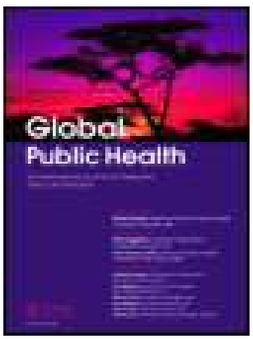

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Building healthy schools through technology-enabled citizen science: The case of the *our voice* participatory action model in schools from Bogotá, Colombia

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ABSTRACT

The physical and social environment of school settings are important for health promotion among children and adolescents. Efforts to create supportive environments at the school level can benefit from including community engagement and empowerment processes to advocate for health promotion. The *Our Voice* model presents a unique opportunity for Latin American students to improve their school environments. The objective of this study was to engage and empower students (9–18 years) from five schools in Bogotá, Colombia to use the *Our Voice* model to assess and seek to improve their local school environments. This study employed *Our Voice's* 'citizen science by the people' method using a mobile application for data collection. The *Our Voice* initiative included the following four phases: (1) Design, planning and recruitment; (2) Data collection; (3) Community meetings for thematic analysis, priority setting and initial design of feasible solutions; and (4) Community meetings with decision-makers to advocate for changes. The citizen scientists identified and advocated for safer physical activity-supportive environments and healthier food and drinks availability. This study allowed children and adolescent citizen scientists to make their voices heard by policymakers and empowered them as agents of change in the process of building healthier schools.

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Citizen science; school; healthy habits; environment; participatory action model

Introduction

Healthy lifestyles are essential to ensure the growth and adequate development of children and adolescents (Hills et al., 2007; Vilchis-Gil et al., 2015). Health-related behaviours such as physical activity and healthy eating develop during childhood and adolescence and could track into adulthood (Kelder et al., 1994; Pearson et al., 2017). In this regard, the World Health Organization (WHO) recommends that children and adolescents participate in at least 60 min of moderate-to-vigorous physical activity (MVPA) per day (World Health Organization, 2010) and limit the intake of added sugar to less than 10% of total energy intake (World Health Organization, 2015).

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Within a socio-ecological framework of health behaviours, physical and social environments are important determinants of individual behaviours (Sallis et al., 2008), and for children and adolescents, the school setting is an important place for health promotion (Langford, Bonell, Jones, Pouliou, et al., 2015). Therefore, modifying the school environment is a promising approach to complement other widely implemented health education interventions such as strategies aimed at improving knowledge, developing skills and modifying norms related to multiple health outcomes (Bonell et al., 2013).

In Latin America, school-based interventions have been found to be promising for the prevention of childhood overweight and obesity through the promotion of physical activity and healthy eating (Lobelo et al., 2013). In Bogotá, Colombia, the school environment explains approximately 36% and 67% of the variance in school-based MVPA and sedentary time, respectively (Katzmarzyk et al., 2018). Also, the food environment in schools from Bogota is characterised for a high availability of unhealthy food options and limited availability of healthy foods (Martinez-Ospina et al., 2019). This suggests that environmental changes at the school level could be effective in improving health-related behaviours such as physical activity, sedentary behaviours and healthy eating (Katzmarzyk et al., 2018; Lobelo et al., 2013).

As proposed by the Ottawa Charter for Health Promotion, creating supportive environments for health and strengthening community actions for prioritising and contributing to better health are key actions for health promotion (World Health Organization, 1986). However, interventions to promote healthy habits in the school environment often have not incorporated, or sometimes have ignored, students' perceptions about challenges and opportunities related to practicing healthy lifestyles in their schools. Previous studies that have included students' perceptions have been conducted in high-income countries, mainly to assess specific interventions (Langford, Bonell, Jones, & Campbell, 2015; Morton et al., 2016). In this sense, the use of community-engaged (i.e. 'by the people') citizen science approaches presents a unique opportunity for Latin American students to improve their school environments (King et al., 2019). The *Our Voice* model has shown initial promise in fostering improved local environments for enhancing active transit to school in a northern California community with a largely Latino population (Rodriguez et al., 2019). Findings from that investigation support the promise of this participatory action model for creating healthier environments in and around school settings.

In this context, the objective of this study was to engage and empower students from five public schools in Bogotá, Colombia to participate in the *Our Voice* initiative to assess and seek to improve their local school environments. The initiative trained students as citizen scientists to use an innovative mobile app to assess environmental features impacting the practice of healthy habits at school, and then use their own data to develop feasible strategies for improving the school environment for health. Citizen scientists are defined as participants of a study who engage in several steps of a research, such as data collection, data analysis and data-based advocacy processes (King et al., 2016).

Materials and methods

Study setting

Bogotá is the capital of Colombia, with 7.2 million people (Departamento Administrativo Nacional de Estadística DANE, 2020). In 2017, almost 1.5 million people were between 5 to 16 years old (Secretaria de Educación del Distrito, 2017), and 57% of the school enrolment in Bogotá was in public schools (Secretaria de Educación del Distrito, 2017). Bogotá's government provides a school food programme in public schools (PAE by its acronym in Spanish), implemented to reduce student drop-out (Ministerio de Educación Nacional, 2013). The PAE gives approximately 900,000 daily food rations (including snacks, breakfast and lunch) to children and adolescents in public schools from Bogota.

Our voice

This study is part of the global *Our Voice* Citizen Science Research Initiative. *Our Voice* employs a 'citizen science by the people' method that involves community participation in real-world data collection and analysis, followed by resident discussion, prioritisation, and use of their findings to advocate for local health-enhancing change (King et al., 2019). This initiative utilises information technology for data collection, specifically, the Stanford Healthy Neighborhood Discovery Tool (hereinafter Discovery Tool). This mobile application allows users to record geocoded photographs and audio and/or text narratives as well as rate environmental features as positive or negative. The Discovery Tool has been translated into 10 languages and has been deployed successfully around the world by community members aged 9–90+ to assess their local environments (Buman et al., 2013).

The *Our Voice* initiative includes four phases: (1) Design, planning and recruitment of students as citizen scientists; (2) Data collection by citizen scientists; (3) Community meetings for resident-driven thematic analysis, priority setting and initial design of feasible solutions; and (4) Community meetings with relevant decision-makers to advocate for specific and realistic changes. For this project, we also incorporated an additional data analysis process by the research team. Each phase is described below:

Design, planning and recruitment

School selection. Five schools from Bogotá were selected according to the following criteria: (1) schools were located in urban areas of the city; (2) were co-educational (girls and boys); (3) all grades of the school were based at the same location (elementary, middle and high school); (4) the school was not exclusively for students with physical or cognitive disabilities; and (5) the school had shown support for additional school-based physical activity programmes occurring outside of the formal physical education curriculum, such as school recess physical activity programmes and extra-curricular sports.

Study design. This investigation employed mixed methods (quantitative, qualitative, and observational measures) to evaluate the potential utility of the *Our Voice* initiative for engaging students from across school levels (elementary to high school) in both technology-enabled data collection as well as data interpretation and advocacy activities to drive positive school environment change.

Sampling and recruitment. Each school was invited to participate in the study via a letter to the respective principal, and all the invited schools accepted. A goal of 15 students per school was targeted, ensuring student representation from each classroom from the elementary, middle and high school grades (i.e. grades 4–11). To improve the community engagement and empowerment process, 60% of participants were peer-selected student leaders and the other 40% were a random sample of students. In this case, representatives from each classroom (selected by their peers each school year) were invited to participate in the study as leaders of their school community. Informed consent forms were signed by the parents and informed assents were signed by the students. All phases of the study and questionnaires were reviewed and approved by the Institutional Review Board of the Universidad de los Andes in Bogotá (Minutes 690 of 2017).

Data collection

Upon obtaining consent from each participant, trained personnel administered a two-part self-report survey assessing sociodemographic and lifestyles information. These surveys took approximately 20 min to complete. Children completed the lifestyles survey at the school and parents completed the sociodemographic survey by phone.

Sociodemographic variables. Age was obtained as years of life completed at the time of the survey. According to the definition used by the Colombian government, students were classified as: children (≤ 12 years) and adolescents (>12 years) (Congreso de la República de Colombia, 2006). Socioeconomic status (SES) of each student's neighbourhood was categorised for this study as low (1–2), medium (3–4) or high (5–6) based on the classification from Bogotá's city Planning Department, which has six categories based on the physical characteristics of the household and neighbourhood (Secretaria Distrital de Planeación, 2017).

Anthropometric measurements. Anthropometric data (i.e. body weight and height) were measured directly by trained researchers. Weight (to the nearest 0.1 kg) was measured using a portable Tanita SC-240 Body Composition Analyzer (Tanita, Arlington Heights, IL, USA) after shoes were removed. Height was measured with a portable Seca 213 stadiometer (Seca, Hamburg, Germany) with shoes removed and at the end of a deep inhalation with the participant's head in the Frankfort Plane (Lohmann et al., 1988). Body mass index (BMI) was calculated as weight (kg)/height^2 (metres) and categorised according to the WHO growth reference tables (de Onis et al., 2007) as underweight and risk of underweight (<-1 BMI Z-score), normal (≥-1 BMI Z-score ≤1) and overweight or obese (>1 BMI Z-score).

Lifestyle variables. Food consumption was self-reported in response to an adapted food frequency questionnaire from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE), which assessed 23 food and beverage groups (Katzmarzyk et al., 2013).

Self-reported physical activity was assessed as the number of days that the child was involved in MVPA for at least 60 min over the previous seven days (U.S. Centers for Disease Control and Prevention, 2012).

The use of active transportation to school was assessed with questions adapted from the Health Behavior in School-aged Children study (Gropp et al., 2013). Children were asked about the main mode of transport that they used to go to school and for the return school-to-house journey. Their responses were classified as: active transportation and motorised transportation.

Environmental assessments using the discovery tool mobile app. At the beginning of the study, citizen scientists were asked to participate in a geocoded walk around their school grounds, for up to 30-minutes, while using the Discovery Tool app, which they accessed on an Android mobile phone. The licensed app was downloaded to smartphones provided by the research team for the walk. Citizen scientists received a brief training of 5–10 min on how to use the Discovery Tool. The research team accompanied the citizen scientists on the walks to provide guidance on the use of the Discovery Tool in case it was needed, without interfering with the data collection. Using the Discovery Tool app, participants were asked to take photos and record audio narratives reflecting their perceptions of the barriers and enablers affecting the practice of healthy lifestyles in their school environment. After each walk, de-identified data were uploaded via Wi-Fi to a secure Stanford University server. All data were anonymized and assigned with a numerical ID, and protected with a username and password, unique for each study site and only known by two researchers. Photos that captured visible faces were deleted. The environmental assessments occurred between April and July 2017.

Acceptability of the discovery tool. At the end of each walk, participants completed a survey about the acceptability of the Discovery Tool app. The survey, a paper-based questionnaire administered by the research staff, included a six-point Likert scale (nothing, not much, a little, more or less, something, very) to rate their enjoyment, comfort, usefulness and danger perception by using the app, as well as the likelihood of recommending the tool to their friends and acquaintances.

Community meeting for priority setting

Following the Discovery Tool data collection, an anthropologist from the research team conducted one meeting that included all the participants at each school. The group sizes for these meetings ranged from 16 to 23 students. These meetings were conducted between July and September 2017. In these meetings, as part of the participatory approach of Our Voice, the participants individually reviewed the photos and audio transcriptions of their environmental assessments to conduct an initial thematic analysis. After reviewing their own data, participants were asked to share the main topics identified from their photos and narratives with their peers, and to collectively group their data by categories, naming those categories according to the topics for which the photos were related. Based on the collective data review, the groups then identified (a) the main facilitators to practicing healthy lifestyles in the school environment, i.e. features that should be maintained; and (b) barriers to practicing healthy lifestyles in the school environment, i.e. features that should be improved. Once the facilitators and barriers were compiled, each group of citizen scientists prioritised the topics of attention for their school according to their shared assessment of the order of importance. Based on this prioritisation, the participants brainstormed specific feasible solutions to the identified barriers to contribute to the improvement of their schools as health-promoting environments.

In the final phase of the same meeting, participants received basic training in advocacy skills to exercise their civil rights, both with respect to the school environment and more generally. This training was led by the Environment and Public Health Clinic of the Universidad de los Andes School of Law.

Advocacy community meeting

After the initial community meeting, a meeting between citizen scientists and local policymakers was scheduled and facilitated by the research team at each school. Meetings were conducted between October and December 2017. Relevant policymakers were selected based on the prioritised topics at each school, and included local representatives from the school district administration, local school management board, school directors, representatives from the massive transport system (TransMilenio) and the Botanical Garden of Bogota (leaders of the school gardening initiative). Each meeting began with the research team explaining the aims of the project. The citizen scientists then presented the prioritised facilitators and barriers for adopting healthy lifestyles in the school environment, as well as the feasible solutions that they had generated, using their data, to improve their schools. Policy makers responded to the community's suggestions and concerns, discussed potential solutions, and committed to pursuing avenues of change to the extent of their ability.

Thematic analysis

At each community meeting, members of the research team took detailed field notes. In order to provide a wider picture of facilitators and barriers across schools and the conclusions of the meetings, the transcribed Discovery Tool narratives and community meetings' field notes were thematically analyzed by the research team. This thematic analysis aimed to identify data-based categories from the environmental assessments conducted by the citizen scientists, as well as commitments and challenges that emerged from policymakers and citizen scientists at the community meetings. One analyst transcribed the data verbatim. For a systematic revision and thematic synthesis, all transcripts were entered in an Excel spreadsheet, pairing each transcript with demographic data (gender, age, school) of the citizen scientist who collected the photo and narrative. Four analysts independently read all transcripts and proposed categories to organise transcripts into clusters that contained similar information. During research team meetings, analysts agreed on the data-based categories and sub-themes that could synthesise facilitators and barriers across schools. Upon consensus, two analysts coded all transcripts using those data-based categories. Discrepancies were discussed at research team meetings until one final Excel document with complete coding for all data was consolidated.

Follow up

Two years after the last community meeting, as part of a results-focused gathering with citizen scientists and community members, the research team held a follow up meeting at Universidad de los Andes. An invitation was sent to each school and the principals selected one or two students among those who were still enrolled to attend this event. Citizen scientists shared their experiences in the project and the observed changes that had occurred as a result of the advocacy efforts.

Results

A total of 39 children (9–12 years old) and 58 adolescents (13–18 years old) participated in the project as citizen scientists. Participants were on average 13.4 (*SD* = 2.2) years old. More than half of the participants were female and lived in neighbourhoods with low socioeconomic status. Regarding BMI, 13% of the sample were at risk or were underweight; 66% had a normal BMI; and 21% were overweight or obese. Overall 53.6% and 42.2% of the citizen scientists reported a daily consumption of fruits and vegetables, respectively. One out of five students reported drinking sugar-sweetened beverages five or more times per week. Only 14% of the citizen scientists were physically active for at least 60 min 6–7 days per week, commensurate with national recommendations. However, over 50% used active modes of transport (walking, cycling or skating) to get to school (Table 1).

Acceptability of the discovery tool

Table 2 presents the results from the acceptability assessment of the Discovery Tool. The majority of the citizen scientists found the Discovery Tool fun (75%) and useful for documenting issues about their schools (78.4%). More than 80% of the participants reported feeling comfortable carrying the device. Regarding perceptions of safety when using the device, approximately 50% of the participants reported not feeling nervous or having attention drawn to themselves by carrying the device. Also, the majority (78%) did not perceive a danger in carrying the device. Most of the citizen scientists would recommend the device to other people (78.4%), and over 80% of them reported that they would use it again. When asked if they would be willing to use it for a longer time period, the proportion of students interested dropped to 66% (Table 2) – although this still represents two-thirds of participants.

Environmental assessments using the discovery tool

All participants assessed their school environments with the Discovery Tool. A total of 820 pictures were taken across the five schools, ranging from 89 to 261 per school, with a mean of 9 (SD 4.9) photos taken per citizen scientist. A total of 633 audio narratives were recorded, ranging from 88 to 206 per school, with a mean of 9 (SD 5.2) narratives taken per citizen scientist. Based on these data, a total of 8 main themes and 29 sub-themes relating to the practice of healthy lifestyles in the school environments were identified (Table 3). The most common topics included the general infrastructure of the school, sports and recreation opportunities, green spaces, and the food environment, among others presented in Table 3.

Facilitators and barriers were identified among these themes. The main facilitators for health at school included the availability of sports facilities and equipment as well as physical activity programmes; the friendliness of the environment (e.g. aesthetics) and the air quality of green spaces; the availability of school feeding programmes; the availability of healthy foods; and water fountain availability.

Table 1. Characteristics of the citizen scientists in the school environment of five schools in Bogota, Colombia.

	Total Sample n (%)	School 1 n (%)	School 2 n (%)	School 3 n (%)	School 4 n (%)	School 5 n (%)
Sex						
Female	63 (64.9)	13 (76.5)	9 (56.3)	12 (52.2)	18 (78.3)	11 (61.1)
Male	34 (35.1)	4 (23.5)	7 (43.7)	11 (47.8)	5 (21.7)	7 (38.9)
Age						
Average (SD[a])	13.4 (2.2)	13.8 (2.5)	13.6 (2.5)	13.5 (2.5)	12.9 (1.8)	13.4 (1.8)
≤ 12 years old	39 (40.2)	5 (29.4)	7 (43.8)	10 (43.5)	11 (47.8)	6 (33.3)
>12 years old	58 (60.8)	12 (70.6)	9 (56.2)	13 (56.5)	12 (52.2)	12 (66.7)
Socioeconomic status						
Low (strata 1 and 2[b])	60 (62.5)	17 (100)	15 (93.8)	1 (4.6)	23 (100)	4 (22.2)
Medium (strata 3 and 4)	32 (33.3)	0 (0)	1 (6.2)	18 (81.8)	0 (0)	13 (72.2)
High (strata 5 and 6)	4 (4.2)	0 (0)	0 (0)	3 (13.6)	0 (0)	1 (5.6)
Body Mass Index categories						
Underweight/Low weight risk	13 (13.4)	0 (0)	3 (18.8)	2 (8.7)	7 (30.4)	1 (5.6)
Normal	64 (66.0)	13 (76.5)	11 (68.8)	14 (60.9)	12 (52.2)	14 (77.8)
Overweight/obese	20 (20.6)	4 (23.5)	2 (12.5)	7 (30.4)	4 (17.4)	3 (16.7)
Fruits consumption						
Never or less than once per week	7 (7.2)	2 (11.8)	2 (12.5)	0 (0)	2 (8.7)	1 (5.6)
Once per week	14 (14.4)	2 (11.8)	4 (25.0)	0 (0)	5 (21.7)	3 (16.7)
2–4 days per week	19 (19.6)	4 (23.5)	5 (31.3)	0 (0)	6 (26.1)	4 (22.2)
5–6 days per week	5 (5.2)	2 (11.8)	0 (0)	3 (13.0)	0 (0)	0 (0)
Once per day everyday	26 (26.8)	3 (17.7)	3 (18.8)	9 (39.1)	7 (30.4)	4 (22.2)
Everyday more than once	26 (26.8)	4 (23.5)	2 (12.5)	11 (47.8)	3 (13.0)	6 (33.3)
Vegetables consumption						
Never or less than once per week	5 (5.2)	2 (11.8)	1 (6.3)	0 (0)	1 (4.4)	1 (5.6)
Once per week	17 (17.5)	3 (17.7)	5 (31.3)	3 (13.0)	6 (26.1)	0 (0)
2–4 days per week	26 (26.8)	7 (41.2)	5 (31.3)	5 (21.7)	6 (26.1)	3 (16.7)
5–6 days per week	8 (8.3)	2 (11.8)	1 (6.3)	1 (4.3)	2 (8.7)	2 (11.1)
Once per day everyday	27 (27.8)	2 (11.8)	2 (12.5)	8 (34.8)	6 (26.1)	9 (50.0)
Everyday more than once	14 (14.4)	1 (5.9)	2 (12.5)	6 (26.1)	2 (8.7)	3 (16.7)
Sugar-sweetened beverages consumption						
Never or less than once per week	42 (43.3)	8 (47.1)	3 (18.7)	11 (47.8)	11 (47.8)	9 (50.0)
Once per week	19 (19.6)	3 (17.6)	5 (31.3)	3 (13.0)	5 (21.7)	3 (16.7)
2–4 days per week	19 (19.6)	3 (17.6)	4 (25.0)	5 (21.7)	4 (17.4)	3 (16.7)
5–6 days per week	3 (3.1)	0 (0)	0 (0)	0 (0)	1 (4.4)	2 (11.1)
Once per day everyday	4 (4.1)	0 (0)	2 (12.5)	2 (8.7)	0 (0)	0 (0)
Everyday more than once	10 (10.3)	3 (17.6)	2 (12.5)	2 (8.7)	2 (8.7)	1 (5.6)
Fast foods consumption						
Never or less than once per week	53 (54.6)	8 (47.1)	8 (50)	12 (52.2)	14 (60.9)	11 (61.1)
Once per week	32 (33.0)	7 (41.2)	6 (37.5)	9 (39.1)	4 (17.4)	6 (33.3)
2–4 days per week	10 (10.3)	2 (11.8)	2 (12.5)	0 (0)	5 (21.7)	1 (5.6)
5–6 days per week	1 (1.0)	0 (0)	0 (0)	1 (4.3)	0 (0)	0 (0)
Once per day everyday	1 (1.0)	0 (0)	0 (0)	1 (4.3)	0 (0)	0 (0)
Everyday more than once	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Days physically active						
0–1 day per week	24 (24.7)	9 (52.9)	6 (37.5)	3 (13.0)	5 (21.7)	1 (5.6)
2–3 days per week	40 (41.2)	6 (35.3)	6 (37.5)	7 (30.4)	12 (52.2)	9 (50.0)
4–5 days per week	19 (19.6)	2 (11.8)	3 (18.8)	5 (21.7)	5 (21.7)	4 (22.2)
6–7 days per week	14 (14.4)	0 (0)	1 (6.2)	8 (34.8)	1 (4.4)	4 (22.2)
Transport to school						
Walk	45 (46.4)	15 (88.2)	10 (62.5)	0 (0)	19 (82.6)	1 (5.6)
Bicycle, skates, skateboard	6 (6.2)	0 (0)	1 (6.3)	1 (4.4)	0 (0)	4 (22.2)
Public transportation or school bus	39 (40.2)	0 (0)	5 (31.3)	19 (82.6)	3 (13.0)	12 (66.7)
Private car	5 (5.2)	1 (5.9)	0 (0)	3 (13.0)	0 (0)	1 (5.6)
Motorcycle	2 (2.1)	1 (5.9)	0 (0)	0 (0)	1 (4.4)	0 (0)

[a] SD: Standard deviation.

[b] In Colombia, socioeconomic status is classified by strata, going from 1 to 6, where 1 represents the lowest socioeconomic status and 6 represents the highest.

Table 2. Acceptability of the Stanford Neighborhood Discovery Tool among the citizen scientists in the school environment in five schools from Bogota, Colombia

	Frequency ($n = 97$)	Percentage (%)
How fun it was to use the tool today?		
Not at all-not much	2	2.1
A little- more or less	22	22.7
Some-very	73	75.3
How comfortable it was to carry the smartphone?		
Not at all-not much	6	6.2
A little- more or less	7	7.2
Some-very	84	86.6
How nervous were you about carrying the smartphone with you?		
Not at all-not much	53	54.6
A little- more or less	20	20.6
Some-very	24	24.7
How much did you feel that you called attention by carrying the smartphone?		
Not at all-not much	51	52.6
A little- more or less	23	23.7
Some-very	23	23.7
How dangerous did it feel to carry the smartphone with you?		
Not at all-not much	76	78.4
A little- more or less	11	11.3
Some-very	10	10.3
How fun it was to use the tool for documenting issues about your school?		
Not at all-not much	3	3.1
A little- more or less	18	18.6
Some-very	76	78.4
How likely it is that you would recommend your friends or acquaintances to use this tool?		
Not at all-not much	5	5.2
A little- more or less	16	16.5
Some-very	76	78.4
If you were asked, how likely would you be to accept to use this tool again?		
Not at all-not much	3	3.1
A little- more or less	13	13.4
Some-very	81	83.5
If you were asked, how likely would you be to use this tool for a longer time?		
Not at all-not much	9	9.3
A little- more or less	24	24.7
Some-very	64	66.0

An example of an audio narrative for such facilitators follows:

> I took this picture because I think that having water fountains available for the school community is very appropriate given that the [bottled] water is a little expensive in the cafeteria. It is very important to drink a lot of water during the day to help our body and its functioning. (Citizen scientist, 16 years old)

The citizen scientists also highlighted special features of their schools such as places and programmes that could promote health, mental health, and relevant skills, such as having a farm at school, arts rooms, inclusive spaces for children with special learning needs, and gardening initiatives.

Such an example follows:

> This is our famous chicken yard; we will also have rabbits very soon (…). Here they take good care of the animals and there are a lot of plants there–broccoli, carrots, lettuce, green peas, onion. The harvest is sent to the cafeteria to prepare their very famous salads, with eggs and everything. (Citizen scientist, 9 years old)

The main barriers diminishing healthy lifestyles at school included the poor maintenance of common areas (like restrooms and classrooms) and green spaces; the availability of unhealthy foods; the high prices of healthier food options; and the lack of civic culture to maintain a clean environment and use the available resources, such as restrooms, correctly.

Table 3. Frequency of categories and sub-themes identified as barriers and facilitators for the practice of healthy lifestyles at the school environment, categorised by the researchers in the thematic analysis.

Categories	Sub-themes	Total of mentions N (%)[a]	Barriers N (%)[b]	Facilitators N (%)[b]	Neutral N (%)[b]
General infrastructure (toilets, cafeteria, library)	Equipment and facilities availability	85 (30.5)	22 (25.9)	60 (70.6)	3 (3.5)
	Common spaces maintenance	42 (15.1)	37 (88.1)	5 (11.9)	0
	Toilets maintenance	27 (9.7)	25 (92.6)	2 (7.4)	0
	Classroom maintenance	11 (3.9)	9 (81.8)	2 (18.2)	0
	Risks due to poor maintenance	80 (28.7)	80 (100)	0	0
	Library availability	8 (2.9)	0	8 (100)	0
	Construction waste or debris storage	26 (9.3)	25 (96.2)	1 (3.8)	0
	Total	**279 (28.3)**	**198 (71.0)**	**78 (28.0)**	**3 (1.1)**
Sports and recreation opportunities	Availability of courts and equipment	141 (55.3)	15 (10.6)	126 (89.4)	0
	Physical activity, recreation or sports programmes/initiatives	114 (44.7)	1 (0.9)	112 (98.2)	1 (0.9)
	Total	**255 (25.9)**	**16 (6.3)**	**238 (93.3)**	**1 (0.4)**
Environment	Pollution	20 (45.5)	20 (100)	0	0
	Recycling initiatives	24 (54.5)	2 (8.3)	22 (91.7)	0
	Total	**44 (4.5)**	**22 (50)**	**22 (50)**	**0**
Food environment	Healthy food availability	38 (38.8)	2 (5.3)	35 (92.1)	1 (2.6)
	Unhealthy food availability	37 (37.8)	37 (100)	0	0
	Feeding programme (school breakfasts, lunch or snacks)	9 (9.2)	1 (11.1)	8 (88.9)	0
	Healthy eating initiatives (not selling sodas)	1 (1.0)	0	1 (100)	0
	Water fountains availability	6 (6.1)	1 (16.7)	5 (83.3)	0
	Food price	7 (7.1)	6 (85.7)	0	1 (14.3)
	Total	**98 (9.9)**	**47 (47.9)**	**49 (50)**	**2 (2.0)**
Special features	Special places for learning (farm, arts room)	28 (35)	2 (7.1)	26 (92.9)	0
	Inclusive spaces (education opportunities for children with special abilities)	13 (16.3)	0	13 (100)	0
	Gardening initiatives	35 (43.7)	3 (8.6)	32 (91.4)	0
	Nursing service	4 (5)	1 (25)	3 (75)	0
	Total	**80 (8.1)**	**6 (7.5)**	**74 (92.5)**	**0**
Green spaces	Friendly environment	68 (49.6)	0	68 (100)	0
	Air quality	29 (21.2)	6 (20.7)	23 (79.3)	0
	Maintenance of green spaces	40 (29.2)	25 (62.5)	14 (35.0)	1 (2.5)
	Total	**137 (13.9)**	**31 (22.6)**	**105 (76.6)**	**1 (0.7)**
Transport	Motorised transport	3 (42.9)	3 (100)	0	0
	Infrastructure for biking	4 (57.1)	1 (25.0)	3 (75.0)	0
	Total	**7 (0.7)**	**4 (57.1)**	**3 (42.9)**	**0**
Civic culture	Garbage disposal	25 (29.4)	16 (64.0)	9 (36.0)	0
	Cleanliness maintenance	34 (40.0)	20 (58.8)	14 (41.2)	0
	Use of resources	26 (30.6)	25 (96.2)	1 (3.8)	0
	Total	**85 (8.6)**	**61 (71.8)**	**24 (28.2)**	**0**
Overall total		**985[c] (100)**	**385 (39.1)**	**593 (60.2)**	**7 (0.7)**

[a]Column percentage
[b]Row percentage
[c]This total is higher than the total number of audios because one single audio could be classified under multiple categories.

Such an example follows:

> I think this is bad because they make us choose between healthy foods and packaged food. Very often the prices are not affordable for the students and we end up choosing junk food that is not good for health. (Citizen scientist, 17 years old)

Examples of pictures and narratives by category are presented in Table 4.

Outcomes of community meetings:

The community meetings allowed the student citizen scientists to discuss and prioritise the main themes among themselves and then communicate those themes and needs for improvement to

Table 4. Photo and audio narrative examples of the perceived barriers and facilitators for the practice of healthy lifestyles at the school environment.

Barriers/ Facilitators	Categories	Audio Narrative	Picture
Barriers	**General infrastructure (toilets, cafeteria, library)**	*I took this picture not only thinking individually, also taking into account that this is the kindergarten zone where the youngest kids play, and as you can observe there is so much construction waste, that can be dangerous for the kids when they are playing here, so I think this needs to be fixed urgently because there have already been accidents for this reason.* (16 years old citizen scientist)	
	Environment	*As we can observe in this picture there is so much garbage accumulated and a set of boxes that can be home for unwanted animals and can affect the health of the students.* (17 years old citizen scientist).	
	Food environment	*I chose this place because here they don't sell fruits or jelly, only burgers and hot dogs. What would we like to have? Healthier foods! Like fruits or something like that.* (12 years old citizen scientist). *I don't like the food kiosk because they don't sell good healthy food, only junk food, and I am diabetic.* (13 years old citizen scientist).	
	Transport	*I took this picture because I think that there are too many parking spots for cars and there should be more parking for bicycles.* (14 years old citizen scientist).	

(*Continued*)

Table 4. Continued.

Barriers/ Facilitators	Categories	Audio Narrative	Picture
	Civic culture	*This is our place for playing, and you can see that there is garbage around, even when there are garbage bins. We have bins but they are broken, some kids hit them and break them, and we cannot avoid the garbage to go all around. Also, there are kids who throw the trash on the ground and this affects our space to play.* (11 years old citizen scientist)	
Facilitators	**Sports and recreation opportunities**	*Here we have the soccer, basketball and volleyball courts. I find this zone very healthy because here we can practice sports, have fun and run. This is what I like about my school, it has big areas for use to recreate. I would also like that they fix them a little because there are holes that get full of water when it rains and that difficult the practice of physical activity* (12 years old citizen scientist).	
	Special features	*This is very cool, here we celebrate the corn festival. For that celebration we prepare food with products from our own garden. That is very cool and it makes young people to start getting interested about nature and growing plants.* (17 years old citizen scientist)	
	Green spaces	*I think that having a lot of trees in the school is good for health, to breath good air and not the polluted air that comes from cars. Having a lot of trees is good for the oxygen we need.* (14 years old citizen scientist).	

the relevant policymakers. A total of 29 policymakers (ranging from 3 to 11 per school) attended the community meetings. The broad themes prioritised by the citizen scientists across the different schools were the following: (1) facilities and maintenance-related improvements; (2) the food environment; (3) sports and recreation opportunities; and(4) school cleanliness and hygiene.

Based on the discussions with the policymakers, several commitments emerged, and several limitations were highlighted. The policymakers involved in the process agreed to do the following: (1) develop a proposal to look for private investment to improve the school facilities that need maintenance; (2) build a bridge between students and the District's Education Department to bring the ongoing needs identified by the student to the attention of that department; (3) better inform policymakers about the School Environmental Projects and promote them; (4) encourage the schoolś participation in inter-sectoral meetings coordinated by the Environmental Department at the local level; and (5) create actions with the schools' Wellness Coordinators (at the school level) for bathroom allocation and maintenance. Among the students, the commitments included the following: (1) take better care of the school environment; and (2) make specific, appropriate requests to the District's Education Department using the participatory and advocacy tools learned in this project, such as the right to petition.

The main limitations for change and improvement highlighted by the policymakers included the following: (1) a dependency on higher-level institutions, such as the District's Education Department, for making decisions; and (2) budgetary constraints for improving infrastructure, services, and programmes (e.g. feeding programmes, recreation facilities, green areas and sports courts).

Follow up insights

In May 2019, the research team held a small, formative citizen scientists' gathering at the university in order to follow up on results from the *Our Voice* process. A total of four citizen scientists from three of the evaluated schools attended. After the *Our Voice* process occurred, students mentioned new initiatives developed at their schools – for example, one student mentioned a tree planting day, and another highlighted the offer of healthier breakfasts. In general, students underscored having acquired a sense of appreciation and accountability for implementing changes at school. They expressed the relevance of making visible improvements to help increase the sense of responsibility among students in taking care of their school environments.

As noted by two citizen scientists:

> At my school they have done campaigns to increase awareness for appreciating the improvements they are building for us. (Citizen scientist, 17 years old)

> I believe it is important to acknowledge the improvements and take care of them. (Citizen scientist, 17 years old)

Discussion

Our study enrolled children and adolescents as citizen scientists and taught them to: (1) use new technologies to collect data about key factors from the physical and social environments that influence the engagement in healthy behaviours at their schools; (2) analyze their information, establish priorities, and collectively identify potential solutions; (3) make their voices heard by relevant policymakers at the school level; and (4) establish commitments and facilitate actions to improve the physical and social environments to promote health at schools. The *Our Voice* initiative empowered students, from elementary through high school, as agents of change. It also led to collective reflections upon notions of co-responsibility in the process of building healthy schools.

Our findings are consistent with previous citizen science processes advanced within the *Our Voice* Global Research Initiative to promote active living and build healthy cities through

community-engaged strategies (King et al., 2020, 2019, 2016). Achievements across diverse *Our Voice* projects, conducted with varying age, cultural, and socioeconomic populations (King et al., 2020; Rodriguez et al., 2019; Rosas et al., 2016; Rubio et al., 2020; Zieff et al., 2018), have illustrated the potential of community- engaged participatory action research as a means of leveraging community members' interests and ideas for promoting health-enhancing behaviours, and to advocate for environmental changes, including built environment improvements (Buman et al., 2012; King et al., 2020). To date, however, only one *Our Voice* study with a school population has been published. It was conducted in two elementary schools in a low-density suburban area in northern California, United States with a significant proportion of Latino families, and resulted in the increased engagement of children in an active school transportation programme relative to the control school (Rodriguez et al., 2019). Our study adds important new information to this growing body of participatory action research by engaging the largest sample of children and adolescents to date in the *Our Voice* process, along with the largest number of schools (five). Beyond corroborating the acceptability of the *Our Voice* initiative within this population, this study highlights students' perceptions regarding the characteristics that comprise healthy schools. As in other *Our Voice* projects, our citizen scientists underscored the relevance of available physical features that enable physical activity and healthy eating.

The main facilitators for health identified by citizen scientists from different schools included the availability of sports facilities and equipment, as well as physical activity programmes. Citizen scientists highlighted the quality and availability of built environment features, as well as the proper use of these resources, which touch on the social environment. These findings are consistent with previous quantitative and qualitative evidence compiled in a systematic review that reported that the availability of adequate and accessible facilities, school cohesion (sense of belonging to the school), and the effective implementation of programmes are key factors for engagement in active behaviours in the school environment (Morton et al., 2016).

Regarding the barriers to healthy behaviours at school, our citizen scientists highlighted the poor maintenance of common areas such as restrooms, classrooms and green spaces, and the availability of unhealthy foods at more affordable prices than healthier options. A number of these barriers, particularly related to infrastructure maintenance, differed from what is typically reported in the school environment literature, likely because most of the evidence available comes from high-income contexts. In contrast, the food-related barriers are consistent with the findings of a systematic review that reported the poor availability and high prices of healthy foods as well as the preference for fast foods as barriers for healthy eating at school (Shepherd et al., 2006). In particular, healthy eating preferences are shaped by social, cultural and economic factors, and do not depend solely on the food offered at schools. We found that children shared notions about healthy eating but did not necessarily put them into practice as observed in Table 1. This suggests that to modify eating behaviours and reduce that gap, joint strategies are needed between families and schools.

Also, citizen scientists in our study acknowledged that maintaining a clean environment and preserving available resources require students' engagement with civic culture and the correct use of resources. Our study, similar to other qualitative research approaches, provided insights via the students' reflections of their own health-related actions, and how these are influenced by the school environment (Jamal et al., 2013).

Policy implications

This *Our Voice* school-based project brought to light the fact that policymakers in the Bogotá local context face constrained budget allocations and competing priorities that limit their ability to enact meaningful improvements in school environments. Budget constraints have been commonly reported in school health studies, usually, because there are other priorities for the education sector (Langford, Bonell, Jones, & Campbell, 2015; Lucarelli et al., 2014). This suggests

that there is a need to communicate the benefits of health promotion for educational attainment, and to strengthen the relationships and activities between the education and health sectors. This observation also highlights the relevance of continuing participatory strategies, like *Our Voice*, aimed at empowering children and adolescents as systematic data gatherers and agents of positive change. Enhancing self- and collective efficacy among young generations may foster civic engagement and a better understanding of how scarce resources may be most appropriately used in their local contexts (King et al., 2019). Students' participation as citizen scientists may also have the potential to spill over into other areas of civic and community life (Sheats et al., 2017), as well as helping in the ongoing maintenance of school-based physical resources.

Strengths and limitations

This study had strengths and limitations that should be considered. First, schools gave active support to conduct the study as they perceived it to be both innovative and useful. However, the involvement of policymakers in being able to offer feasible solutions for the health-related issues that were identified was limited. Second, the citizen scientists in this study were mainly existing student leaders, which facilitated the advocacy process as they were familiar with the role of being agents of change. However, the concrete actions resulting from the advocacy process were reported though not directly or objectively assessed due to study constraints; such systematic changes will need to be more thoroughly assessed in future studies. This point notwithstanding, the follow-up meeting allowed us to obtain insights from the students about the perceived changes that they saw. Third, the joint analysis across five different schools enabled a broad understanding of the notion of health in the school environment at Bogotá's public schools. While there was not a sufficient sample size in each school to conduct formal cross-school comparisons in this first-generation study, those types of comparisons could be instructive in future studies in this area. Despite the relatively small sample size, the number of participants allowed to reach saturation in the community meeting discussions between citizen scientists. Another strength was the engagement of the citizen scientists throughout the study. There were no dropouts in any of the four phases of the Our Voice study. Additionally, it is worth mentioning that this innovative citizen science method harnesses new information and communication technologies in the school environment and can lead to other benefits beyond the principal project objective. Among such benefits is the development of a sense of engaged citizenship in children and adolescents, and strengthening of their abilities to be involved in decision making (Maruch & Aczel, 2018). Also, such engagement could potentially increase levels of empowerment and ultimately decrease school dropout (Nduna & Jewkes, 2012).

Conclusion

This study underscores the importance of enabling opportunities for children and adolescents to systematically collect context-relevant data and critically reflect upon features of the school environment, then prioritise issues and propose potential solutions based on their collective findings. Relevant identified features to build healthy schools included both built and social environment factors, such as availability of physical activity-supportive facilities, equipment, and programmes, and the co-responsibility of properly using and maintaining them. In addition, making healthier food items more affordable and accessible was strongly supported. Finally, local decision-makers will be well-served by inviting and listening to students' data-driven ideas and proposals for improving school environments. Our experience suggests that the changes that result from such engagement will be not only contextually relevant, but also could be broadly impactful, scalable, and potentially sustainable.

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