Research Brief

Food-Based Science, Technology, Engineering, Arts, and Mathematics (STEAM) Learning Activities May Reduce Decline in Preschoolers' Skin Carotenoid Status

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ABSTRACT

Objective: To assess the effectiveness of food-based science, technology, engineering, arts, and mathematics (STEAM) learning activities on preschoolers' liking of 9 target vegetables and objectively-assessed fruit and vegetable (FV) intake.

Methods: Seven hands-on, food-based STEAM learning activities were implemented to expose children to 9 target vegetables in 3 *Head Start* preschools (11 classrooms) across North Carolina. Child-reported vegetable liking scores and skin carotenoid status (SCS) were dependent variables collected at baseline, midpoint, and posttest. Adjusted repeated-measures ANOVA was used to examine intervention impact.

Results: A total of 113 children (intervention = 49; comparison = 64) participated. Children were an average age of 3.7 ± 0.57 years at baseline. Mean target vegetable liking scores for the intervention and comparison groups, respectively, were 3.2 ± 0.19 and 3.2 ± 0.17 at baseline, 2.9 ± 0.17 and 3.1 ± 0.15 at midpoint, and 2.8 ± 0.15 and 3.1 ± 0.13 at posttest. A time × group interaction was not significant for target vegetable liking scores. Mean SCS were 268.6 ± 13.24 and 270.9 ± 12.13 at baseline, 271.3 ± 12.50 and 275.6 ± 11.46 at midpoint, and 267.8 ± 11.26 and 229.6 ± 10.32 at posttest for the intervention and comparison groups, respectively. A time × group interaction was significant for SCS ($F_{1,77} = 3.98$; $P = 0.02$; $r = 0.10$). Both groups declined from baseline to posttest (intervention = 0.06%; comparison = 15.09%), which occurred after winter break, with a smaller decline observed in the intervention group ($P = 0.02$).

Conclusions and Implications: Food-based STEAM learning activities may present a unique opportunity to affect FV intake while meeting academic standards. More research is needed to understand how liking for familiar FV changes over time and its relationship with consumption. In addition, more implementation research featuring larger sample sizes, teachers as the interventionist, and a longer study duration is needed to confirm the outcomes of food-based STEAM learning observed in the current study and the long-term impact this approach may have on children's' dietary quality.

Key Words: food-based learning, fruits and vegetables, skin carotenoids, preschool, food preferences (*J Nutr Educ Behav.* 2020;000:1−9.)

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INTRODUCTION

Low fruit and vegetable (FV) intake in childhood is correlated with increased risk for disease later in life.[1] Food behaviors established in preschool years (ages 3−5 years) can determine long-term dietary quality, including adequate intake of FVs.[2] Unfortunately, children from low-income families are at disproportionally higher risk than the general population for low FV intake and associated diseases, including obesity.[3] Numerous interventions and policies have directed efforts to improve low FV intake among children, particularly in early child care environments.[4,5] Encouraging

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young children to try new foods can be challenging because child neophobia, or *fear of the new*, is prominent during preschool years.[6] Decreasing neophobia for vegetables, in comparison with fruits, is more difficult because children have a predisposition to favor fruits because of their natural sweetness.[2] Previous studies cite that 8−15 taste exposures may be needed to increase the liking of a new vegetable or food.[7,8] Exposing children to foods through hands-on, food-based learning (FBL) has been demonstrated to effectively increase exposures[9] while allowing children to explore FV outside of the mealtime environment.[10] Interventions adopting an FBL approach to increase exposure to healthy foods also show promise in increasing later FV consumption.[5,10]

With over 1 million low-income children enrolled each year,[11] *Head Start* (HS) is an ideal setting for interventions targeting FV intake. However, while programs like HS are interested in the nutritional outcomes of the young children they serve, they also prioritize meeting school readiness goals.[11] To the authors' knowledge, of those studies that have demonstrated the use of FBL as a method to affect preference and consumption, only 1 study[5] has also explored the integration of food-based activities with science, technology, engineering, arts, and mathematics (STEAM) learning as a method to improve children's FV intake. Integrating an FBL approach with STEAM represents a unique opportunity for preschool teachers to engage children across multiple school readiness domains while exposing children to new foods and nutrition education. Preschool teachers face many classroom barriers, including time constraints and competing priorities, affecting the quantity and quality of nutrition education provided.[12,13] Integrating STEAM and FBL has been cited by HS teachers as 1 approach to reduce these barriers[12,14]; however, limited research is available to determine whether integrating FBL and school readiness concepts also has the potential to affect children's FV intake positively. Therefore, the purpose of this pilot study was to assess the effectiveness of STEAM FBL activities on HS children's liking of 9 target vegetables and objectively-assessed FV intake (measured via skin carotenoid status [SCS]). It is hypothesized that vegetable exposure through STEAM FBL activities would significantly increase vegetable liking and objectively-assessed FV intake compared with those not exposed to FBL activities.

METHODS

Eleven classrooms in 3 Eastern North Carolina HS centers (6 intervention classrooms from 1 center, 5 comparison classrooms from 2 centers) participated in this quasi-experimental pilot study during the 2018−2019 school year. The intervention site was chosen because of its geographic location and large size. These features made it easier for researchers to monitor implementation fidelity. Parents/guardians and their children were recruited for participation through school registration, parent meetings, flyers sent home, and pick-up/drop-off times. Participation in this pilot study required that a child be aged 3−5 years, enrolled in a participating HS center, and have written consent from their parent/guardian. Data were collected from children only if a child readily gave assent by agreeing verbally and physically to participate in the research process, regardless of parental consent. Children were excluded if they had identified disabilities and/or did not speak English. Children were required to be part of each time point of data collection (baseline, midpoint, and posttest) to remain in the sample. The East Carolina University and Medical Center Institutional Review Board approved the study (UMCIRB no. 18−002749).

The intervention consisted of 7 hands-on, STEAM FBL activities, implemented over 4 months (October−January), to expose children to 9 target vegetables: broccoli, cauliflower, spinach, radish, sweet potato, cucumber, tomato, carrot, and pea pod. The focus of the intervention was target vegetables that were selected on the basis of prior exposure, as determined by parent report, and/or the potential of the food to influence SCS. Food-based learning activities used a STEAM approach that aligned with HS Early Learning Outcomes Framework.[15] Each activity lasted approximately 15−20 minutes and included circle time (group discussion) and a hands-on activity highlighting a science, mathematics, and/or language concept (Table 1). At the end of each activity, children were given the opportunity to taste the target vegetables present in the activity. Children were encouraged to explore the food using their senses, especially when hesitant to try the food.[16] Eight trained research assistants, who were undergraduate/graduate students majoring in Nutrition Science, delivered all activities to ensure fidelity in delivering the intervention.[17] Before implementation, research assistants, attended a 2-hour training on research ethics, protocols, and procedures. Before data collection, research assistants were also trained on the implementation of best practices for encouraging vegetable consumption on preschool-aged children, including positive role-modeling,[18] engaging children's sense,[19] and providing a positive talk and verbal praise during tastings.[20] Research assistants also completed a mock data collection session to practice procedures using tools and were provided with feedback on how to improve.

Data were collected from parents at baseline and from children at baseline (September 2019), midpoint (December 2019), and posttest (February 2020). At baseline, parents were asked to complete 3 questionnaires addressing (1) basic demographics, including food allergies, (2) child neophobia, and (3) child likes/dislikes/exposure. Parents reported their child's likes/dislikes on a 6-point hedonic scale from he/she loves it to he/she hates it designed after the Preschool Adapted Liking Survey.[21] The survey was adapted to include the 9 target vegetables and used photographs identical to those in the child-liking tool to ensure parent and child ratings could be compared.[21] The majority of target vegetables chosen were common to children, based on parent report. Parent-reported target vegetable exposure for both groups is reported in Figure 1.

Table 1. Activity Descriptions & Target Vegetables for Food-based Science, Technology, Engineering, Arts, Mathematics Intervention Activity Implementation Plan

Activity Title	Activity Description	Target Vegetable(s)[a]	
Vegetable flowers: *Paint the Broccoli Green*	Children explore what makes broccoli green by conducting an experiment steaming broccoli. Children will predict, observe, talk about what they observe, and draw their findings (science/language/art). Children will be able to identify and describe chlorophyll as the pigment that makes broccoli green (language).	Broccoli	
Vegetable flowers: *Monsters Don't Eat Broccoli*	Children are read the book *Monster*'s *Don't Eat Broccoli* by Barbara Jean Hicks (language). Children use measuring cups to prepare a vinaigrette dressing to try with a broccoli sample (mathematics). Children will be able to name 2 vegetable flowers and identify 1 difference and 1 similarity (science/language).	Broccoli Cauliflower Spinach[b]	
Vegetable roots: *Rock Those Roots*	Children explore the function of roots by conducting an experiment planting radishes and sweet potatoes in cups of water to observe the roots grow over time. Children will predict, observe, talk about what they observe and draw their findings (science/language/arts). Children will be able to explain what roots do for vegetables and provide at least 1 example of a root vegetable (Science/Language).	Radish Sweet Potato Spinach[b]	
Vegetable roots: *Rosie Plants a Radish*	Children are read the book *Rosie Plants a Radish* by Kate Petty and Axel Scheffler (language). Children use rulers to measure radishes and sweet potatoes (mathematics). Children will discuss and compare the size of their vegetables with each other. Children will be able to describe 1 important role of plant roots and talk about the physical characteristics of root vegetables (science/language).	Radish Sweet Potato Spinach[b]	
Vegetable fruits: *Can You See the Seeds*?	Children explore and count the seeds of cucumbers and tomatoes using magnifying glasses (science/mathematics). Children compare and contrast vegetable fruits with vegetable flowers and vegetable roots. Children draw what they observe (arts). Children will be able to describe the anatomy (edible flesh, seeds inside) of vegetable fruits (science/language).	Cucumber Tomato	
Vegetable fruits: *Moon Squirters Are My Favorite*	Children are read the book *I Will Never Not Ever Eat a Tomato* by Laura Child (language). Children will discuss what they observe in their vegetable fruits. Children will be able to name and describe 2 vegetable fruits (science/language).	Cucumber Tomato	
Vegetable party	Children will discuss the various vegetables that they have learned about and create a vegetable mural to display in the classroom (arts/language). Children will have the opportunity to taste all of the vegetables.	Broccoli Cauliflower Radish Sweet Potato Tomato	Cucumber Spinach[b] Pea Pod[b] Carrots[b]

[a]Target vegetables were provided for tasting at each lesson; [b]Children were exposed to vegetable, but it was not the primary focus of the learning activity.

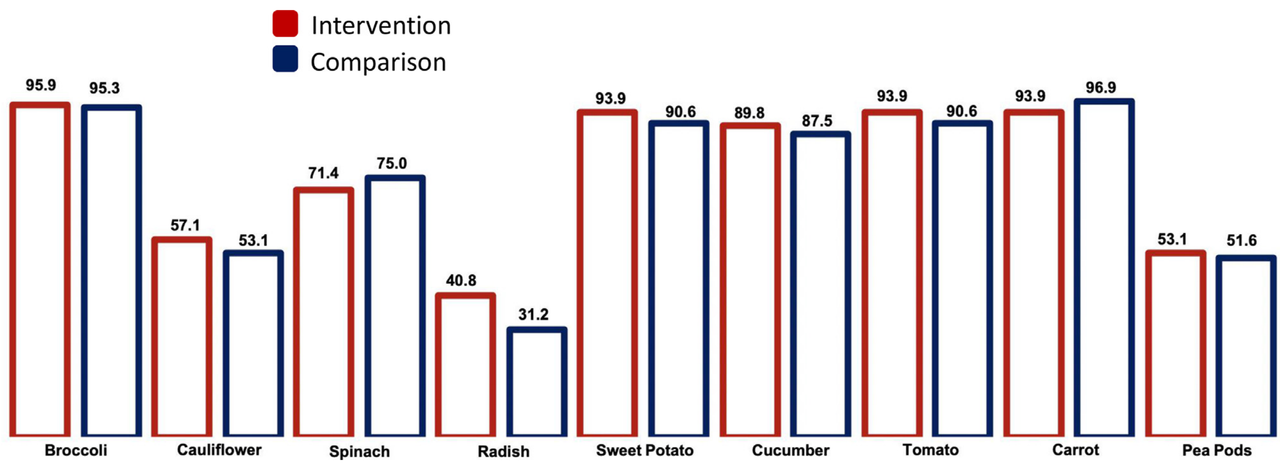

Figure 1. Percent of children exposed to target vegetables as reported by parents at baseline (n = 113). The intervention group received 7 hands-on, science, technology, engineering, arts, and mathematics food-based learning activities, over 4 months to expose children to 9 target vegetables (broccoli, cauliflower, spinach, radish, sweet potato, cucumber, tomato, carrot, and pea pod). At baseline, children were an average age of 3.8 ± 0.57 years and 3.6 ± 0.56 years for the intervention and control groups, respectively.

Children in both groups had the highest reported exposure to broccoli (intervention = 95.9%; comparison = 95.3%) and carrot (intervention = 93.9%; comparison = 96.9%) and the lowest reported exposure to radish (intervention = 40.8%; comparison = 31.2%). Parents who completed and returned the surveys were eligible to enter a drawing for a $100 gift card (1 for each center).

Researchers collected vegetable liking and SCS from children at each of the 3-time points (baseline, midpoint, and posttest). Researchers assessed children's FV liking by modifying a previously validated pictorial FV measure for preschool children.[22] Modifications included the 9 target vegetables and other commonly consumed food items for this age group (eg, hotdog, yogurt).[22,23] The tool includes a nongendered 5-point face scale (*super yummy* to *super yucky*). All photographs used in the pictorial tool were cognitively evaluated by HS children (n = 200) in June 2018. To evaluate, researchers showed children physical variations of common vegetables (eg, tomato sliced vs tomato whole), and final child-liking tool photographs were selected on the basis of children's ability to identify the pictured food items accurately.

Children's SCS was measured using the Veggie Meter (Longevity Link Corporation, Salt Lake City, UT), a noninvasive, quick, and objective indicator of SCS, and a valid approximation of FV intake.[24] After sanitizing the fingers with alcohol wipes, children were instructed to insert their right index finger into the Veggie Meter. The Veggie Meter took 3 measures and provided an average of the measurements, derived from a spectral range score of 350−850, assigned as the child's SCS measure.[25]

Data Analysis

Researchers used SPSS (version 25.0, IBM Corp, Armonk, NY, 2017) for statistical analysis. Categorical data are presented as n (%) and continuous data as means (± SD). Mean child-reported vegetable liking score and Veggie Meter score were calculated at baseline, midpoint, and posttest. Independent *t* tests, chi-square (test of independence), and Fisher exact test were used to calculate and compare demographics at baseline (Table 2). Repeated measures ANOVA was performed to examine the effect of time at the 3-time points and intervention on child-reported liking scores and SCS. The dependent variables were changes in child-reported liking scores and SCS (2 separate models), and the independent variables were sex, age, BMI z-score, and intervention vs comparison. A *post hoc* power analysis using the sample size as reference was conducted with a level set at 0.8 and a total sample size of 74 was needed to show significant differences at ≤0.05. The effect size was 0.15. Classroom clusters were not considered during *post hoc* analyses.

The assumption of sphericity was tested using the Mauchly sphericity test. For vegetable liking ($\chi^2 = 2.48$; degrees of freedom [df] = 2; $P > 0.05$) and vegetable consumption ($\chi^2 = 3.55$; df = 2; $P > 0.05$), Mauchly tests indicated that the assumption of sphericity had not been violated. Before conducting ANOVA analyses, interclass correlations and scatterplots were also examined to compare the change in time across classrooms. A linear mixed model (2-level model: individual and room level) was used to calculate intraclass correlations (between-subject variation/[between-subject variation + within-subject variation]). Researchers examined cluster (room) level variability in intercept across clusters. The intraclass correlations for child-reported target vegetable liking and SCS were 0.04 (3.6% of total variability) and 0.07 (6.5% of total variability), respectively. Because of the small amount of variance explained by room differences, rooms were not clustered during analyses.[26−28] Differences were considered statistically significant at $P < 0.05$.

RESULTS

A total of 113 children (intervention = 49; comparison = 64; 6.6 ± 3.40

Table 2. Child Demographics at Baseline and Attrition Rates for Data Collection Measures at Each Time Point for Intervention and Comparison Groups (n = 113)

	Intervention (n = 49)			Comparison (n = 64)				
Characteristics	**n (%)**	**M**	**SD**	**n (%)**	**M**	**SD**	**Test Statistic**	***P***
Sex (n)[a]								
Male	24 (49)	–	–	41 (62)	–	–	1.94	0.16
Female	25 (51)	–	–	23 (38)	–	–		
Race/ethnicity[b]								
Black/African American	42 (85.7)	–	–	49 (76.6)	–	–	3.99	0.40
Hispanic	1 (2.0)	–	–	6 (9.4)	–	–		
White	2 (4.1)	–	–	4 (6.3)	–	–		
Asian	0 (0)	–	–	1 (1.6)	–	–		
Other	4 (8.2)	–	–	3 (4.7)	–	–		
Age[c]	–	3.82	0.57	–	3.59	0.56	2.1	0.04
BMI percentile for age[c]							2.37	0.51
Underweight (< 5th percentile)	2 (4.1)	–	–	3 (4.7)	–	–		
Normal (5th to 85th percentile)	28 (57.1)	–	–	32 (50)	–	–		
Overweight (85th to 95th percentile)	5 (10.2)	–	–	13 (20.3)	–	–		
Obese (≥ 95th percentile)	14 (28.6)	–	–	16 (25)	–	–		
BMI z-score[c]	–	0.71	1.38	–	0.73	1.40	−0.07	0.95
Parent-reported neophobia score	–	3.87	1.27	–	3.90	1.44	−0.11	0.91
Target vegetable liking score	–	3.21	1.07	–	3.18	1.10	0.13	0.90
SCS	–	267.16	100.22	–	265.03	67.53	0.14	0.89

	Baseline	**Midpoint**	**Final**	**Baseline**	**Midpoint**	**Final**
Attrition, n (% dropout)[d]						
Target vegetable liking scores	48 (0)	45 (6.3)	33 (26.7)	64 (0)	48 (25)	42 (12.5)
SCS	49 (0)	46 (6.1)	38 (17.4)	64 (0)	50 (21.9)	45 (10)

M indicates mean; SCS, skin carotenoid status.
[a]Test statistic: chi-square (test of indepedence); [b]test statistic: Fisher exact test; [c]test statistic: independent *t* test.
Note: Attrition rates in table reflect children's participation in data collection measures at each time point. Twenty-nine children were missing measures from both target vegetable liking and SCS. Values reported for each measurement are independent and do not account for this overlap. Overall attrition for target vegetable liking was 31% for intervention group and 34% for comparison group. Overall attrition for SCS was 22% for intervention group and 30% for comparison group. Attrition analysis revealed that between children who were dropped from the analysis and those were not, there were no significant differences at baseline in sex ($\chi^2 = 0.429$; degrees of freedom [df] = 1; n = 113; $P = 0.55$), ethnicity (Fisher exact test = 2.397; $P = 0.75$), age (t = 0.542; df = 111; $P = 0.89$), target vegetable liking (t = 0.947; df = 110; $P = 0.346$), Veggie Meter (Longevity Link Corporation, Salt Lake City, UT) (t = 0.900; df = 111; $P = 0.370$), neophobia (t = 0.607; df = 110; $P = 0.545$), or BMI z-score (t = 0.062; df = 110; $P = 0.951$). Continuous variables were calculated and compared using independent *t* tests, categorical variables were calculated and compared using chi-square (test of independence) and race was calculated using Fisher exact test. The intervention group received 7 hands-on, science, technology, engineering, arts and mathematics food-based learning activities, over a 4-month period, to expose children to 9 target vegetables (broccoli, cauliflower, spinach, radish, sweet potato, cucumber, tomato, carrot, and pea pod).

children/classroom) participated in the pilot study. Demographic and baseline data are reported in Table 2. Children were 57% male, had an average age of 3.7 ± 0.57 years at baseline, and predominantly Black/African American (81%) followed by Hispanic (6%). The Centers for Disease Control and Prevention growth charts were used to calculate children's BMI percentiles and z-scores.[29] Approximately 16% of children were overweight (85th to 95th percentile) and 27% obese (> 95th percentile).[30] No major food allergies were reported. There were no significant differences between groups at baseline for demographics or primary measurements, including BMI z-score, level of parent-reported neophobia, SCS, or target vegetable liking. Exposure dose, measured by the attendance of STEAM-based FBL activities varied during the intervention; approximately 38% of children attended 6 or more activities, 49% of children attended 4–5 activities, and 13% of children attended 1–3 activities.[17] Attrition data is also reported in Table 2. At the end of the study, 37 children were dropped from the analysis because they were absent at a time of data collection or declined to participate. There was no statistically significant difference between the 2 groups with respect to age, sex, or baseline measurements ($P > 0.05$). Children were required to be part of each time point of data collection (baseline, midpoint, and posttest) to remain in the sample.

The mean target vegetable liking for the intervention group was 3.2 ± 0.19 at baseline, 2.9 ± 0.17 at midpoint, and 2.8 ± 0.15 at posttest. The mean target vegetable liking for the comparison group was 3.2 ± 0.17 at baseline, 3.1 ± 0.15 at midpoint, and 3.1 ± 0.13 at posttest. Repeated measures ANOVA determined that a time-by-group interaction was not significant for target vegetable liking ($F_{2,68} = 0.82$; $P = 0.44$; $r = 0.02$) (Figure 2). The achieved power for this time-by-group analysis of target vegetable liking was 0.14, with an effect size of 0.02. Mean SCS for the intervention group was 268.6 ± 13.24 at baseline, 271.3 ± 12.50 at midpoint, and 267.8 ± 11.26 at posttest. Mean SCS for the comparison group were 270.9 ± 12.13 at baseline, 275.6 ± 11.46 at midpoint, and 229.6 ± 10.32 at the posttest. Skin carotenoid status levels were significantly higher in the intervention group at posttest compared with the comparison ($t = 2.54$; $df = 85$; $P = 0.01$) (Figure 3). Repeated measures ANOVA determined that a time-by-group interaction was also significant for change in SCS ($F_{1,77} = 3.98$; $P = 0.02$; $r = 0.10$). The achieved power for this time-by-group analysis of SCS was 0.70, with an effect size of 0.10. Skin carotenoid status declined in both groups (intervention = 0.06%; comparison = 15.09%) from baseline to posttest with a significantly smaller decline observed in the intervention group ($P = 0.02$).

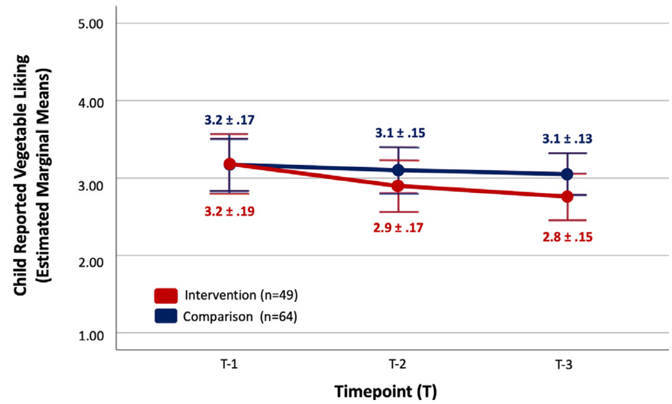

Figure 2. Child-reported target vegetable liking after 7-week intervention with 3-to-5-year-olds (n = 113). The intervention group received 7 hands-on science, technology, engineering, arts, and mathematics food-based learning activities, over 4 months to expose children to 9 target vegetables (broccoli, cauliflower, spinach, radish, sweet potato, cucumber, tomato, carrot, and pea pod). Time of assessment: T1, baseline; T2, midpoint; T3, posttest. Scale: 1, *super yucky*; 5, *super yummy*. In between T2 and T3, children were absent from school for 3 weeks for winter break; however, the duration between data collection points was approximately equal. The values for mean and SE were reported. Repeated-measure ANOVA reported no significant difference from baseline ($F_{2,68} = 0.82$; $P = 0.44$; $r = 0.02$). Covariates appearing in the model are evaluated at the following values: sex, age = 3.71, BMI z-score = 0.71.

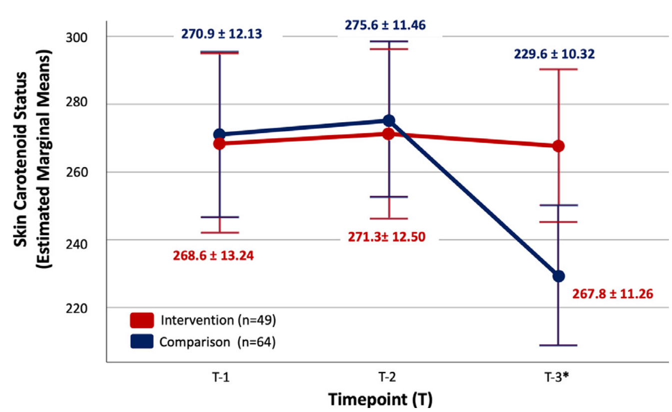

Figure 3. Skin carotenoid status after 7-week intervention with 3-to-5-year-olds (n = 113). The intervention group received 7 hands-on science, technology, engineering, arts, and mathematics food-based learning activities, over 4 months to expose children to 9 target vegetables (broccoli, cauliflower, spinach, radish, sweet potato, cucumber, tomato, carrot, and pea pod). Time of assessment: T1, baseline; T2, midpoint; T3, posttest. Scale = 0−850 for Veggie Meter (Longevity Link Corporation, Salt Lake City, UT) score. In between T2 and T3, children were absent from school for 3 weeks for winter break; however, the duration between data collection points was approximately equal. The values for mean and SE were reported. Repeated measures ANOVA reported significant difference from baseline ($F_{1,77} = 3.98$; $P = 0.02$; $r = 0.10$). Covariates appearing in the model are evaluated at the following values: sex, age = 3.73, BMI z-score = 0.74. *Indicates SCS levels that were significantly higher in the intervention group at posttest than the comparison group (t = 2.54; degrees of freedom = 85; $P = 0.01$).

DISCUSSION

This study showed that STEAM FBL activities in HS classrooms did not appear to improve the liking of target vegetables, but there was evidence to suggest that children exposed to the intervention experienced a significantly smaller decline over time in SCS, compared with the comparison group. A STEAM-based learning approach has the potential to prepare children for kindergarten while also having a positive influence on children's dietary intake.[4,5,31] The intervention and comparison groups demonstrated an overall decline in the liking of target vegetables; however, a previous study has reported that preschool children's vegetable liking may decrease before increasing.[32] Another prior study using the same scale also reported that preschoolers' consumption of healthful foods preceded improvements in reported liking or willingness to try.[33]

Another consideration is the number of vegetable exposures children experience. Prior research suggests that 8–15 taste exposures may be needed to increase liking of a new vegetable or food[7,8]; however, there is limited research to support the understanding of how children's liking evolves for familiar vegetables. The majority of the children in the current study had already been exposed to target vegetables at home or school (Figure 1). Prior research indicates that improving liking for novel vegetables may be easier than familiar vegetables because no prior exposure or predisposed disliking exists.[34] Although selecting novel vegetables for a food-based intervention might allow researchers to assess change in liking more easily, long-term intake of these vegetables could be affected if children do not have access to the vegetables outside of the learning environment.[35,36]

Science, technology, engineering, arts, and mathematics FBL activities appeared to have significantly affected children's FV intake as approximated by SCS. Children in both groups experienced an increase in SCS between baseline and midpoint data collection. However, this was followed by a decline in SCS from midpoint to posttest in both groups, with children in the intervention group experiencing a significantly smaller decline than the comparison group. The decline in both groups' SCS may reflect children's absence from school during winter break for approximately 3 weeks between midpoint and posttest. Because SCS is representative of dietary intakes of 4–6 weeks prior,[37] the increase of both groups SCS from baseline to midpoint could reflect children's consumption of the same available meals and snacks while at HS. However, the decrease in SCS between midpoint and posttest reflects FV consumption that occurred mainly outside of the HS environment during the break. Prior research indicates that children enrolled in HS may not have the same access to FV at home compared with that in school,[3] which may account for the decreases in observed SCS. Because the 11 classrooms included in the current study were affiliated with a single HS program, this helped ensure children from all classrooms (intervention and comparison) generally received the same menu items during the intervention. The smaller decreases in SCS observed in the intervention group may suggest intervention children were consuming more carotenoid-rich FVs during and after the intervention when these foods were available for consumption at home and school.

The study has several limitations. First, because of the small sample size, the results should not be generalized to children and HS classrooms not included in this study. The nonrandomized nature of the study design means the results are not immune to selection bias. Second, because of the nature of the pilot design, attendance on the days the intervention activities were implemented and were not included as a control variable in analyses. Because comparison group participants were not exposed to an alternative program, nor was general comparison group attendance measured, including attendance as a control variable was not possible. Another limitation was the lack of control for the clustering of the data within centers. Finally, a *post hoc* analysis was conducted instead of an *a priori* power analysis. Researchers' access to HS classrooms for this pilot was limited to the 3 participating centers; therefore, the sample size was limited to only the children enrolled in those 3 centers. Classroom clusters were not considered during *post hoc* analyses. However, the study retained the power needed to detect significant differences in measurements.

Finally, the Veggie Meter tool also has limitations. Although the Veggie Meter is useful for observing changes and improvements in SCS in both children and adults,[38] current understanding does not allow for estimation of FV consumed in relation to change in SCS. In addition, although the Veggie Meter has been validated in adults,[24,39] it has yet to be validated in preschool children. Average SCS of the 2 groups measured in the current study (intervention = 267.2 ± 100.22; comparison = 265.0 ± 67.53) were lower than a previous study that used the Veggie Meter to assess SCS of children aged 2-5 years (n = 947), reporting an average SCS of 380.[25] However, children in the Ermakov et al[27] study lived in San Francisco, CA, and different sociodemographic, vegetable availability and seasonality factors may have influenced SCS. The average SCS of the current study was higher than a previous study in the same geographical region as the current study, reporting a median Veggie Meter score of 258, 219, and 214 among preschool, middle school, and high school participants, respectively.[40] Although the Veggie Meter has its limitations, measurement of skin carotenoids is valuable because it allows more objective quantification of consumption, compared with mealtime observations or parental reports.[41]

IMPLICATIONS FOR RESEARCH AND PRACTICE

Aligning FBL and STEAM-based learning activities may present a unique opportunity to affect FV consumption for preschoolers while also meeting academic standards. Researchers and practitioners developing FBL programs may consider embedding STEAM-based content into their approaches to decrease well-described teacher barriers such as limited time[12]; however, it is necessary to carefully consider the integration of FBL to understand the level of exposure needed for more familiar vegetables. Additional research is necessary to understand how liking for familiar FVs changes over time and its relationship with actual consumption. Results warrant larger-scale research to confirm the effectiveness of STEAM-based FBL to increase FV intake measured by SCS in young children and increase understanding of preference development for familiar vegetables. In addition, because HS teachers are encouraged to participate in FBL, and prior research acknowledges their influence on children's dietary intake,[42,43] it would be recommended that teachers administer the FBL activities in future experiments, which may positively affect outcomes and increase sustainability.

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