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Margaret Miller
Edith Cowan University

Donna Barwood
Edith Cowan University

Amanda Devine
Edith Cowan University

Julie Boston
Edith Cowan University

Sandra Smith
Edith Cowan University

See next page for additional authors

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RESEARCH ARTICLE

Rethinking Adolescent School Nutrition Education Through a Food Systems Lens

MARGARET MILLER, MAppSci[a] DONNA BARWOOD, PhD[b] AMANDA DEVINE, PhD[c] JULIE BOSTON, PhD[d] SANDRA SMITH, MResPr[e] MARTIN MASEK, PhD[f]

ABSTRACT

BACKGROUND: Obesity-driven nutrition education in schools does not appear to result in healthier adolescent food choices. This study explored food systems as an alternative pedagogical approach to engage students in nutrition education.

METHODS: After playing a food systems computer game, 250 13- to 16-year-old students in 5 Western Australian secondary schools, participated in group discussions to distinguish learning and interests in food systems. Discussion records were thematically coded using constant comparative analysis.

RESULTS: Students reported crop growth, food production and food waste, healthier food choices, and food systems as knowledge outcomes of game play. They requested additional content on food production, costing, handling, processing, and accessing local produce. Experiential activities were preferred pedagogical approaches.

CONCLUSIONS: Cross-curricular pedagogy which embraces human and planetary health through a food systems lens, can engage adolescents in nutrition education. Transformational computer games are effective to engage, educate and stimulate inquiry in food systems education.

Keywords: adolescent; school; nutrition education; food system; sustainability; computer game.

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Schools have a long-standing public health policy connection as a primary setting to promote adolescent health, including good nutrition.[1-4] In recent years, due to increasing rates of child and adolescent obesity, schools with their reach, educational purpose, and supportive environments have experienced renewed public health focus as a means to deliver nutrition education for obesity prevention.[5,6] In many cases, obesity prevention is the main driver of school nutrition education curriculum and outcome measurement.[6-9] Yet significant barriers to implementation and data showing worldwide upward trends in child obesity and chronic disease have led some to question the proliferation and relevance of obesity-driven nutrition education and interventions in schools because their impact is not assured.[5,7-12] In Australia, where school-based food and nutrition education is mandated, adolescent food patterns, like those of many other western countries, are regarded as poor.[13] One in 4 (25%) Australian children aged 5-17 years and nearly half (41%) of Australian youth aged 15-24 years are classified as

[a]Honorary Associate Professor, (m.miller@ecu.edu.au), School of Medical and Health Sciences, Edith Cowan University, 270 Joondalup Drive, Joondalup, Perth, WA, 6027, Australia.
[b]Honorary Senior Lecturer, (d.barwood@ecu.edu.au), School of Education, Edith Cowan University, 270 Joondalup Drive, Joondalup, Perth, WA, 6027, Australia.
[c]Associate Dean, (a.devine@ecu.edu.au), Public Health and Occupational Health & Safety, Edith Cowan University, 270 Joondalup Drive, Joondalup, Perth, WA, 6027, Australia.
[d]Academic Coordinator of Industry Engagement, (julie.boston@ecu.edu.au), School of Education, Edith Cowan University, 270 Joondalup Drive, Joondalup, Perth, WA, 6027, Australia.
[e]Lecturer, (sandra.smith@ecu.edu.au), School of Education, Edith Cowan University, 270 Joondalup Drive, Joondalup, Perth, WA, 6027, Australia.
[f]Associate Professor, (m.masek@ecu.edu.au), School of Science, Edith Cowan University, 270 Joondalup Drive, Joondalup, Perth, WA, 6027, Australia.

Address correspondence to: Margaret Miller, Honorary Associate Professor, (m.miller@ecu.edu.au), School of Medical and Health Sciences, Edith Cowan University, 270 Joondalup Drive, Joondalup, Perth, WA 6027, Australia.

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overweight or obese.[14] Unhealthy diets, lifestyles, and increasing waistlines are attributed causes of increasing rates of early onset of type-2 diabetes in young Australians.[13-15]

Adolescence generally refers to the period between ages 11 and 21 years.[16] During this phase, physical growth, identity development, and independence are shaped by personal, social, and environmental influences which operate within complex macrosystems, including food systems.[17,18] Food availability and access at home, at school and in the community, as well as external influences such as advertising and peer pressure, are powerful influences on adolescent food and drink choices.[17,19] Food choices are also influenced more by peers than siblings, with social interactions partly accounting for the health-negative consumption of energy dense, low nutrient value foods.[20] The prominence of fast-food density in urban environments predominantly within the western world and at times, near schools, further explains the high (44%) adolescent energy intake from discretionary and ultra-processed foods.[13,19,21,22] Other research highlights poor knowledge, disinterest, and a lack of opportunity as impacts creating barriers to healthy eating.[23,24] These influences can lead to practices that compromise healthy eating behaviors in adolescents, impacting physical growth, development, and nutritional status across the lifespan.[13,14,24-26] School-based nutrition education is a global policy imperative receiving increased focus for obesity prevention.[5,6] Yet educating adolescents to increase knowledge about healthy food choices is no guarantee that individuals will adopt healthy dietary behaviors.[24,26,27] Achieving dietary behavior change is complex, challenging, dynamic, and predominantly contextual.[23,24,28,29] The home, school, and community environments in which students live, and their interest, motivation and skills to select and prepare healthy foods are critical to acting on their knowledge of healthy choices.[19,28,30,31] For effective nutrition education, development of broader food literacy is recommended, including an understanding of food systems in which dietary choices are made.[30,32]

The food system is a complex web of activities and influences that revolve around the sequence of events in a food supply chain; primary production of food commodities, processing, distribution, access, marketing, consumption, and waste management.[33,34] Food systems education is intended to create an awareness of the entire process, along with key drivers, including food security, nutrition and health, economic returns, social benefits, political ideologies, and environmental sustainability.[35] Cumulative research and transformative thinking about achieving global sustainable development goals has identified the need for radical changes in industrial food systems prevalent in countries such as Australia, not only for better nutrition and obesity prevention but also to protect the planet from climate change and environmental degradation.[36-38] While such changes will require policy change and commitment across many sectors, several commentators note this could be driven by citizens with enhanced understanding of food systems and critical food literacy to influence change.[12,28] Educating adolescents about food systems is therefore critical for developing this awareness and consciousness for protecting and improving human and planetary health.

In Australia, food and nutrition education is variously positioned and implemented across the schooling years but predominantly within the subject areas of Health and Physical Education and Design and Technologies.[39,40] Additional opportunities to engage with and better understand food and food systems can be embraced through learning in Science, Humanities, and Social Sciences (notably Geography and Commerce), and through cross-curriculum priority Sustainability.[41-43] The extent to which broader understandings of food choices and environmental impacts are captured in Australian classrooms remains contested because pedagogical decisions are often based on jurisdictional policy and/or guidelines. Differences in curriculum delivery and the success of classroom-based learning are also attributed to teachers' education, pedagogical preferences, life-experience, and personal philosophies, with teacher self-efficacy, confidence, competence, and access to professional learning as key.[7,8,44-46] Time poor, experienced teachers have been found to utilize outdated, deficit, and didactic pedagogical approaches, focusing on individual choices and what young people are doing wrong as opposed to what they are doing right.[47,48] Fidelity to programs and sufficient time allocation also impact pedagogical success.[7,31] In Australia, to guide teachers in their pedagogical practice, health teachers are encouraged to utilize pedagogies that have educative purpose, focus on a strengths-based approach, develop health literacy skills, provide opportunities to value movement and promote critical inquiry.[39]

Despite the challenges and competing interests in schools, research suggests supportive environments that build on a student's understanding of food and nutrition education content can engage and support lifelong approaches to healthier food choices.[8,42] Authentic, relevant contexts are key to personalize and connect student learning, which is further enhanced using stimulating discussion and diverse pedagogies to develop understanding and skills.[49] Contento and colleagues also highlight the importance of participatory and experiential learning activities that help build student motivation, self-efficacy, and personal agency to make healthy food choices despite unfavorable environments.[29,31] Recently, interactive computer games deliberately aligned to curriculum and learning outcomes, but which extend beyond

nutrition facts and food categorization, have been identified as promising vehicles for nutrition and food systems education.[50-54] Through game play, it is possible to simulate aspects of the real world, model large, complex food systems across a shortened timeframe and allow students to virtually experience the consequences of actions all within 1 lesson.[55] Time-consuming processes such as sowing, growing then harvesting crops, food processing, marketing and the implications of food choices can be simulated.

This study aimed to explore food systems education as a viable means to interest and engage adolescents in nutrition education. The study examined the learning outcomes from adolescent students playing a computer game focused on managing the commercial, environmental, and health aspects of a food supply chain for potatoes. Qualitative responses from participating students were explored to determine possibilities for additional learning and the potential of computer game play as a pedagogy engaging students in nutrition and food systems education.

METHODS

Design

This research is part of a larger mixed methods study: the Nutrition Transformational Games (NTG) project conducted in 2016-2020. While the NTG project examined all aspects of the design and construction of a transformational game for use in nutrition and food systems education, this qualitative case study research conducted in 2017-2018 focused on the educational content and pedagogies to engage adolescents in learning.

Participants

The participants, 95 boys and 155 girls 13-16 years old, were recruited from years 7 to 10 in a mix of Government, Independent, and Catholic Education secondary schools based in metropolitan Perth, Western Australia (WA). Five participating schools provided a demographic spread according to the Australian Curriculum Assessment and Reporting Authority's (ACARA) Index of Community Socio-Educational Advantage (ICSEA).[56] The ICSEA value is based on the socio-educational backgrounds of the student population.

Participants were recruited via individual invitation through their schools and specifically selected classes that fit the age demographic for game play research. Informed consent was obtained from school principals, teachers, students, and parents and/or guardians. Permissions for Government and Catholic schools to participate in the study were obtained from the Department of Education and Catholic Education in WA, respectively. Permission for Independent schools to participate was obtained from the school principal.

Instrumentation

Two classroom-based activities were undertaken in this research. First, students, working in pairs or threes, played a prototype computer game, Farm to Fork.[57] This game was developed following formative research with other students and designed to align with learning outcomes of particular curricula of the Australian Curriculum.[35,39-41,52,53] The game tasked students to grow, process, and market potatoes to maximize health and commercial returns, while specifically minimizing food and resource waste. Game play was used as an instrument to stimulate student opinions and group discussions; an approach shown in formative work to increase student responses in focus group discussions and to clarify concepts and content descriptions through associations with aspects of the game.[52,53]

After student game play a focus group discussion activity was held in the classroom.[58] This followed the set protocol outlined below to explore the students' and the group's opinions of the game, game contents, and learning effects. Responses from students in each group to each question were recorded on a group paper-based worksheet with space to answer each question.

Procedure

Students were self-assigned to small groups (3 to 5 students) based on friendship or class seating arrangements. The groups were given 1 of 3 topics addressed by the game, assigned with the aim of having equal groups per topic. The topics were:

1. Growing, processing, and marketing foods.
2. Waste in food supply chains.
3. Making healthy food choices.

The task for each group, in relation to their assigned topic, was to discuss each question and record their responses on the group worksheet provided. The questions were:

1. What did you learn from the computer game?
2. What else would you like to learn about this topic?
3. What activities would you like to do in the classroom to learn more about this topic?

A research team member led the classroom activity using the set protocol, while other team members monitored discussion within each group. When needed, standard prompt questions were asked to engage all students, such as ''What do you/others think?'' The monitors also instructed and supervised a student scribe per group to record with minimal abbreviation, all opinions generated. After 25 minutes, each group made a 2- to 3-minute presentation to the class based on their group discussion. Groups

then swapped worksheets and were given 5 minutes to discuss and add anything they felt was missing from the previous groups' responses to the topic question. A final swap was made so that every group had a chance to discuss and record responses to each of the 3 topics. Worksheets were then collected by the research team.

Data Analysis

Qualitative responses from student engagement in the focus group discussions were transcribed from the worksheets, collated into separate Word documents for each topic and question, then thematically analyzed using constant comparative analysis.[59,60] This analysis involved 3 distinct steps. First, qualitative data for each topic and question were reviewed by a research assistant to become familiar with the content, then data were inductively analyzed to locate contextual themes. Next, the data were reviewed by a second researcher, to understand the complexity of the focus group discussions and to affirm the patterned or recurring themes across the data.[60] Any differences were resolved through researcher discussion. Punch reports this process as iterative and exhaustive in identifying patterned and/or repeated themes.[60] Finally, the number of responses per thematic code were quantified to capture the volume of outcomes in relation to perceived learning and proposed learning.

RESULTS

What Students Learned

Key themes relating to the 3 assigned topics and representing learning outcomes from student game play are summarized in Table 1. For topic 1: growing, processing, and marketing foods, nearly half (45.9%) of the 94 group responses related directly and/or indirectly to the complexity and steps in the food production process, including the time needed to grow and produce food. The students reported being surprised at these steps and were concerned at how easy it is to waste food during food production. In their discussions, 30% of group responses aligned with the theme that waste is generated in the food supply chain. A perception that was later confirmed when students discussed waste (topic 2), with most of the 76 group responses for this topic reporting that the food supply system generates a lot of waste (41.9%), and food processing increases waste (20.3%). Other important learning themes related to topic 2 included impacts of waste on the economy, environment and society (13.5%) and waste reduction (18.9%), with students commenting that the game made them aware of ''environmental problems in our ecosystem.'' For topic 3: learning about healthy food choices, about two thirds of the 73 group responses focused on ways to make healthy food choices (36.3%) and the health benefits from making healthy food choices (27.3%). One group related food processing to ''the junk food problem,'' commenting that it contributed to people ''getting more fat.''

Table 1. **Game-Attributed Student Learning Themes per Discussion Topic**

Learning Theme	Response N	Response %
Topic 1: Growing, processing, marketing foods (N = 94)		
The complexity of the food production process	29	31.0
The time needed for food production, especially growing food	14	14.9
Waste occurs in the food supply chain	18	20.8
Processed foods are less nutritious and generate more waste	8	9.2
Advertising and marketing influence food choices	8	9.2
Facts about growing potatoes	11	8.0
Buying local and returns to farmers	4	4.6
Nothing	2	2.3
Topic 2: Waste in the food supply system (N = 76)		
The food supply system generates a lot of food waste	33	41.9
Food processing increases waste	15	20.3
Impacts of food waste on the economy, environment and society	10	13.5
Waste can be reduced	14	18.9
Nothing	4	5.4
Topic 3: Making healthy food choices (N = 73)		
Ways to make healthier choices	24	36.3
There are health benefits from healthy food choices	18	27.3
Healthy eating is recommended	7	10.6
Healthy eating is not difficult	5	7.6
Social and environmental benefits of healthy eating	4	6.1
Other	12	7.6
Nothing	3	4.5

What Students Wanted to Learn in Addition to the Game Topics

Key themes for additional learning regarding the game topics are summarized in Table 2, with most group responses for topic 1 (n = 83) revealing that the students wanted to learn more about growing, processing, and marketing foods (37.9%). They were particularly interested in how to produce foods other than potatoes (22.9%), including the steps to grow and harvest (15.7%), accessing seasonal, local food (14.4%), processing and packaging (13.2%), and marketing of foods (14.4%). Students suggested information about ''more crops'' and ''more foods and animals like cows to make milk'' could make them more ''aware of what happens to food before we eat it.'' They also wanted to experience ''what could happen if crops were harvested too early?'' and ''how much water is needed to grow potatoes?''

Interest in learning more about the topic of waste in the food system was also high (72 group responses),

Table 2. **Desired Additional Learning Themes per Discussion Topic**

Learning Theme	Responses N	Responses %
Topic 1: Growing, processing, marketing foods (N = 83)		
How to grow or produce other foods besides potatoes	19	22.9
Specific steps in growing and harvesting	13	15.7
Seasonality, location, home grown, accessibility	12	14.4
Processing and packaging	11	13.2
Marketing	12	14.4
Economy	6	7.2
Home use	4	4.8
Effects on the environment	4	4.8
Other	2	2.4
Topic 2: Waste in the food supply system (N = 72)		
How to reduce waste	26	36.2
What is waste and how is it produced?	13	18.0
What happens to waste?	13	18.0
Waste statistics	12	16.7
Effects of waste	8	11.1
Topic 3: Making healthy food choices (N = 64)		
Identifying healthy foods	35	54.7
Making healthy foods	14	21.9
Importance and benefits of healthy eating	9	14.0
Cost of healthy eating	3	4.7
Importance and benefits of eating locally	3	4.7

with the students typically questioning why food ''scraps'' from processing were not reused. They identified highest interest in ways to reduce waste (36.2%), suggesting additional learning could focus on ''how to be food-wise'' and ''recyclable products,'' they wanted to know more about how waste is produced (18.0%), statistics pertaining to waste (16.7%) and the effects of waste (11.1%).

Most of the interest in learning more about making healthy food choices (n = 64) focused on the identification of healthy foods (54.7%), producing healthy foods (21.9%), and the benefits of healthy eating (14.0%). The students were interested in ''how to change people's preferences for unhealthy foods,'' why ''fries have a high demand?'' ''how many people really buy unhealthy foods?'' and ''why people find junk food tastier?''

How Students Would Like to Learn More About Topics in the Game

Group responses (n = 138) identified immersion activities (48.6%) as the most preferred pedagogical approach to learn more about the game topics. This included activities like computer game play, field trips, growing food, cooking food, and composting and recycling activities. They perceived these types of experiential activity as a better way to self-connect to food production. Research and discussion activities (16.7%), games and quizzes (13.8%), and videos and other media (10.1%) were the other suggestions (Table 3).

DISCUSSION

The poor diets, increasing prevalence of unhealthy weight and early onset of type-2 diabetes in young Australians suggests that school-based policy, curriculum reform, and obesity interventions are either not fully implemented or are not working, and more is needed for Australian schooling to effect healthier eating in the young.[11-15,50] The current study investigated food supply chain management via computer game play as a pedagogical approach in nutrition education to support learning outcomes promoting adolescent health.

The study results confirm that a shift in focus toward food systems may help schools to effectively engage and support adolescents to become critical and reflective consumers of food products. The Farm to Fork game aligns with current global understanding that human and planetary health are linked and that the way we produce, distribute, and consume food are important contributors to both outcomes.[35-38,61] Our results show that students are interested in learning more about these aspects of food systems, thus providing a focus for engagement in education. By considering the whole food system schools can provide opportunities for engaging students and developing food literacy not just in health learning areas but also across science, geography, business, and economics—and more broadly in sustainability

Table 3. **Preferred Pedagogies for Learning More About Game Topics**

Pedagogical Approach	Learning Topic: Food growing, processing, marketing	Learning Topic: Waste in the food system	Learning Topic: Making healthy food choices	Sub-total	% all (N = 138)
Immersion activities	18	18	31	67	48.6
Research and discussions	6	9	8	23	16.7
Games and quizzes	3	7	9	19	13.8
Videos and media	5	4	5	14	10.1
Creative activities like posters	3	2	1	6	4.3
Incursion activities	2	2	2	6	4.3
Cross-curricular activities	3	0	0	3	2.2

education. Suggestions for achieving this in the Australian Curriculum context are outlined in the teacher guide to the Farm to Fork game.[35]

The strength of this study is the use of a purposely designed computer game that provided students with experiential learning of complex processes related to food systems over a relatively short time frame.[35,55] The game not only provided education but also stimulated inquiry, and students were given an opportunity to describe in their own words, immediately after playing the game, their impressions about what they had learned and what else it triggered them to want to learn and how. Like other Australian research, this study confirms that adolescents want to be engaged in food and nutrition education, but it also shows students are interested in a more holistic understanding of food beyond health, including how it is produced and the environmental and economic inputs and impacts.[24,53]

The finding of dominant participant requests for similar game play for other foods also reveals that well-designed food systems games can stimulate inquiry to explore various factors associated with a range of foods including both fresh produce and ultra-processed foods. This form of inquiry, and critical reflection toward behavior and health is a tenet deeply rooted in the philosophical underpinnings of Australian curricular and particularly, the Australian Curriculum for Health and Physical Education.[39]

The participants were curious about when and how agricultural commodities became processed and ultra-processed, low nutritional foods, and they wanted to know more about the long-term impacts of these food choices. The immersive activity of computer game play, via a shortened timeframe, provided a meaningful decision-making element that allowed them to make sense of, experiment and connect food choices with health. In the case of this study and the computer game Farm to Fork, the participants were able to experiment with growing, processing, and marketing foods, as well as manipulating food supply and advertising campaigns to observe the effects on purchases of healthy or unhealthy foods, and ultimately on avatar weight status and broader community health. The favorable qualitative responses from this study indicate that other similarly designed games could broaden adolescents' critical perspectives on their food environment and help them to develop contextual health literacy skills, especially in settings outside the home and when influenced by peers. Such settings include school meal services, sports venues, fast food outlets, and ultra-processed food retailers.[17,62,63]

The findings of this study also show that adolescents are interested in learning more about the steps in the industrial food chain and specifically, the impacts of food production, processing, and packaging on the environment. The participants were surprised and concerned by the amount of waste in food production and were compelled to learn and do more about reducing food-related waste and/or recycling wasted food produce. Their request to better understand food-related waste, food by-products, food reuse, and food up-cycling demonstrates their interest in more sustainable and ethical living. This inquiry and critical reflection linking consumer and environmental health bodes well for young people's engagement with food-related citizenship education in secondary schools and reflects the Australian Curriculum's cross-curriculum priority for students to be educated with the tools and language to engage in sustainable practices.

The potential for linking health promotion and environmental sustainability together in schools has been noted previously, especially for food and nutrition.[64-66] An increasing number of interventions have explored the feasibility in secondary schools not only of linked cross-curriculum education but also of supportive school policies and environments that model healthy sustainable food systems such as school produce gardens, farm and supply chain-related activities, local provisioning of school meals, and food-related waste management.[67-70] Active involvement of secondary students in such activities can offer the immersive learning experiences favored by students in this study and thus reinforce formal classroom learning in the broader school and community environment.

IMPLICATIONS FOR SCHOOL HEALTH POLICY, PRACTICE, AND EQUITY

To harness the curiosity young people have toward food systems and effectively capture the potential of the school setting, this study has several implications that could support healthier food choices in adolescents. We therefore recommend the following:

- Broaden pedagogical approaches in nutrition education by applying a food systems lens to classroom learning. For this approach, we encourage teachers to move away from an end-user perspective and embrace a more holistic and experiential view of nutritional health. That is, start from the beginning and facilitate students to connect with food, food production, food processing, food marketing, and food consumption so they better understand the systems that influence and are influenced by their food choices.
- Provide opportunities for engaging students and developing food literacy across science, technologies, geography, business, and economics, with an understanding that food systems education contributes to student development as global citizens supporting better human and planetary health.

- Explore computer game technology and/or immersive activities in nutrition and health education more broadly, to simulate behavioral choices and consequences both beneficial and otherwise. Allow students to take virtual or imaginary health risks, make mistakes, problem solve and interact with predictable and unpredictable health outcomes.
- Engage students in complementary experiential learning through supportive environments that model healthy food systems such as school produce gardens, farm and supply chain-related activities, local provisioning of school meals, and food-related waste management.

Limitations

This study has several limitations. First, the sample size, although over 200 students, was constrained to 5 urban schools. More themes may have been generated across the 3 topics with the inclusion of additional schools in different contexts, such as rural. Therefore, generalization to other localities and contexts within and outside Australia is informative but not specific.

For practical purposes, data collected during focus group discussions were self-reported by a student notetaker and may limit accurate, comprehensive transcript reporting of the group discussions. Ideally, studies would record and transcribe the student discussions to ensure the range of suggestions were a complete representation of the discussions.

Discussion was in response to questions set by the researchers and related to the topics in the featured game. Therefore, the qualitative themes generated in this research are game specific and unlikely to address all aspects of food systems education, nor specifically their influences on adolescent food choices.

Finally, student consideration of classroom pedagogies for food systems education may be limited to that of previous experiences, especially the immediate experience of computer game play, and may not have considered all pedagogical approaches available.

Conclusions

Findings from this study suggest that learning approaches which embrace human and planetary health through a food system lens can engage adolescents in nutrition education. The study highlighted playing transformational computer games as an engaging way to educate and stimulate inquiry in food systems education, and that young people want to learn more about production, processing, marketing, and healthy food choices in a range of food systems.

Human Subjects Approval Statement

The Edith Cowan University Human Research Ethics Committee approved the NTG project and secondary analysis for this study (#16604). WA State government and Catholic Education provided additional approvals for the research in relevant schools. School principals, teachers, students, and parents of students involved provided informed consent.

Conflict of Interest

J.B. and M.Ma. have no conflicts of interest. Specified authors are/were members of the following WA School Curriculum and Standards Authority Advisory Committees: M.Mi., Year 11-12 Agribusiness Syllabus; D.B., Year 7-10 Health and Physical Education panel; S.S., Year 7-10 Technologies panel; A.D., Year 11-12 Food Science and Technology panel.

REFERENCES

1. World Health Organization. *Improving Health Through Schools: National and International Strategies*. Geneva, Switzerland: World Health Organization; 1999.
2. St Leger L, Young I, Blanchard C, Perry M. *Promoting Health in Schools: From Evidence to Action*. Saint Denis, France: International Union for Health Promotion and Education; 2010.
3. World Health Organization. *Global Standards for Health Promoting Schools and Their Implementing Guidance*. Geneva, Switzerland: World Health Organization; 2020.
4. World Health Organization. *Nutrition Action in Schools: A Review of Evidence Related to the Nutrition-Friendly Schools Initiative*. Geneva, Switzerland: World Health Organization; 2020.
5. World Health Organization. *Report of the Commission on Ending Childhood Obesity*, Vol. 2-7. Geneva, Switzerland: World Health Organization; 2016:30-33.
6. Evans CE, Allbar SA, Vargas-Garcia EJ, Xu F. School-based interventions to reduce obesity risk in children in high-and middle-income countries. *Adv Food Nutr Res*. 2015;76:29-77.
7. Koch PA, Contento IR, Gray HL, et al. Food, Health, & Choices: curriculum and wellness interventions to decrease childhood obesity in fifth-graders [published correction appears in *J Nutr Educ Behav*. 2020;52(6):667]. *J Nutr Educ Behav*. 2019;51(4):440-455.
8. Jacob CM, Hardy-Johnson PL, Inskip HM, et al. A systematic review and meta-analysis of school-based interventions with health education to reduce body mass index in adolescents aged 10 to 19 years. *Int J Behav Nutr Phys Act*. 2021;18:1. https://doi.org/10.1186/s12966-020-01065-9.
9. Saavedra Dias R, Barros AN, Silva AJ, et al. The effect of school intervention programs on the body mass index of adolescents: a systematic review with meta-analysis. *Health Educ Res*. 2020;35(5):396-406.
10. Bennett L, Burns S. Implementing health-promoting schools to prevent obesity. *Health Educ*. 2020;120(2):197-216.
11. Powell D, Gard M. The governmentality of childhood obesity: Coca-Cola, public health and primary schools. *Discourse*. 2015;36(6):854-867.
12. Rose N, Lourival I. Hegemony, counter hegemony and food systems literacy: transforming the global industrial food system. *Aust J Environ Educ*. 2019;35:110-122.
13. Australian Institute of Health and Welfare. *Nutrition Across the Life Stages*. Cat. no. PHE 227. Canberra, Australia: Australian Institute of Health and Welfare; 2018.
14. Australian Institute of Health and Welfare. *Overweight and Obesity Among Australian Children and Adolescents*. Cat. no. PHE 274. Canberra, Australia: Australian Institute of Health and Welfare; 2020.

15. Australian Institute of Health and Welfare. *Australia's Health 2020: Data Insights*. Canberra, Australia: Australian Institute of Health and Welfare; 2020.
16. Nagel MC. *In the Middle: The Adolescent Brain, Behaviour and Learning*. Camberwell, Australia: Australian Council for Educational Research (ACER) Press; 2014.
17. Story M, Neumark-Sztainer FS. Individual and environmental influences on adolescent eating behaviours. *J Am Diet Assoc*. 2002;102(3):S40-S51.
18. Marcone M, Madan P, Grodzinski B. An overview of the sociological and environmental factors influencing eating food behaviour in Canada. *Front Nutr*. 2020;7:77.
19. Ronto R, Cairns J, Ball L, Pendergast D, Harris N. Adolescents' views on high school food environments. *Health Promot J Austr*. 2021;32(3):458-466.
20. Ragelienė T, Grønhøj A. The influence of peers' and siblings' on children's and adolescents' healthy eating behaviour. A systematic literature review. *Appetite*. 2020;148:104592.
21. Bivoltsis A, Trapp G, Knuiman M, Hooper P, Ambrosini GL. The evolution of local food environments within established neighbourhoods and new developments in Perth, Western Australia. *Health Place*. 2019;57:204-217.
22. Cooksey-Stowers K, Schwartz MB, Brownell KD. Food swamps predict obesity rates better than food deserts in the United States. *Int J Environ Res Public Health*. 2017;14(11):1366.
23. Farringdon F, Hands B, Chivers P. Don't know, don't care or confused: what do Australian adolescents know about Australian dietary guidelines? *Curric Stud Health Phys Educ*. 2018;9(2):141-156.
24. Ronto R, Ball L, Pendergast D, Harris N. Adolescents' perspectives on food literacy and its impact on their dietary behaviours. *Appetite*. 2016;107:549-557.
25. Ronto R, Ball L, Pendergast D, Harris N. Food literacy at secondary schools in Australia. *J Sch Health*. 2016;86(11):823-831.
26. Vaitkeviciute R, Ball LE, Harris N. The relationship between food literacy and dietary intake in adolescents: a systematic review. *Public Health Nutr*. 2015;18:649-658.
27. Bailey CJ, Drummond MJ, Ward PR. Food literacy programmes in secondary schools: a systematic literature review and narrative synthesis of quantitative and qualitative evidence. *Public Health Nutr*. 2019;22(15):2891-2913.
28. Koch PA. Learning, food, and sustainability in the curriculum. In: Sumner J, ed. *Learning, Food, and Sustainability*. New York, NY: Springer; 2016.
29. Contento I. Nutrition education: linking research, theory, and practice. *Asia Pac J Clin Nutr*. 2008;17(Suppl 1):176-179.
30. Slater J. Food literacy: a critical tool in a complex foodscape. *J Fam Consum Sci*. 2017;109(2):14-20.
31. Contento IR, Koch PA, Lee H, Calabrese-Barton A. Adolescents demonstrate improvement in obesity risk behaviors after completion of choice, control & change, a curriculum addressing personal agency and autonomous motivation. *J Am Diet Assoc*. 2010;110(12):1830-1839.
32. Amin SA, Panzarella C, Lehnerd M, Cash SB, Economos CD, Sacheck JM. Identifying food literacy educational opportunities for youth. *Health Educ Behav*. 2018;45(6):918-925.
33. HLPE. Setting the stage: approach and conceptual framework. In: *HLPE* Nutrition and Food Systems. A Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome, Italy: HLPE; 2017:23-41.
34. Food and Agriculture Organization of the United Nations. *Sustainable Food Systems Concept and Framework*. Available at: https://www.fao.org/3/ca2079en/CA2079EN.pdf. Accessed May 13, 2021.
35. Edith Cowan University. *Farm to Fork Game in the Classroom Teacher Resource Guide*. Available at: https://edithcowan.itch.io/farm-to-fork. Accessed June 28, 2023.
36. Willett W, Rockström J, Loken B, et al. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet*. 2019;393(10170):447-492.
37. Lawrence MA, Baker PI, Pulker CE, Pollard CM. Sustainable, resilient food systems for healthy diets: the transformation agenda. *Public Health Nutr*. 2019;22(16):2916-2920.
38. Béné C, Oosterveer P, Lamotte L, et al. When food systems meet sustainability - current narratives and implications for actions. *World Dev*. 2019;113:116-130.
39. Australian Curriculum Assessment and Reporting Authority. The Australian Curriculum: Health and Physical Education 8.4. Available at: https://www.australiancurriculum.edu.au/f-10-curriculum/health-and-physical-education/. Accessed May 5, 2021.
40. Australian Curriculum Assessment and Reporting Authority. The Australian Curriculum: Technologies 8.4. Available at: https://www.australiancurriculum.edu.au/f-10-curriculum/technologies/. Accessed May 5, 2021.
41. Australian Curriculum Assessment and Reporting Authority. Cross-Curriculum Priorities: Sustainability 8.4. Available at: https://www.australiancurriculum.edu.au/f-10-curriculum/cross-curriculum-priorities/sustainability/. Accessed May 5, 2021.
42. Love P, Booth A, Margerison C, Nowson C, Grimes C. Food and nutrition education opportunities within Australian primary schools. *Health Promot Int*. 2020;35:1291-1301.
43. Shakeri S, Butcher T, Eather N, Riley N. Integrating food literacy and food numeracy across the Australian secondary curriculum. *J HEIA*. 2020;26(1):25-36.
44. Barwood D, Cunningham C, Penney D. What we know, what we do and what we could do: creating an understanding of the delivery of health education in lower secondary government schools in Western Australia. *Aust J Teach Educ*. 2017;41(11):15-30.
45. Metos JM, Sarnoff K, Jordan KC. Teachers' perceived and desired roles in nutrition education. *J Sch Health*. 2019;89(1):68-76.
46. Hamilton L, Goodman MA, Roberts L, Dial LA, Pratt M, Musher-Eizenman D. Teacher experience, personal health, and dieting status is associated with classroom health-related practices and modeling. *J Sch Health*. 2020;91(2):155-163.
47. Barwood D, Penney D, Cunningham C. A paradox or a culture of acceptance? The idiosyncratic workforce delivering health education in lower secondary government schools in Western Australia. *Asia Pac J Health Sport Phys Educ*. 2017;8(3):193-209.
48. Sanderson A. Food in an Australian Primary School Curriculum: A Critical Sociological Study [PhD thesis]. Brisbane, Australia: Queensland University of Technology; 2013.
49. Department of Education South Australia. *Teaching for Effective Learning Framework*. Available at: https://www.education.sa.gov.au/schools-and-educators/curriculum-and-teaching/teaching-effective-learning/teaching-effective-learning-framework. Accessed January 5, 2022.
50. Gard M, Enright E. Computer says no: an analysis of three digital food education resources. *Asia Pac J Health Sport Phys Educ*. 2016;7(3):205-218.
51. Baranowski T, Ryan C, Hoyos-Cespedes A, Lu AS. Nutrition education and dietary behaviour change games: a scoping review. *Games Health J*. 2019;8(3):153-176.
52. Barwood D, Smith S, Miller M, Boston J, Masek M, Devine A. Transformational game trial in nutrition education. *Aust J Teach Educ*. 2020;45(4):18-29.
53. Miller M, Barwood D, Furfaro M, Boston J, Smith S, Masek M. Identifying differences in nutrition-related learning

[Correction added on 12 July 2023, after first online publication: the URL link in Reference 35 has been updated in this version.]

interests of adolescent students. *J Sch Health*. 2021;91(4):277-284.
54. Hermans RC, van den Broek N, Nederkoorn C, Otten R, Ruiter ELM, Johnson-Glenberg MC. Feed the alien! The effects of a nutrition instruction game on children's nutritional knowledge and food intake. *Games Health J*. 2018;7(3):164-174.
55. Honey MA, Hilton ML. *Learning Science through Computer Games and Simulations*. Washington, DC: National Academics Press; 2011.
56. Australian Curriculum Assessment and Reporting Authority. What Does the ICSEA Value Mean? Available at: https://docs.acara.edu.au/resources/20160418_ACARA_ICSEA.pdf. Accessed January 5, 2022.
57. Edith Cowan University. *Revised Access to Farm to Fork ECU Game and Classroom Teacher Resources*. Available at: https://www.researchgate.net/project/Transformational-games-in-nutrition-education/update/63a9c38b97e2867d5076031c. Accessed February 8, 2023.
58. Vaughn S, Schumm J, Sinagub J. Use of focus groups with children and adolescents. Chapter 9. In: *Focus Group Interviews in Education and Psychology*. Thousand Oaks, CA: Sage Research Methods; 2013. https://doi.org/10.4135/9781452243641.
59. Xu W, Zammit K. Applying thematic analysis to education: a hybrid approach to interpreting data in practioner research. *Int J Qual Methods*. 2020;19:1-9.
60. Punch K. *Introduction to Research Methods in Education*. Los Angeles, CA: Sage Publications; 2009.
61. Meybeck A, Gitz V. Sustainable diets within sustainable food systems. *Proc Nutr Soc*. 2017;76(1):1-11.
62. Caswell MS, Hanning RM. Adolescent perspectives of the recreational ice hockey food environment and influences on eating behaviour revealed through photovoice. *Public Health Nutr*. 2018;21(7):1255-1265.
63. Shareck M, Lewis D, Smith NR, Clary C, Cummins S. Associations between home and school neighbourhood food environments and adolescents' fast-food and sugar-sweetened beverage intakes: findings from the olympic regeneration in East London (OREIL) study. *Public Health Nutr*. 2018;21(15):2842-2851.
64. Sendall MC, Lidstone J, Fleming M, Domocol M. Nurses and teachers: partnerships for green health promotion. *J Sch Health*. 2013;83(7):508-513.
65. Davis JM, Cooke SM. Educating for a healthy, sustainable world: an argument for integrating health promoting schools and sustainable schools. *Health Promot Int*. 2007;22(4):346-353.
66. Jones M, Dailami N, Weitkamp E, et al. Food sustainability education as a route to healthier eating: evaluation of a multi-component school programme in English primary schools. *Health Educ Res*. 2012;27(3):448-458.
67. Jones M, Dailami N, Weitkamp E, Kimberlee R, Salmon D, Orme J. Engaging secondary school students in food-related citizenship: achievements and challenges of a multi-component programme. *Educ Sci*. 2012;2:77-90.
68. Berlin L, Norris K, Kolodinsky J, Nelson A. The role of social cognitive theory in farm-to-school-related activities: implications for child nutrition. *J Sch Health*. 2013;83(8):589.
69. Black JL, Velazquez CE, Ahmadi N, et al. Sustainability and public health nutrition at school: assessing the integration of healthy and environmentally sustainable food initiatives in Vancouver schools. *Public Health Nutr*. 2015;18(13):2379-2391.
70. Reys LG. Growing a new school food culture. In: *EarthEd. State of the World*. Washington, DC: Island Press; 2017:73-82.