnership with teachers, we implemented the curriculum in elementary schools across the state of North Carolina, United States. Over two school years (2018–2020), 36 teachers from 31 schools across 18 counties participated in the study, providing 644 paired pre-post student responses (n=204 control; n=440 treatment). About 10% of the sample (n=49 treatment, n=18 control) reported speaking a language at home other than English. We tested hypotheses that the curriculum would increase pro-environmental behavior change among all students, but particularly among those from linguistically diverse households using multiple linear regression. Results indicate that the curriculum effectively encouraged pro-environmental behaviors for all students on average, but particularly among linguistically diverse students, adding to growing examples of the equigenic effects of environmental and nature-based education. These findings are consistent with research demonstrating that EE can contribute to behavior change among young learners and may be particularly well-suited to resonate with the unique contributions of linguistically diverse learners.

KEYWORDS

linguistically diverse, environmental education, marine debris, pro-environmental behavior, culturally relevant teaching, culturally relevant education

1. Introduction

From its inception, environmental education (EE) has been framed as a public good that is essential for individual and societal flourishing (Tbilisi Declaration, 1977). At the heart of this framing is a recognition that EE can equip people and communities with the knowledge, skills, and motivations they need to shape a future they want (Tbilisi Declaration, 1977). Accordingly, EE design and delivery efforts should acknowledge, respect, and reflect the diverse identities and value systems present around the globe. Encouragingly, the field of EE has attempted to focus on engaging both program providers and participants from diverse backgrounds. Programmatic efforts have expanded to place greater emphasis on funding and creating initiatives to engage participants from systemically excluded groups, and significant momentum is building around EE organizations and programs that serve this charge (Flores and Kuhn, 2018). Latino Outdoors, Outdoor Afro, and LGBT+ Outdoors, for example, are nonprofits that strive to increase participation in outdoor recreation activities for Latinx, Black, and sexually and gender diverse communities, respectively, (Latino Outdoors, 2021; LGBT Outdoors, 2022; Outdoor Afro, 2021). However, there is considerable room for improving inclusion in hiring, retention, and grant selection practices within the environmental movement in general (Green 2.0, 2020), and equity within EE that is inclusive of class, race, ethnicity, and other forms of diverse identities (Haluza-DeLay, 2013; Aguilar et al., 2017; Stapleton, 2020).

The EE research community has responded in parallel with studies to better understand how EE impacts diverse communities (Tuck et al., 2014; Stapleton, 2020; Rodrigues and Lowan-Trudeau, 2021). This is encouraging, as understanding how to best include students from diverse backgrounds is critical to equipping all learners with the skills and dispositions they need to effectively engage in shaping their own futures. For example, students who feel a sense of inclusion and belonging at school experience numerous positive outcomes, including improved learning, academic achievement, motivation, retention, persistence, and attendance at school (Walton et al., 2015; Murphy et al., 2018; Borman et al., 2019; Binning et al., 2020; Williams et al., 2020; Gray et al., 2022). A first step at understanding how to foster such a sense of belonging is to better understand how learners from diverse identities may uniquely engage with EE programming. Relevant EE studies focused on specific identities have examined how factors such as race and ethnicity (Larson et al., 2011; Stevenson et al., 2013; Clark et al., 2020; Szczytko et al., 2020), gender (Stevenson et al., 2021), and learning differences (Szczytko et al., 2018), may shape how various learners benefit from EE opportunities. Key findings across these studies are that EE programming typically benefits those with non-dominant identities as well as, or to a greater degree than, those with dominant identities, leveling the playing field by differentially helping groups who typically fall behind (i.e., producing equigenic impacts: Kuo et al., 2019). For instance, findings from Szczytko et al. (2020) showed that race was not a factor in young people's connection to nature, despite previous assumptions to the contrary, and Clark et al. (2020) found that EE programs centering on fisheries had positive impacts on all learners, not just a certain group. Additionally, multiple studies have reported that EE programming has positive impacts particularly for girls (Stevenson et al., 2021) and children with learning disabilities (Szczytko et al., 2018). Environmental education interventions have also been shown to support environmental behavior among African American learners (Larson et al., 2011; Stevenson et al., 2013) and pro-environmental attitudes among students identifying as Hispanic or African Americans (Stevenson et al., 2013). Likewise, conclusions from a study that analyzed results from 105 EE interventions encouraged intentionality, creativity, and inclusivity when developing and implementing EE programs (Ardoin et al., 2020).

Efforts to understand how to best serve linguistically diverse learners with EE programming are needed for several reasons. Throughout this paper, we use the term "linguistically diverse," rather than "language minority," or "non-dominant language" to avoid negative connotations associated with the word minority and signify the dynamic, contextual nature of a linguistic landscape within any given geographical region. As language represents a fundamental element of human connection (Shannon and Weaver, 1949; Chandler, 2007), research around how linguistically diverse populations interpret EE programming can support efforts to serve an increasingly diversifying and interconnected world. Moreover, scholars suggest that many EE programs may be easily positioned to build-in strategies that respond to learners' linguistic diversity (Arreguín-Anderson and Kennedy, 2013). For instance, linguistic diversity is on the rise across the United States, and especially among student populations, as young children who have at least one parent who speaks a language other than English in the home now constitute nearly one-third of all children between the ages of 0 and 8 (Park et al., 2018). Though resources and programs such as bilingual schools have grown, they do not have adequate reach to serve all students who need them (Lam and Richards, 2020). This includes EE programming, the majority of which is conducted in English (Arreguín-Anderson and Kennedy, 2013). Thus, linguistically diverse youth must frequently navigate the cultural dichotomy between their home environments and westernized, English-dominated classrooms and educational programs (Park et al., 2018). This dynamic is particularly acute in places like Texas, where 78% of parents are Spanish-speaking (Arreguín-Anderson and Kennedy, 2013; Park et al., 2018), New Mexico and Arizona, where 71% of parents are Spanish-speaking (Park et al., 2018), or in California, where 23% of students are linguistically diverse (Genesee et al., 2005). In a US context, Spanish is often the dominant minority language, but other major languages include Chinese and Arabic (Park et al., 2018). Understanding how linguistically diverse learners engage with EE programming is a first step to ensuring they are fully integrated into EE's mission of fostering environmentally literate individuals and communities.

Environmental education interventions that employ intergenerational learning (IGL) approaches could represent one strategy that may simultaneously support culturally and linguistically diverse students as well as encourage pro-environmental behaviors. As children from linguistically diverse households often assume the role of translator within their family, they may be particularly effective at engaging parents (Blanchet-Cohen and Reilly, 2017). Serving as a translator may provide practice for youth to transform complex, unfamiliar scientific information into a description that makes sense and has value to their family context – essentially, making the information culturally-relevant (Blanchet-Cohen and Reilly, 2017). Several studies have highlighted how EE approaches that empower youth – such as giving them decision-making authority in choosing environmental actions (Haynes and Tanner, 2015), or encouraging them to talk with their parents or other adults (Williams and Chawla, 2016; Valdez et al., 2018) – have resulted in increased environmental behaviors among both youth and the adults with whom they communicate (Lawson et al., 2019; Hartley et al., 2021). In this way, IGL approaches may support EE outcomes such as self-efficacy, youth empowerment, or environmental engagement and behavior (Bernal, 2001; Haynes and Tanner, 2015; Williams and Chawla, 2016), as well as leverage unique strengths of linguistically diverse learners as potential EE ambassadors at home. As has been found in other studies examining EE impacts on diverse identities (Blanchet-Cohen and Reilly, 2017; Braun, 2019), IGL approaches may have unique benefits and challenges for linguistically diverse learners. For instance, some studies have shown that Asian and Latinx students have stronger family relational ties and greater familial expectations than peers from European backgrounds (Fuligni et al., 1999), and others have found that immigrant children served as environmental ambassadors in their families after engaging with a culturally-responsive environmental education program (Blanchet-Cohen and Reilly, 2017). Encouraging IGL may provide an opportunity for learners to draw on these strong family ties to foster a sense of empowerment and validation, although family structures that emphasize parental authority may diminish this opportunity. Research examining cultural and language diversity specifically within IGL-based EE programs is extremely limited, with only two studies that we are aware of at the time of this writing (Chineka and Yasukawa, 2020; Parth et al., 2020). Results of the two studies were mixed and suggested that culture may prove to be a barrier to positive IGL impacts in countries outside of the United States. As such, more research is needed across both US and non-US contexts to understand the degree to which linguistically diverse learners are challenged by, or are particularly adept at, learning in EE contexts, particularly those that are designed in ways that may draw on their unique assets.

Here we begin addressing the need for further EE research focusing on linguistically diverse populations in a United States context with a pre-post treatment-control experimental evaluation of a marine debris curriculum designed to promote IGL and pro-environmental behaviors among 4th and 5th grade students in North Carolina, United States from 2018 to 2020. We chose the topic of marine debris as it remains a pressing environmental issue and provides an opportunity for students with varying proximities to waterways to learn about the inherent connectivity between ecosystems. Further, it is a tangible issue that is accessible to young learners (Torres et al., 2019). In this study, we examine differential impacts of the curriculum on pro-environmental behaviors exhibited by students from linguistically diverse households. Given the potential for linguistically diverse students to respond positively to IGL-based approaches as discussed above, we hypothesized that participation in the curriculum might drive increased pro-environmental marine debris behaviors among all students (hypothesis 1), but particularly those from linguistically diverse households (hypothesis 2).

2. Materials and methods

2.1. Ethics statement

Data collection procedures were approved by the North Carolina State University Institutional Review Board (IRB# 12847). We provided teachers with signed consent forms or opt out consent waivers per school district preference to distribute to parents/guardians, and students were provided age-appropriate assent information at the beginning of the surveys. Only assenting students with parent permissions were allowed to participate.

2.2. Curriculum

The Duke University Marine Lab (DUML) marine debris curriculum used in this study (DeMattia et al., 2020) was not designed specifically for linguistically diverse learners, but as most well-designed EE programs are, it contains asset-based elements that make it culturally responsive. As opposed to deficit-based approaches that attribute low achievement along narrowly defined criteria to a personal deficiency, asset-based approaches embrace cultural differences and acknowledge systemic and structural influences (Rios-Aguilar and Kiyama, 2012; Baquedano-López et al., 2013). EE programs often are characterized by their flexible style, less formal approach, and overall adaptability (Sandoval, 2014), which are congruous with many tenets of culturally responsive teaching (CRT; Pownall, 2022). For instance, the marine debris curriculum provides some structure for educators with a few in-school activities that can be easily adapted to most schoolyards or backyards (e.g., understanding drag and how it affects marine animals by playing a running game with umbrellas). The curriculum then transitions to student-led investigations, which draw on specific perspectives, experiences, and priorities of students to investigate challenges related to marine debris in their community (DeMattia et al., 2020). This community, place-based, and student-driven focus in the marine debris curriculum could

help to affirm participants' various identities and encourage participants' unique cultural contributions, which has been shown to improve the benefits to learners of diverse racial, ethic, socioeconomic, or linguistic backgrounds (Munez, 2019; Matthews and López, 2020; Pownall, 2022). Building on work by Pownall (2022), who scaffolded her findings from Geneva Gay (2018) seminal book, *Culturally Responsive Teaching: Theory, Research, and Practice*, we provide context for how activities from the marine debris curriculum map to both culturally responsive teaching and EE best practices (Table 1).

2.3. Sampling

For the purposes of this study, we chose to focus on 4th and 5th grade elementary school students, who were roughly 7–11 years old, from North Carolina, United States. Research demonstrates that young children have open minds about environmental topics and are able to engage in systems-level thinking on environmental topics (Forrester, 2009; Craig and Allen, 2015). Accordingly, we wanted to explore impacts of the curriculum and associated IGL activities among this age group. We used hierarchical sampling (Ericson and Gonzalez, 2003) in that we first recruited teachers; and through teachers, recruited students who were enrolled in the teachers' classes. To recruit both treatment and control teachers, we advertised the study through a North Carolina Department of Public Instruction listserv, which reached all elementary public school science teachers across North Carolina. Interested teachers then self-selected to participate. Those who expressed interest were invited to participate in an on-site, coastal teacher professional development workshop at the Duke University Marine Lab in Beaufort, North Carolina, highlighting activities within the DUML marine debris curriculum (DeMattia et al., 2020). We simultaneously invited teachers to participate as control teachers using a delayed treatment design, where teachers on the waiting list for the first workshop were invited to become control teachers during the first year in exchange for acceptance into another summer workshop at a later date. Consent for minors to participate was granted by the participating students' parent/legal guardian, and assent for non-minors to participate was self-granted.

We followed this procedure during both the 2018–2019 and 2019–2020 school years, which resulted in 36 teachers from 31 different schools across 18 counties participating in the study. Of those 18 counties, 8 (44%) were coastal plains counties, 2 (11%) were from mountain-region counties, and 8 (44%) were from the Piedmont (inland) area of North Carolina; 12 (67%) schools were in counties classified as rural. We surveyed 2,201 children associated with the participating teachers in pre-surveys. After data cleaning and pairing the pre-survey responses with the post-survey responses, we had 644 paired student responses ($n = 204$ control; $n = 440$ treatment). Slightly more children identified as girls (53.1%) than boys (45.3%), with 1.5% identifying as a gender not represented by these categories. Most respondents (44.7%) identified as White or Caucasian, with fewer identifying as Black or African American (11.2%), Hispanic or Latinx (8.1%), Asian or Pacific Islander (3.1%), Native American (4.7%), multiracial (16.0%) or as an identity not listed (12.2%). About 10% of the sample ($n = 49$ treatment, 18 control) students reported speaking another language than English at home.

2.4. Instrument development

We developed our survey instruments by drawing on previously published tools focused on levels of environmental literacy and climate literacy among children. To measure marine debris behaviors of children, we drew on questions used in behavior scales in Lawson et al. (2019) and Stevenson and Peterson (2015). The marine debris-focused question asked, "*How often do you do the following activities*?" (e.g., "*Use a reusable water bottle,*" "*Refuse to use plastic straws at home or in restaurants,*" and "*Pick up trash when I see it,*" among others), and children responded to the eight items on a five-point frequency scale ranging from "*Never*" to "*Every chance I get*," which were designed to measure self-reported behavior frequency. We also asked students to self-report race, age, language spoken at home, and if that language spoken at home was not English, what the language was. Pilot testing of the child instrument was conducted in Summer 2018 with three, 4th grade, North Carolina classes ($n = 56$). A member of the research team visited the pilot classrooms in person during the pilot sessions, and we administered the survey online using a Qualtrics survey link. While taking the survey, children were given the opportunity to directly provide comments on anything that they found difficult to understand or comprehend. They also provided direct feedback to the researcher afterwards; 3–5 students from each class also participated in follow-up cognitive interviews to help refine items and the overall survey clarity (Desimone and Le Floch, 2004). In the pilot data, we found the marine debris behavioral scale to have acceptable internal consistency (Cronbach, 1951; $\alpha = 0.79$) and to be a single factor scale, per confirmatory factor analysis (Comrey and Lee, 2009). See supplemental information for item wording, including the full behavior scale as well as additional reliability and validity statistics.

2.5. Data collection

Teachers facilitated data collection for this study at the beginning and end of the 2018–2019 and 2019–2020 school years. Although the first study year was conducted during normal school operations, the second study collection year was impacted by the global COVID-19 pandemic, as schools rapidly shut down in March 2020 and post-surveys were given online as opposed to in classrooms as at previous data collection points. A total of 36 teachers participated in data collection, with some participating in both years, either as repeat treatment teachers or as control and then treatment teachers ($n = 4$),

TABLE 1 Elements of Duke University Marine Lab (DUML) Marine Debris Curriculum that match culturally responsive teaching tenets and environmental education (EE) elements as drawn from Pownall, 2022. The DUML Marine Debris Curriculum is freely available online: https://sites.duke.edu/communityscience/files/2020/06/DUML-Marine-Debris-Curriculum2020.pdf

Culturally responsive teaching (CRT) tenet	Applications to environmental education (EE) strategies	Activity in Duke University Marine Lab (DUML) Marine Debris Curriculum	Citation
Develop a knowledge base about cultural diversity	Partner with cultural organizations to collaborate on relevant, existing initiatives	2.1 Waterway Cleanup: Collect & Quantify Marine Debris	Vaquero (2015)
	Develop connections between personal, social, and ecological well-being	1.1 Waste & Plastics: Waste Audit	Fien (2003); Schindel and Tolbert (2017)
		1.1 Waste & Plastics: *A Plastic Ocean*	
		1.2 STEM: Marine Debris Entanglement	
		2.1 Waterway Cleanup: Collect & Quantify Marine Debris	
		3.1 Community Art: Circle of Viewpoints	
Include ethnic and cultural diversity content in the curriculum	Link EE content to relevant, cultural student experience (*funds of knowledge*)	3.2 Civic Engagement & Communication: Public Presentation of Art & Civic Action	Agyeman (2002); Del Campo et al. (2016); Stern et al. (2010)
	Co-create programs with communities or cultural groups	2.1 Waterway Cleanup: Collect & Quantify Marine Debris	Pease (2015); Simon (2016)
		3.2 Civic Engagement & Communication: Public Presentation of Art & Civic Action	
Demonstrate cultural caring and build learning communities	Design lessons around cooperative learning	1.1 Waste & Plastics: How Long 'til it's Gone?	Sleeter (2012)
		1.2 STEM: Physics of Marine Debris Movement	
		2.1 Waterway Cleanup: Collect & Quantify Marine Debris	
		2.1 Waterway Cleanup: Data Analysis & Quantification	
		3.1 Community Art: Marine Debris Mosaic	
		3.1 Community Art: Journey of X Mural	
		3.1 Community Art: PSAs	
		3.2 Civic Engagement & Communication: Public Presentation of Art & Civic Action	
	Demonstrate care for people, place, and community social and economic well-being (*environmental carework*)	1.1 Waste & Plastics: *A Plastic Ocean*	Fien (2003); Schindel and Tolbert (2017)
		1.2 STEM: Marine Debris Entanglement	
		2.1 Waterway Cleanup: Collect & Quantify Marine Debris	
		3.1 Community Art: Circle of Viewpoints	
		3.2 Civic Engagement & Communication: Public Presentation of Art & Civic Action	
Cross-cultural communication	Use storytelling to convey information	3.1 Community Art: Circle of Viewpoints	Gay (2002); Jenkins (2020); Sowerwine et al. (2019)
		3.1 Community Art: Journey of X Mural	
		3.1 Community Art: PSAs	
		3.2 Civic Engagement and Communication: Public Presentation of Art & Civic Action	
	Convey cultural traditions using hands-on activities	1.1 Waste & Plastics: Waste Audit	Sowerwine et al. (2019)

(Continued)

TABLE 1 (Continued)

Culturally responsive teaching (CRT) tenet	Applications to environmental education (EE) strategies	Activity in Duke University Marine Lab (DUML) Marine Debris Curriculum	Citation
		1.1 Waste & Plastics: How Long 'til it's Gone?	
		1.2 STEM: Physics of Marine Debris Movement	
		1.2 STEM: Marine Debris Entanglement	
		2.1 Waterway Clean-up: Collect & Quantify Marine Debris	
		2.1 Waterway Clean-up: Data Analysis & Quantification	
		3.1 Community Art: Marine Debris Mosaic	
		3.1 Community Art: PSAs	
		3.2 Civic Engagement & Communication: Public Presentation of Art & Civic Action	
	Use art to build cultural understanding and share community stories	3.1 Community Art: Marine Debris Mosaic	Del Campo et al. (2016); Sowerwine et al. (2019)
		3.1 Community Art: Marine Debris Poetry	
		3.1 Community Art: Circle of Viewpoints	
		3.1 Community Art: Journey of X Mural	
		3.1 Community Art: PSAs	
Cultural congruity in delivery of information	Storytelling teaching style		Gay (2002); Jenkins (2020)
	Communicative learning		D'Amato and Krasny (2011)

and some working in teacher-pairs, of which 5 total classrooms were represented (control: $n = 0$; treatment: $n = 41$; Table 2). Most teachers were associated with a single class of elementary children (average class size = 18–20), but 4 participating teachers taught entire grade levels as science or other specialists, some teaching as many as 256 children per year. We provided teachers with survey links and an administration protocol, which they followed during class time. Treatment teachers administered surveys prior to (pre-tests) and after (post-tests) implementing the marine debris curriculum. Control teachers administered surveys on a similar timeline.

3. Analysis

To generate composite scores for behavior, we added each item-level score. The marine debris frequency behavior questions for children ranged from *Never* (1) to *Every chance I get* (5) with a range of composite scores from 5 to 40, where a score of 5 would indicate that the child never completed any marine debris behaviors and a score of 40 would indicate that they completed all eight of the marine debris behaviors every chance they got. To test our hypotheses, we used sequential multiple linear regression to model changes in student marine debris behavior as a function of the pre-test behavior scores (to control for ceiling effect: Theobald and Freeman, 2014), membership in the treatment group, and linguistic diversity in model 1 (hypothesis 1) and added an interaction between linguistic diversity and membership in the treatment group in model 2 (hypothesis 2). To account for the possibility that students from the same classroom may have responded similarly to the treatment intervention, we allowed the intercepts for the respective student-groups to vary, i.e., we included a "random intercept" term in the respective models. The possibility that teachers participating in multiple years of the study may have provided a different level of intervention to students was controlled for by a fixed-effect variable for the year of course delivery. That variable noting the year of data collection was important in the context of the emergence of COVID-19, which may have influenced student survey responses on many levels. All data analyses were conducted using STATA 14.2.

Although the initial study design was a multi-level clustered data analysis using ordinary least squares (OLS), we also opted to address concerns of unbalanced clusters using a Bayesian ANCOVA (Dettweiler et al., 2017; Rouder et al., 2017) using JASP, an open-source statistical software specializing in Bayesian statistics (JASP Team, 2022). As results from the Bayesian ANCOVA were consistent with findings from the regression, we chose to report the regression findings; Bayesian results can be found in the Supplemental information.

4. Results

Student behavior scores ranged from 8 to 38 (out of possible 5–40) on the pre-test and 8–40 on the post-test. Mean pre-test

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TABLE 2 Number of students associated with teachers across years and treatment groups (total teachers=35; total students=644; total control students=204; total treatment students=440). Several teachers participated for multiple years, with some switching from control to treatment groups in year two.

	Year 1		Year 2	
Teacher code	Control	Treatment	Control	Treatment
1	2			
2	9			
3	12			2
4	15			11
5	18			
6	22			
7	27			1
8			1	
9			1	
10			7	
11			9	
12			12	
13			17	
14			43	
15		11		
16		12		7
17		15		
18		15		
19		17		1
20		21		
21		24		7
22		32		
23		37		
24		41		1
25				1
26				1
27				3
28				4
29				5
30				6
31				9
32				13
33				18
34				27
35				62
Total	105	225	90	179

scores were 23.49 (SD = 5.66) and mean post-test scores were 24.92 (SD = 5.79). The pre-test mean was 23.2 (SD = 5.48) among students whose primary language was English and 21.89 (SD = 4.24) among linguistically diverse students in the control group, and 23.8 (5.77) and 23.0 (5.94) in the treatment group, respectively. On the post-test, students whose primary language was English scored an average of 24.3 (SD = 5.96), while linguistically diverse students scored 22.4 (SD = 5.96) in the control group, and 25.2 (SD = 5.61) and 26.4 (SD = 5.41) in the treatment group, respectively (Figures 1, 2).

Table 3 displays regression results, which controlled for the timing of the COVID-19 pandemic as well as the nested sampling

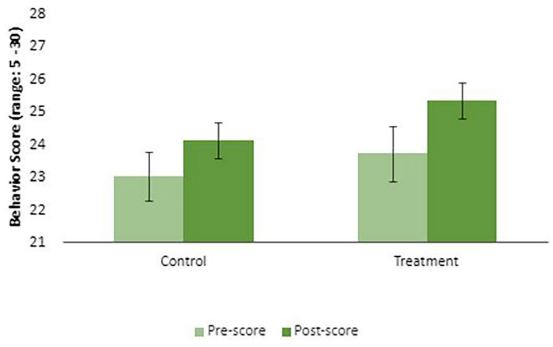

FIGURE 1
Pre versus post-test behaviour scores for student in the control (*n*=201) and treatment (*n*=422) groups. Error bars represent a 95% confidence interval.

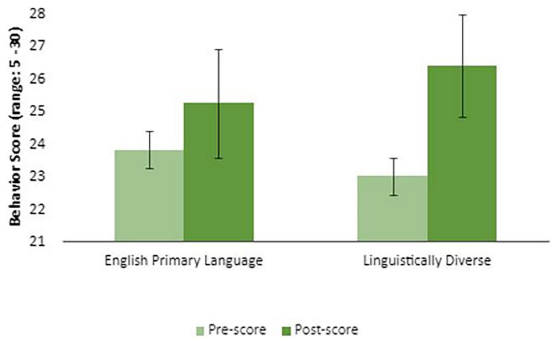

FIGURE 2
Pre versus post-test behaviour scores for student in the treatment group who responded that English was their primary language (*n*=366) and linguistically diverse students (*n*=46). Error bars represent a 95% confidence interval.

design, supported both hypotheses. In model 1, membership in the treatment group, compared to the control group, significantly predicted changes in behavior scores ($B = 0.943$, $p = 0.030$). In model 2, which included an interaction term between treatment group membership and linguistically diverse students, the main effect of the treatment group was not significantly related to changes in behavior, but the interaction term was ($B = 3.05$, $p = 0.036$;). Neither random effects nor treatment year were significant in either model. Given the considerable attrition between the pre- and post-surveys, we examined differences between the sample used in this paper ($n = 644$) and the full dataset of pre-test surveys ($n = 2{,}201$). We found no differences in pre-test behavior scores (full dataset mean = 23.1, SD = 6.0; sample for this paper mean = 23.49, SD = 5.67; $t = 1.507$, $p = 0.132$) or linguistic diversity (full dataset mean = 0.13, SD = 0.34; sample for this paper mean = 0.11, SD = 0.31; $t = 0.0437$ $p = 0.973$). As surveys were given during class time, attrition was likely attributed to teacher attributes (e.g., the onset of the COVID-19 pandemic in year 1, a lack of instructional time to complete the curriculum, etc.), rather than those of students.

5. Discussion

Our results indicate that the marine debris curriculum effectively encouraged pro-environmental behaviors for all students on average, but particularly among linguistically diverse students, adding to growing examples of the equigenic effects of environmental and nature-based education (Kuo et al., 2019; Faber Taylor et al., 2022). For example, nature-based or EE experiences often particularly benefit youth that can fall behind in mainstream educational context – such as among students with ADD (Taylor et al., 2001); students with other emotional, cognitive, or behavioral disabilities (Szczytko et al., 2018); uninterested students (Dettweiler et al., 2015); low-achieving students (Camasso and Jagannathan, 2018); or girls in science (Stevenson et al., 2021). In this study, the marine debris program designed to support student-led investigations of marine debris and associated action (DeMattia et al., 2020) supported development of marine debris behaviors, as has been found similarly in dozens of other studies in which EE promotes behavior change (Heimlich and Ardoin, 2008; Stern et al., 2008; Monroe et al., 2013). Further, the marine debris curriculum seemed to resonate particularly with linguistically diverse students such that most of the treatment impacts were accounted for by students from linguistically diverse households, a population that has been shown to fall behind their peers whose first language is English (Kanno and Kangas, 2014). These findings not only support our hypotheses but add to the growing evidence that EE may benefit all students in aggregate, but may provide particular support to specific groups of students who are typically underserved by mainstream educational structures and strategies (Camasso and Jagannathan, 2018; McCree et al., 2018; Sivarajah et al., 2018; Szczytko et al., 2018).

The culturally-responsive pedagogical strategies in the marine debris curriculum may explain why participation impacted linguistically diverse students more than their peers. To a large degree, professional guidelines for EE programming align with culturally responsive teaching methodologies (Burgess, 2019; Pownall, 2022). For instance, both emphasize student-centered approaches and learning within the context of culture (Burgess, 2019). In addition, IGL approaches emphasized in this curriculum may particularly align with culturally responsive approaches, as conversations with parents may promote agency (Blanchet-Cohen and Reilly, 2017) and may facilitate learning within the context of culture, shaping the curriculum to cultural contexts of families, and including the perspectives of parents (Pascal and Bertram, 2021). Because linguistically diverse learners including those in the Latinx community often have strong family structures (Fuligni et al., 1999), this IGL approach may be an example of how an asset-oriented perspective, wherein approaches intentionally draw on the diverse forms of experiences and expertise of learners (Lee, 2021), produces benefits for learners. Research on asset-oriented perspectives purports that within any given community, there exist individuals with diverse forms of expertise that are rooted in their unique social positions. That line of research supports explanations for our findings that perhaps the contributions of the linguistically diverse students' own expertise combined with their

TABLE 3 Changes in marine debris behavior as predicted by behavior pre-test scores, treatment group membership, linguistic diversity, and year of participation. Model 1 displays treatment effects for the entire sample, and model 2 includes an interaction term to detect differential treatment effects among linguistically diverse students.

Variable	Changes in marine debris behaviors											
	Model 1						Model 2					
	B	*β*	SE	*p*	*95% CI*		*B*	*β*	SE	*p*	*95% CI*	
Pre-curriculum behavior levels	−0.491***	−0.484	0.036	<0.001	−0.562	−0.420	−0.491***	<0.001	0.036	<0.001	−0.562	−0.420
Treatment	0.943*	0.077	0.433	0.030	0.094	1.792	0.645	0.156	0.455	0.156	−0.247	1.536
Linguistically diverse students	0.903	0.048	0.659	0.171	−0.389	2.195	−1.273	0.300	1.228	0.300	−3.681	1.134
Year	−0.632	−0.055	0.409	0.122	−1.434	0.169	−0.64	0.116	0.408	0.116	−1.440	0.159
Linguistically diverse * treatment	n/a			n/a	n/a	n/a	3.046*	0.036	1.452	0.036	0.120	5.892
Intercept	13.236***						13.446***					
N	607						607					
R^2	0.253						0.259					
Sigma	4.902						4.896					

Coding for all variables was as follows: Treatment students: 1 = Treatment; 0 = Control; Linguistically diverse students: 0 = non-linguistically diverse students, 1 = linguistically diverse students; Year: 0 = 2018–2019, 1 = 2019–2020. B = unstandardized; β = standardized. ***$p < 0.001$; **$p < 0.01$; *$p < 0.05$.

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unique social positions both in their classrooms and at home could have contributed to their increase in behavior change in the context of complex social-ecological problems. Though future research should investigate whether this asset-based explanation is consistent with the perspectives and experiences of students, our results suggest that IGL approaches may hold promise for ensuring EE programs are adaptable to a diversity of cultures.

Discovering consistent treatment effects between year one and two was somewhat surprising, given the COVID-19 pandemic emerged between the years. Though not part of our study hypotheses, we might have expected lower treatment effects in year two (during the pandemic) than year one on average, but particularly among linguistically diverse students. The COVID-19 impacts, including job loss, mental health, and physical health outcomes, as well as lower academic achievement among students, were more acutely felt in minoritized populations, including Latinx communities (Noe-Bustamante et al., 2021). Research suggests that people have finite pools of worry, or a limited capacity for worrying about issues (Weber, 2006; Shome and Marx, 2009), and that underrepresented groups were burdened more so by worries and struggles during COVID-19 than majority groups (Noe-Bustamante et al., 2021). As our sample included 10.5% of students speaking a language other than English at home, including 7% of students speaking Spanish at home, we might have expected lower levels of student engagement in year two. However, our results found that young people from linguistically diverse households saw the capacity for more behavior change over both years. These results call for additional investigations into the social emotional resilience of youth from these groups and their capacity for empowerment to engage in action despite, or in response to, hardships. This possibility is certainly consistent with environmental activism among minoritized groups, including the founders of environmental justice movements, who have argued for environmental change as a way to move toward the liberation of all people (Thomas, 2022).

Our study adds to others demonstrating that EE can contribute to behavior change among young learners by highlighting how linguistically diverse learners may benefit as participants in EE. Though the outcomes of interest within EE are diverse (e.g., connection to nature, social capital, environmental knowledge: Krasny, 2020), many frameworks understand these outcomes as precursors to individual (Hollweg et al., 2011) or collective (Ardoin et al., 2022) behavior change. This is not the first evaluative EE study to find that EE contributes to behavior change (Camp and Fraser, 2012; Ardoin and Heimlich, 2021), so our results are maybe not surprising, but are encouraging in terms of achieving the goals of EE. Perhaps more significantly, our results suggest that linguistically diverse learners may be a particularly receptive audience to EE programming. In this way, linguistically diverse learners are a key audience that deserve more attention in EE programming and EE research not only because of the changing demographics of the world and EE's commitment to serving and benefiting all learners (Stapleton, 2020), but also because linguistically diverse learners may be an audience that can help accelerate the goal of environmentally literate individuals and communities. As other studies have shown in similar contexts with young people (Lawson et al., 2019; Hartley et al., 2021), this possibility has the potential to be even more significant when considering EE can be more effective when multiple generations participate in EE programming together.

6. Limitations

Generalizability of this research study's reported findings should be approached with caution due primarily to the small clusters and unbalanced sample sizes within this study. Educational research studies that report outcomes associated with an educational intervention frequently contain contextual variability among different classes, teachers, and classroom settings, which cannot be perfectly controlled, and therefore not perfectly replicable in future studies (Dettweiler et al., 2017). We tried to address this critique on educational research design studies by controlling for teacher clusters within the analysis and introducing a random intercept term in respective models.

7. Conclusion

Our study represents one of a small handful of EE studies that focus specifically on linguistically diverse students (Tangen and Fielding-Barnsley, 2007), and the first United States-specific study of which we are aware. Results in this study found that students who engaged in the marine debris curriculum experienced significant changes in their pro-environmental behavior scores as compared with a control group. Moreover, these treatment effects were particularly pronounced, and mostly explained by, the linguistically diverse learners within the treatment sample. Though many EE studies have provided examples of how EE programming can promote pro-environmental behavior change, this is the first of which we are aware that is specific to linguistically diverse learners. In the context of current research looking to support culturally relevant practice, including emerging research on asset-based educational pedagogy, this study suggests that EE teachers, practitioners, researchers, and programming managers should consider how to more meaningfully engage linguistically diverse learners in their EE programs, and how those learners may benefit from their engagement in those programs. Future research should continue to include this group for several reasons. First, as the globe becomes more connected, linguistic diversity will become more important for accomplishing culturally responsive EE programming. Secondly, linguistically diverse learners may have unique assets culturally and within their families that create contexts in which they are primed to both strongly benefit from engagement with environmental content and subsequently become engaged in environmental action. Third, there remain many more questions to be answered. For example, studies with larger sample sizes (i.e., more statistical power) may detect nuances among different populations of diverse learners, and qualitative studies may uncover the mechanisms driving equigenic effects on environmental

behaviors detected in this study. Similarly, though we measured behavior change among students, their responses were self-reported, and focused on individual-level behaviors. Future research could examine the persistence and duration of treatment effects, whether the efficacy of this type of programming may spillover into more collective behaviors, and whether observed behaviors operate similarly to self-reported behaviors. This study is a start on a key and growing area of research aimed at understanding not only how EE can better include diverse groups, but more importantly, how mainstream EE can learn from diverse communities to strengthen efforts towards building environmental literacy in support of people and the planet.

Author's note

The authors of this paper recognize that we are all highly educated, all trained in the Eurocentric, colonial norms present in the academy, and all work at large research institutions within the United States. As such, we want to call attention to the fact that findings presented in this paper may already be known among grassroots, community-driven, and informal circles that are many times not included in academic publications such as this one. Therefore, the authors ask the reader to keep in mind that although our publication may be one of the first of its kind within a United States-centric academic context, that it is possible and likely that findings such as the ones presented here may already be extant within other geographic locations, realms of knowing, and/or gray literature that do not automatically prioritize privileged and traditionally trained academic voices.

Data availability statement

The datasets presented in this article are not readily available because de-identified data supporting the conclusions of this article can only be made available by the authors when consistent with IRB regulations. Interested parties should contact the corresponding author. Requests to access the datasets should be directed to Jenna Hartley, jennamh@unc.edu.

Ethics statement

The studies involving human participants were reviewed and approved by the North Carolina State University Institutional Review Board (IRB# 12847). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

KS, DL, and MP contributed to study design. JH was responsible for data collection, data preparation, and preliminary analysis with assistance from BM on data preparation. JH and SP were responsible for the initial drafting of the manuscript, with assistance from KS and MP. KS supported with the secondary analysis. DL, MP, and KS edited the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2022.1058864/abstract#supplementary-material

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