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A systematic review of the health and well-being impacts of school gardening: synthesis of quantitative and qualitative evidence

Heather Ohly¹, Sarah Gentry², Rachel Wigglesworth¹, Alison Bethel³, Rebecca Lovell¹ and Ruth Garside¹*

Abstract

Background: School gardening programmes are increasingly popular, with suggested benefits including healthier eating and increased physical activity. Our objectives were to understand the health and well-being impacts of school gardens and the factors that help or hinder their success.

Methods: We conducted a systematic review of quantitative and qualitative evidence (PROSPERO CRD42014007181). We searched multiple databases and used a range of supplementary approaches. Studies about school gardens were included if they reported on physical or mental health or well-being. Quantitative studies had to include a comparison group. Studies were quality appraised using appropriate tools. Findings were narratively synthesised and the qualitative evidence used to produce a conceptual framework to illustrate how benefits might be accrued.

Results: Evidence from 40 articles (21 quantitative studies; 16 qualitative studies; 3 mixed methods studies) was included. Generally the quantitative research was poor. Evidence for changes in fruit and vegetable intake was limited and based on self-report. The qualitative research was better quality and ascribed a range of health and well-being impacts to school gardens, with some idealistic expectations for their impact in the long term. Groups of pupils who do not excel in classroom activities were thought to particularly benefit. Lack of funding and over reliance on volunteers were thought to threaten success, while involvement with local communities and integration of gardening activities into the school curriculum were thought to support success.

Conclusion: More robust quantitative research is needed to convincingly support the qualitative evidence suggesting wide ranging benefits from school gardens.

Keywords: School, Gardens, Systematic review, Health, Well-being, Mixed methods

Background

School gardening and food growing have become popular activities in thousands of schools around the world. National school gardening programmes exist in some countries, such as the Royal Horticultural Society Campaign for School Gardening in the UK [1] and the Stephanie Alexander Kitchen Garden Program in Australia [2]. The individuals and organisations behind these programmes believe that school gardening has the potential to improve children’s health, social development and academic attainment.

Since the 1990s, an increasing number of research studies have attempted to evaluate the effectiveness of school gardening programmes. More recently, several reviews of the literature on school gardening have been published [3–8]. Five of these reviews were limited to US studies and, whilst they found some empirical evidence for the health and well-being impacts of school gardening, some of their conclusions were based on theoretical rationale [3–7]. They recommended further research, using more rigorous study designs, on the effectiveness of...
school gardening programmes, mediation pathways and implementation factors.

The most comprehensive review, by the National Foundation for Education Research, included international studies and found evidence for positive impacts of growing activities on pupils’ nutrition and attitudes towards healthy eating [8]. It also concluded there was modest evidence for social well-being benefits, especially for lower ability pupils or those who have become disengaged from learning. This review was described as being “underpinned by a systematic process for searching, selection, screening, coding, appraisal and synthesis” (page 3). However, it did not clearly and consistently report methods (inclusion criteria; quality appraisal criteria) and results (CONSORT flow diagram; number of studies with health and well-being outcomes; description of included studies – design, methods, quality etc.) as would be expected in a systematic review. In addition, since 2011, more studies have been published on the impact and meaning of school gardening programmes, including a large cluster randomised controlled trial of the Royal Horticultural Society Campaign for School Gardening in the UK [9, 10] and several qualitative studies from the UK and the US [11–13]. Therefore, it was justified and timely to conduct a robust, mixed methods systematic review of the health and well-being impacts of school gardening, to support and inform the further development of this popular school-based intervention. This review aims to answer the following questions:

- What are the health and well-being impacts of school gardens?
- Are there different impacts for different age groups?
- What are the effects on other family and community members?
- What do school gardens mean to those who use them?
- Are there any factors that help or hinder the successful development, use or sustainability of school gardens?

**Methods**

We conducted a systematic review of quantitative and qualitative literature according to a pre-specified protocol that was registered with the International Prospective Register of Systematic Reviews (PROSPERO: CRD42014007181). We used the methods of thematic synthesis described by J. Thomas and A. Harden [14]. As this was an evidence synthesis of existing research, ethical approval was not required.

**Search strategy**

A search strategy was devised by the research team, led by our Information Specialist (AB), through examination of key studies and discussion. It captured the concepts of school gardening and horticulture activities. The following MeSH terms were used: school exp; gardening exp; child nutrition sciences. No methods filters were used. The master search strategy (Table 1) was adapted and run in the following electronic databases in February 2014 and updated in May 2015: MEDLINE, EMBASE, PsycINFO, HMIC and SPP (using the OVID interface); AEI, BEI, ASSIA, BNI 1994-current and ERIC (using the ProQuest interface); AMED and CINAHL (using the EBSCOHost interface). Additional grey literature databases were also searched: OpenGrey, EThOS and British Library Catalogue. The review by the National Foundation for Education Research was a useful source of includable references [8]. Reference lists of included studies were scrutinised for other relevant studies. Forward citation searches were undertaken on included studies. Citation searches were also performed in Web of Science using three key references [15–17].

**Inclusion criteria**

Studies were considered eligible for inclusion if they met the following criteria:

**Population:** School children, school staff, family and community members (all ages) were included. Studies conducted in OECD countries and published in English were included.

**Table 1** Search strategy for the health and well-being impacts of school gardening (as used in Medline)

|   |   |
|---|---|
| 1 | school*.tw. |
| 2 | educat*.tw. |
| 3 | garden*.tw. |
| 4 | horticult*.tw. |
| 5 | (horticult* adj3 (school* or educat*)).tw. |
| 6 | (Food or fruit* or vegetable*).tw. |
| 7 | ((Food or fruit* or vegetable*) adj2 grow*).tw. |
| 8 | ((Food or fruit* or vegetable*) adj2 production).tw. |
| 9 | ((Food or fruit* or vegetable*) adj2 producing).tw. |
| 10 | (Food or fruit* or vegetable*) adj2 plant*.tw. |
| 11 | 7 or 8 or 9 or 10 |
| 12 | exp Schools/ |
| 13 | exp Gardening/ |
| 14 | "Child Nutrition Sciences"/ |
| 15 | 1 or 12 |
| 16 | 3 or 13 or 14 |
| 17 | 15 and 16 |
| 18 | 11 and 15 |
| 19 | (educat* adj3 garden*).tw. |
| 20 | 17 or 18 or 19 |
**Interventions:** Studies were included if they reported the effects of participation in school gardening activities. The definition of ‘school’ included all educational settings up to 18 years, including special schools. The definition of ‘gardening’ included growing or cultivating any kind of plants (such as vegetables, fruits, trees, shrubs and flowers). Gardening activities included preparing the soil, planting, weeding, watering, harvesting and garden-related cooking and tasting activities. These gardening activities were either integrated into the curriculum, or conducted outside of lesson time (e.g., lunchtime clubs, after school clubs, school-organised trips to community allotments). Gardening activities for school-age children that did not involve schools were not included (e.g., summer holiday clubs or community youth interventions).

**Comparators:** Quantitative studies were only included if groups participating in school gardening activities were compared with control groups or groups participating in alternative activities (such as nutrition education without gardening activities). This criterion was not relevant for qualitative studies.

**Outcomes:** Studies were included if they reported quantitative or qualitative health and well-being outcomes including dietary intake; food-related knowledge, attitudes and preferences; physical, mental or emotional health; quality of life indicators. Qualitative findings also included themes, concepts and metaphors relating to the experience and meaning of school gardens, and any perceived factors that help or hinder their success. Additional outcomes, including adverse or unintended outcomes, were only considered where they were reported alongside health and well-being outcomes.

**Study design:** Suitable quantitative study designs included randomised controlled trials (RCT), non-randomised controlled trials, and other ‘controlled before and after’ studies. Suitable qualitative study designs included any recognised methods of data collection and analysis from any discipline or theoretical tradition. The types of data collection methods included (but were not limited to): focus groups, individual interviews, participant or systematic observation, documentary analysis, audio/visual/note collection. Methods of analysis included (but were not limited to): grounded theory, narrative analysis, thematic analysis, phenomenological analysis, discourse analysis.

**Selection process**
References identified through the search strategy were uploaded into ENDNOTE (X7, Thomson Reuters). References (titles/abstracts) were independently double screened using the eligibility criteria (by reviewers HO/RW/SG). Studies appearing to meet the criteria were obtained as full text articles. Full texts were independently double screened using the same criteria (by reviewers HO/RW/SG/RG). Any disagreements were resolved through discussion with the whole team.

During full text screening, additional inclusion criteria were developed as an iterative process. For example, studies in which school gardening was one of multiple components in a ‘whole school approach’ intervention (in combination with farm visits, school food policy development, school meals and catering reforms, nutrition education or cookery programmes) were not included if the reported outcomes were not specifically attributable to school gardening. Some qualitative studies did report health and well-being impacts attributable to school gardening (i.e., distinct from other components) and these studies were included. Studies that did not report sufficient information about data collection and/or analysis methods to enable critical appraisal were excluded (such as conference abstracts for which the full text was not available).

**Data extraction**
Standardised, piloted data extraction sheets were developed for the review to ensure consistency between studies and between reviewers. The data extracted for each study included, where possible: study design, sample characteristics, description of school gardening activities (intervention group), description of alternative activities (comparison group), duration of intervention, data collection methods, analysis methods and duration of follow up. For quantitative studies, health and well-being outcomes (and other secondary outcomes) were extracted. For qualitative studies, findings in the form of participants’ quotes and author themes and concepts were extracted. Data were extracted by one reviewer (HO) and independently double checked (by reviewers RW/SG/RG). Any disagreements were resolved through discussion with the whole team.

**Quality appraisal**
The quality of included quantitative studies was appraised using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies. Each study was rated strong, moderate or weak for the following components: selection bias, study design, confounders, blinding, data collection, withdrawals and drop outs. A ‘global’ or overall rating was then allocated using the standard system: strong (no weak ratings), moderate (one weak rating), or weak (two or more weak ratings).

The quality of included qualitative studies was appraised using criteria suggested by Wallace et al. [18]. In addition to the standard ratings of yes, no, can’t tell, we used ‘partial’ in some cases, for example studies in which some ethical
issues were addressed and others were not (Wallace criterion 12). We also generated overall quality ratings using our own system: strong (11–12 ratings of yes); moderate (6–10 ratings of yes); weak (1–5 ratings of yes).

Studies were appraised by one reviewer (HO) and independently double checked (by reviewers RW/SG/RG). Any disagreements were resolved through discussion with the whole team.

Data synthesis
It was not possible to meta-analyse any of the quantitative data we extracted due to study design and data limitations (further information provided in Tables). Authors were contacted to clarify some study details (such as precise methods of dietary assessment) before this decision was confirmed. Data from quantitative studies were therefore tabulated, grouped by similar outcomes and the effectiveness of the school gardens in influencing health and well-being outcomes was described narratively.

The qualitative data were synthesised thematically in order to understand the perceived well-being and wider impacts of gardens, as well as factors influencing success and sustainability, in order to make practical recommendations for interventions [14, 19]. Narrative synthesis has three overlapping stages: 1) coding of the findings of primary qualitative studies; 2) organising codes into descriptive themes and concepts; 3) generating analytical themes – this final stage goes beyond the interpretations of the original studies and aims to generate new understandings or hypotheses in relation to the review questions [14]. Initially, all study findings were coded, including those that did not relate directly to health and well-being impacts. Where multiple publications reported findings from the same qualitative study, we were careful not to ‘double count’ findings. Therefore, where multiple publications by the same team of authors reported similar themes, only one publication has been referenced for each theme (the oldest one). In stages 1 and 2, we used an inductive approach to code the data (line by line) and identify common themes and categories of themes between studies. This was done manually rather than using software, using the principles of constant comparison and reciprocal translation [20]. Care was taken to recognise divergent data and to interpret the raw data (where presented) rather than uncritically accept the authors’ interpretations. In stage 3, we developed a conceptual model to summarise and illustrate proposed mechanisms for the health and well-being impacts of school gardening. The qualitative synthesis was completed by two reviewers (HO/SG) in discussion with the rest of the team. Throughout the synthesis, we considered study quality, context and transferability as we developed our conceptual model.

Results
Search results
Electronic searches identified a total of 3442 records after the removal of duplicates. Title and abstract screening resulted in the exclusion of 3279 records that did not meet the inclusion criteria. 124 of the remaining potentially relevant articles were obtained in full text format (whilst 39 were unobtainable) and another 22 eligible articles were found by citation and manual searching. Full text screening resulted in the exclusion of 106 articles (Fig. 1). A total of 40 articles (hereafter referred to as studies) were eligible for inclusion.

Study characteristics
The 40 included studies were from the UK, Portugal, USA and Australia. Twenty four studies (including three that were mixed methods studies) reported quantitative methods and findings (Table 2). There was some duplication where multiple publications reported findings from the same trials, which were: five cluster randomised controlled trials (RCT) [9, 10, 21–23] and 13 non-randomised controlled trials [15–17, 24–39] (Table 2). Nineteen studies (including three that were mixed methods studies) reported qualitative methods and findings using a variety of study designs which met our inclusion criteria [11–13, 24–26, 40–52] (Table 3). Again there was some duplication where multiple publications reported findings from the same sample (Table 3).

Only two school gardening interventions, the RHS Campaign for School Gardening and the Stephanie Alexander Kitchen Program, generated quantitative and qualitative evidence for the same intervention (Tables 2, 3 and 4) [9, 10, 24–26, 50]. The studies were conducted in pre-schools [21, 31, 49], primary schools [9, 10, 12, 15, 24–26, 30, 43–45, 47, 48, 50–52], elementary schools [13, 16, 17, 23, 27–29, 31, 32, 35–37, 39, 41, 46], upper elementary schools [33, 34], middle schools [38, 40, 46], junior high schools [17], high schools [11, 42, 46] and secondary schools [12, 44, 52] (Tables 2 and 3). The school gardening interventions included a variety of components and characteristics (Table 4). For example, some were purely gardening interventions [9–13, 17, 21, 27, 31, 39–42, 44, 46, 49–51], whereas others incorporated cooking and/or nutrition education alongside the gardening activities [15, 16, 22–26, 28–30, 32–38, 43, 45, 47, 48, 52].

Duplication and differences in reporting
Where multiple publications duplicated findings from the same trials, we have been very careful to present and synthesise the findings of these studies without duplication; for example elements of Morgan’s findings were republished by Jaenke [15, 30]). To confuse matters, differences were found in the reporting of the same outcomes between different studies. For example, Jaenke and
Morgan both reported data from a school garden-based nutrition education program in Australia \((n = 127)\) but they reported slightly different findings in the control group for fruit and vegetable intake [15, 30]. Neither of these reported findings were statistically significant and we have presented the most recent findings [15] (Table 7). Another case of duplication and differences in reporting was in the evaluation of the pilot of the Stephanie Alexander Kitchen Garden Program in Australia [25, 26]. Both studies reported children’s willingness to try new foods, but with slightly different sample sizes \((n = 770/n = 764)\) and therefore slightly different findings. We have presented the findings from the original study which also reported the largest sample size [25] (Table 9). As illustrated, in cases such as these, the data from the study reporting the largest sample size (or, if the sample sizes were equal, the most recent study) were presented in our review tables.

**Quality appraisal of included studies**

Where multiple studies reported quantitative data from the same trial (quantitative) or the same sample (qualitative), they were appraised collectively (Tables 5 and 6). Most of the quantitative studies were rated as weak, with six studies rated as moderate [10, 15, 23, 28–30] (Table 5). Quality criteria that were commonly rated weak (in more than half the studies) using the EPHPP system were selection bias,
| First author (year) | Publication type | Study design | Country | Type of schools | Sample size (baseline) | Sample characteristics | Intervention group (duration) | Comparison or control group | Outcomes (health and well-being only) |
|---------------------|------------------|--------------|---------|----------------|-----------------------|------------------------|-----------------------------|-------------------------------|----------------------------------|
| Block (2012)[24]    | Journal paper    | Non-randomised controlled | Australia | Primary | 764 children (reported as 770 in Block et al. 2009) 562 parents | 8–12 years 54 % girls | Stephanie Alexander Kitchen Garden Program (45–60 min in garden class & 90 min in kitchen class/week for 12+ mnths) | No intervention (but Gibbs et al. reported that some children were exposed to some gardening and cooking activities) | Child quality of life |
| Block (2009)[25]    | Report           |              |         |              |                       |                        |                             |                               | Willingness to try new foods |
| Gibbs (2013)[26]    | Journal paper    |              |         |              |                       |                        |                             |                               | Willingness to try new foods |
| Brouwer (2013)[27]  | Journal paper    | Cluster RCT  | USA     | Pre-school   | 12 children           | 3–5 years             | Watch Me Grow (weekly activities for four months) | No intervention (delayed) | Vegetable intake, Fruit intake, Food group and essential nutrient intakes |
| Christian (2014) (1)[28] | Journal paper: Trial 1 | Cluster RCT  | UK      | Primary     | 1138 children (reported as 1256 in the journal paper) | For two groups respectively: Mean 8.2/8.1 year 50/51 % boys 30/35 % White British (diverse) | Royal Horticultural Society (RHS) led gardening activities (18 months with regular support visits and termly teacher training sessions from RHS) | Teacher led gardening activities (18 months with termly teacher training sessions from RHS) | Vegetable intake, Fruit intake, Food group and essential nutrient intakes, As above plus: FV knowledge, Attitudes towards FV |
| Christian (2014) (2)[9] | Report: Trial 1 | Cluster RCT | UK      | Primary     | 1391 children | For two groups respectively: Mean 8.3/8.2 years 52/48 % boys 23/17 % White British (diverse) | Teacher led gardening activities (15 months with termly teacher training sessions from RHS) | No intervention | Vegetable intake, Fruit intake, Food group and essential nutrient intakes, FV knowledge, Attitudes towards FV |
| Cotter (2013)[22]   | Journal paper    | Cluster RCT  | Portugal | NR           | 155                  | 10–12 years           | Aromas school gardening club (2 h/week for 6 months) plus regular lectures on the dangers of high salt intake | Regular lectures on the dangers of high salt intake | Body Mass Index (BMI), Waist circumference, Blood pressure (SBP/DBP), Urinary sodium, Urinary creatinine, Estimated salt intake |
| Wells (2014)[23]    | Journal paper    | Cluster RCT  | USA     | Elementary  | 285                  | 8–12 years           | Healthy Gardens, Healthy Youth pilot program: gardening activities plus curriculum of 20 lessons (1 year) | No intervention (control group received gardens at the end of the study) | Physical activity |
| Study | Year | Journal Type | Country | Study Type | Age/Gender | Intervention Details | Control Group | Outcome Measures | Additional Details |
|-------|------|--------------|---------|------------|------------|----------------------|---------------|-----------------|-------------------|
| Cotugna (2012) [27] | 2012 | Journal paper | USA | Elementary | 359 | Age or gender not reported; For A/B/C respectively: 73/41/37 % White 37/34/38 % low income | Gardening education program (duration unknown) first time in School B and second time in School C | No intervention | Students who chose salad for lunch |
| Davis (2011) [28] | 2011 | Journal paper | USA | Elementary | 107 (reported as 104 in Davis et al. 2011) | 9–11 years 59 % overweight or obese For two groups respectively: Mean 9.7/9.9 years 38/59 % boys 97/93 % Latino | LA Sprouts: cooking and nutrition lessons plus gardening activities (90 min per week for 12 weeks) | No intervention | Body Mass Index (BMI) Waist circumference Total body fat Blood pressure (SBP/DBP) Vegetable intake Fruit intake Food group and macronutrient intakes |
| Gatto (2012) [29] | 2012 | Journal paper | Australia | Primary | 127 | Fifth and sixth grade students 11–12 years 54 % boys | Nutrition education: How do you grow? (3 h over 10 weeks) plus gardening: How does your garden grow? (180 min per week for 10 weeks) | Nutrition education only: How do you grow? (3 h over 10 weeks) No intervention | Willingness to taste vegetables Taste ratings of vegetables Fruit intake Vegetable intake |
| Jaenke (2012) [15] | 2012 | Journal paper | Australia | Primary | 127 | | Nutrition education: How do you grow? (3 h over 10 weeks) + gardening | Nutrition education only: How do you grow? (3 h over 10 weeks) No intervention | Willingness to taste vegetables Taste ratings of vegetables Fruit intake Vegetable intake Ability to identify vegetables Willingness to taste vegetables Taste ratings of vegetables FV knowledge Quality of school life |
| Morgan (2010) [30] | 2010 | Journal paper | USA | Elementary | 122 | 10–13 years Mean 11.1 years 44 % boys | Nutrition education: Nutrition in the garden, plus gardening (12 weeks) | Nutrition education only: Nutrition in the garden (12 weeks) No intervention | Fruit intake Vegetable intake Vitamin A intake Vitamin C intake Fibre intake |
| McAleese (2007) [16] | 2007 | Journal paper | USA | Elementary | 122 | 10–13 years Mean 11.1 years 44 % boys | Nutrition education: Nutrition in the garden, plus gardening (12 weeks) | Nutrition education only: Nutrition in the garden (12 weeks) No intervention | Fruit intake Vegetable intake Vitamin A intake Vitamin C intake Fibre intake |
| Meinen (2012) [31] | 2012 | Journal paper | USA | Elementary schools and early childhood sites | 404 youth 567 parents | 7–13 years 54 % boys For two groups respectively: Mean 9.9/10.1 years Majority/88 % White | Youth gardening program: Got Dirt? (4 months) | No intervention | Willingness to try new FV Like/dislike of FV Knowledge of FV FV consumption |
| Study | Design | Location | Grade | Sample Size | Intervention Details | Control Group | Outcome Measures |
|-------|--------|----------|-------|-------------|----------------------|--------------|------------------|
| Morris (2001) [32] | Journal paper | USA | Elementary | 97 | First grade students | Nutrition education plus gardening (8 months) | No intervention | Nutrition knowledge, Willingness to taste vegetables, Taste ratings of vegetables |
| Morris (2002) (1) [33] | Journal paper | USA | Upper elementary | 215 (reported as 213 in journal paper) | 9-10 years, 84% African American, 3% Asian American, 3% Hispanic, 66% White | In-class nutrition education including hands-on gardening activities (9 lessons over 17 weeks) | No intervention | Nutrition knowledge, Vegetable preference |
| Morris (2002) (2) | Report | USA | Elementary | 38 | 9-10 years, 50% boys, 71% White | In-class nutrition education only (9 lessons over 17 weeks) | No intervention | Nutrition knowledge, FV preference, FV consumption, FV consumption expectations |
| O’Brien (2006) [35] | Journal paper | USA | Elementary | 38 | 9-10 years, 50% boys, 71% White | After school gardening club (8 lessons with 30 min gardening over 10 weeks) | No intervention | Nutrition knowledge, FV preference, FV consumption, FV consumption expectations |
| Parmer (2009) [37] | Journal paper | USA | Elementary | 115 | 70% boys, 46/27/28% girls | Nutrition education plus gardening (1 h alternating nutrition education and gardening for 28 weeks) | No intervention | Nutrition knowledge, FV preferences, FV consumption |
| Parmer (2007) [36] | Dissertation | USA | Elementary | 115 | 70% boys, 46/27/28% girls | Nutrition education plus gardening (1 h alternating nutrition education and gardening for 28 weeks) | No intervention | Nutrition knowledge, FV preferences, FV consumption |
| Ratcliffe (2011) [38] | Journal paper | USA | Middle | 320 | 11-13 years, 22% African American, 29% Asian American, 3% Pacific Islander, 7% White or other | Garden-based learning activities integrated into science class (20 min instruction and 40 min hands-on gardening per week for 4 months) | Covered the same health and science objectives but did not include a gardening program | Vegetable knowledge, Vegetables preferences, Willingness to taste, Vegetable consumption |
| Robinson (2005) [39] | Journal paper | USA | Elementary | 281 | Third, fourth and fifth grade students (no further info) | School gardening curriculum: Texas Agricultural Extension Service (varied intensity over one school year) | No intervention (until after study period) | Life skills: working with groups; self-understanding; leadership; decision making; communication; volunteerism |
| Waliczek (2001) [17] | Journal paper | USA | Elementary and junior high | 589 | 8-15 years, 43% boys at post-test | Project GREEN school garden program (Spring semester) | No intervention | Interpersonal relationships |

*Also included for qualitative findings (see Table 3): FV fruits and vegetables, SBP systolic blood pressure, DBP diastolic blood pressure*
| First author (year) | Country | Sample characteristics | Aims | Sampling methods | Intervention | Data collection methods | Analysis methods |
|---------------------|---------|------------------------|------|-----------------|--------------|------------------------|-----------------|
| Ahmed (2011) [40]   | USA     | Administrators (n = 2), teachers (n = 4) and garden staff (n = 3) at one rural middle school; school population 50% Native Hawaiian; low socio-economic status | To examine perceptions of educators about the effects of school-based gardens on children’s health and obesity | Snowball sampling starting with the school principle and garden leader | School garden program founded to prevent nutrition-related illness (with community involvement) | Semi structured interviews (4 years after garden established) | Grounded Theory approach using descriptive, open coding; list of themes used to develop a conceptual model |
| Alexander (1995) [41] | USA     | Students (n = 52), teachers (n = 5), parents (n = 3), principal and Master Gardener at one inner city elementary school; students 70% Hispanic; many from single parent homes | To identify the effects on school children participating in classroom gardens | NR | Master Gardeners' Classroom Garden Project | Interviews (individual and group) and observation | Constant comparative method; multiple sources of data evaluated for emerging themes |
| Anderson (2011) [42] | USA     | Students (n = 14) at one rural high school | To determine the impact of hydroponically grown vegetables on obesity indices | Purposely selected students twice during the two-year project | Hydroponic gardening system | Focus groups (n = 7 at each time point i.e. twice during the two-year project) |
| Block (2012) [24]   | Australia | Six program schools and six comparison schools; all primary At program schools only: classroom teachers (n = 26); volunteers (n = 17), other parents (n = 20), children (n = 124), kitchen and garden specialist staff (n = 10) | To explore participants’ expectations and experiences of the program, changes in the school and home environment, highlights and areas for potential improvement | Convenience sampling (all adults invited to participate) and purposive sampling (teachers selected children with range of ages and program experience) | Stephanie Alexander Kitchen Garden Program | Focus groups, individual interviews, participant observation, field notes and researcher reflections (at various time points before, during and after the program) Inductive thematic content analysis to identify emerging themes and patterns, which were then further analysed according to their relationship with the existing evidence base and theoretical perspectives |
| Block (2009) [25]   | Australia | At all participating program and comparison schools: school principals (n = 12) | To evaluate the achievement of the program in increasing child appreciation of diverse, healthy food | | | |
| Gibbs (2013) [26]   | Australia | At all participating program and comparison schools: school principals (n = 12) | To explore motivations for and impacts of volunteering with the gardening program | | | |
| Townsend (2014) [43] | Australia | At all participating program and comparison schools: school principals (n = 12) | To explore motivations for and impacts of volunteering with the gardening program | | | |
| Bowker (2007) [44]   | UK      | Two classes from one primary school and one secondary school; 7–14 years | To gain an understanding of what the children themselves think about school gardening | Quota sampling to identify two schools; within each school a class unit was selected to further refine the sample; 12 children in each class were randomly selected for interviews | Gardens for Life (to support and extend learning in other curriculum areas) | Concept maps (n = 72) supported by contextual observation, semi-structured interviews (n = 24) (after 6 months) and children’s drawings Interpretative approach - broad concepts were identified and organised into categories; concept grids and depth scores used to look for patterns |
| Chawla (2014) [11]   | USA     | Students (n = 52), teachers and school principals from four high schools | Research questions: How do students experience natural | Purposive sampling to span the high school age range | Four different gardening programs at four high schools: | Ethnographic observations recorded through field notes,
Table 3 Summary of included qualitative studies (n = 16) (Continued)

| Study | Country | Participants | Settings | Research Design | Data Collection | Analysis |
|-------|---------|--------------|----------|----------------|----------------|---------|
| Chiumento (2012) | UK | Students (n = 36) with signs of Behavioural, Emotional & Social Difficulties (BESD) from two primary and one secondary schools; 10–15 years; 61 % boys; mix of nationalities and ethnicities including children seeking asylum; deprived ward in Liverpool | NR | Students were referred by schools, providing pen profiles of current difficulties including potential behavioural risk factors | Haven of Greenspace (social and therapeutic horticulture); pupil led sessions using NFER five ways to well-being framework (monthly for 6 months) | Draw and write journals (children); closing semi-structured interviews (link teachers); reflective process diary by group therapists | Thematic analysis of interview transcripts; random selection of journals analysed with quality checks |
| Cutter-Macenzie (2009) | Australia | Students (n = 7) from one city primary school; 6–12 years; all students participating in program (n = 70) had English as a second language and some were recent migrants | NR | To assess the impact of the program against its objectives which included helping to develop strong local communities and school communities; and fostering healthy eating habits | Multicultural school gardens program created to enable disadvantaged schools to establish a culturally focused gardening program (2 years) | Children as researchers including journals, photographs and peer interviews (n = 10); researcher’s field visits, observations and interviews with children and teachers (after 3 months) | Interviews with key members Constant comparative analysis; results used to create best practice models for schools in California and across the United States |
| Hazzard (2011) | USA | Administrators, teachers, parent and community volunteers and garden coordinators (n = 7) from 10 schools (elementary, middle and high schools) | NR | To ascertain and report best practices for schools implementing or sustaining instructional school gardens | California Instructional School Garden Program (CISGP) | Interviews with key members Constant comparative analysis; results used to create best practice models for schools in California and across the United States |
| Henryks (2011) | Australia | Parents of children enrolled at the school (n = 5) and another member of the wider community (n = 1) at one primary school | NR | Purposive sampling by email invitation to volunteers | Stephanie Alexander Kitchen Garden Program | In-depth interviews Thematic analysis used to build a conceptual map of the experiences of the school kitchen garden volunteers, including the motivations, benefits and challenges that volunteers experienced; combination of inductive and deductive approaches |
| Study | Country | Participants | Setting | Methods | Findings |
|-------|---------|--------------|---------|---------|----------|
| Lakin (2008) | UK | Head teacher, a governor, a teacher and groups of children in Year 3 (n = 5) and Year 6 (n = 5) at one semi-rural primary school; 7–11 years | NR | School B selected to represent example of good practice; children selected by the head teacher for their involvement in the innovations | Health Promoting Schools: Gloucestershire Food Strategy |
| Miller (2007) | USA | Teachers (n = 19) and children (n = ?) from one early education setting: Dimensions Educational Research Foundation; 3–6 years | To examine the skills young children are developing when they are engaged in developmentally appropriate activities in the greenhouse and garden | Dimensions outdoor classroom including garden and greenhouse areas (two small group activities a month) |
| Ming Wei (2012) | USA | Students (n = 20), teachers (n = 9), school principal, school counsellor, student services coordinator and parents/caregivers (n = 4) from one rural elementary school; students 55% girls; from low to middle income families; native culture | To better understand the experience of student learning in the context of school garden-based education and to determine the relevance of school gardens as a site for learning making | The Discovery Garden: using an interdisciplinary standards-based school garden curriculum |
| Passy (2010) | UK | Two samples (two stages) from 10 primary schools e.g. stage 1: senior leaders (n = 11), garden leads (n = 10), other members of teaching staff (n = 10), teaching assistants (n = 2), parent governors (n = 2), other parents (n = 2) and pupils (n = 43) | To assess the impact that using a school garden had on primary pupils' learning, behaviour and health and wellbeing | Stratified random sampling from list of participating schools; weighted towards those with higher levels of benchmark achievement | Campaign for School Gardening (Royal Horticultural Society) |
| Somerset (2005) | Australia | Teachers responsible for vegetable gardens at 12 primary schools | To investigate the nature and extent of the use of school gardens in a defined region of eastern Australia | All schools with vegetable gardens (outdoor or greenhouse) as identified by telephone survey | Schools with vegetable gardens (no one intervention) |

*Table 3: Summary of included qualitative studies (n = 16) (Continued)*
control for confounders, and follow-up rate (withdrawals and drop-outs) (Fig. 2). While five qualitative studies were rated as strong, most of the qualitative studies were rated as weak or moderate quality [11, 24–26, 43] (Table 6). This reflects the often unclear reporting about some aspects of quality in qualitative studies, such as theoretical perspective, adequacy of sample and selection methods, data collection methods, analysis methods, consideration of limitations and of ethical issues.

Quantitative evidence for the health and well-being impacts of school gardening

Fruit and vegetable intakes
Thirteen studies reported children’s fruit and vegetable intakes [9, 10, 15, 16, 21, 26–28, 30, 31, 36–38] (Table 7). Only two studies reported statistically significant increases effects [16, 38]. Both used outcomes based on children’s self-report, and were non-randomised studies that were rated weak in the quality appraisal.

Nutrient intakes (and other dietary outcomes)
Six studies reported children’s nutrient intakes or other dietary outcomes [9, 10, 16, 22, 26, 28] (Table 8). Four studies reported statistically significant changes in nutrient intake [9, 10, 16, 28]. However, in two studies there was only one statistically significant finding from the multiple nutrient indicators measured, [9, 28] one of which related to a decrease in dietary fibre in the control group, rather than improvements in the intervention group [28]. The other study showed more convincing positive effects for three nutrient indicators, but data were based on children’s self-report and was selectively reported for three nutrients only [16].

Food preferences
Thirteen studies reported children’s food preferences, including willingness to taste and taste ratings for fruits and vegetables [15, 25, 26, 29–38] (Table 9). Eight of the studies reported statistically significant intervention effects showing increased preference for fruits and vegetables [15, 30, 32–34, 36–38]. However, these are subjective measures which are highly susceptible to social desirability bias, especially in children who may be eager to please after learning about healthy foods and growing vegetables during school gardening time. We consider food preferences as an early step on the pathway towards behaviour change, but not indicative of behaviour change in itself.

Knowledge and attitudes towards food
Ten studies reported children’s knowledge and attitudes towards food [10, 30–38] (Table 10). Seven of the studies reported statistically significant intervention effects [10, 30, 33, 34, 36–38]. For the most part these were positive effects, showing improved knowledge or attitudes towards food in the intervention groups. Interestingly, one cluster RCT (Trial 1) in the UK found that students who participated in expert-led gardening activities (intervention group) for 18 months were less likely to have positive attitudes towards fruits and vegetables, compared with students who participated in teacher-led gardening activities (comparison group), suggesting that teacher-led activities might be more effective [10]. However, this study had mixed results with other outcome measures showing no statistical difference between teacher and expert-led gardening. As stated above for children’s food preferences, these measures of knowledge and attitudes are susceptible to social desirability bias and reflect possible behaviour change mechanisms rather than actual behaviour change.

Physical health and activity
Two studies reported physical health measures, both including waist circumference, body mass index (BMI), and systolic and diastolic blood pressure [22, 28] (Table 11). The only statistically significant difference was reported in a non-randomised controlled study for diastolic blood pressure, which lowered more in the intervention group (cooking, nutrition and gardening) compared to the control group [28]. However, all of the blood pressure readings in this study were within the normal range for school children (systolic: 85–120; diastolic: 50–80) so this finding may not be clinically relevant as an improvement in physical health. Another
| First author (year) | Name of school gardening intervention | Gardening component | Cooking as key component | Nutrition education component | Integrated with wider curriculum | Produce used in school catering | Outdoors some or all of the time | Delivered by specialists | Delivered by teachers | Teachers trained by specialists | Community involvement | Theory-led intervention |
|---------------------|---------------------------------------|---------------------|--------------------------|-------------------------------|--------------------------------|-------------------------------|-------------------------------|-------------------------|------------------------|-------------------------------|----------------------|------------------------|
| Ahmed (2011) [40]   | No name (school garden program founded to prevent nutrition-related illness) | ✓                   | ✓                        |                               |                               |                               |                               |                         |                       |                               |                      |                        |
| Alexander (1995) [41] | Master Gardeners’ Classroom Garden Project | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      |                               |                      |                        |
| Anderson (2011)     | Hydroponic gardening system            | ✓                   | ✓                        |                               |                               |                               |                               |                         | ✓                      |                               |                      |                        |
| Block (2012) [24]   | Stephanie Alexander Kitchen Garden Program | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Block (2009) [25]   |                                      | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Gibbs (2013) [26]   |                                      | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Henryks (2011) [47] |                                      | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Townsend (2014) [43]|                                      | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Bowker (2007) [44]  | Gardens for Life                      | ✓                   | ✓                        |                               |                               |                               |                               |                         |                       |                               |                      |                        |
| Brouwer (2013) [21] | Watch Me Grow                         | ✓                   | ✓                        |                               |                               |                               |                               |                         |                       |                               |                      |                        |
| Chawla (2014) [11]  | No name (four different gardening programs at four high schools) | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Chiumento (2012) [12]| Haven of Greenspace (social and therapeutic horticulture) | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Christian (2014) [1],[9] Christian (2014) [2][10] | Royal Horticultural Society (RHS) Campaign for School Gardening | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Passy (2010) [50]   |                                      | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Cotter (2013) [22]  | Aromas school gardening club          | ✓                   | ✓                        |                               |                               |                               |                               |                         |                       |                               |                      |                        |
| Cotugna (2012) [27] | Gardening education program           | ✓                   | ✓                        |                               |                               |                               |                               |                         |                       |                               |                      |                        |
| Cutter-Macenzie (2009) [45] | Multicultural School Gardens Program | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Davis (2011) [28]   | LA Sprouts                             | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Gatto (2012) [29]   |                                      | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Hazzard (2011) [46] | California Instructional School Garden Program | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Jaenke (2012) [15]  | How do you grow? How does your garden grow? | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Morgan (2010) [30]  |                                      | ✓                   | ✓                        |                               |                               |                               |                               | ✓                       | ✓                      | ✓                             |                      |                        |
| Study Reference | Intervention Description                                                                 | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
|-----------------|------------------------------------------------------------------------------------------|----|----|----|----|----|----|----|----|----|----|
| Lakin (2008)    | Health Promoting Schools: Gloucestershire Food Strategy                                   | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| McAleese (2007) | Nutrition in the garden                                                                   | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Meinen (2012)   | Youth gardening program: Got Dirt?                                                        | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Miller (2007)   | Dimensions outdoor classroom including garden and greenhouse areas                        | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Ming Wei (2012) | The Discovery Garden                                                                      | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Morris (2001)   | No name (nutrition education plus gardening)                                              | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Morris (2002)   | No name (nutrition education plus gardening)                                              | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| O’Brien (2006)  | No name (based on Junior Master Gardener)                                                 | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Parmer (2009)   | No name (based on Pyramid Café/Health and Nutrition from the Garden)                     | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Parmer (2007)   | No name (based on Pyramid Café/Health and Nutrition from the Garden)                     | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Ratcliffe (2011)| No name (garden-based learning activities)                                                | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Robinson (2005) | No name (school gardening curriculum)                                                     | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Somerset (2005)| No name (schools with vegetable gardens)                                                   | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Viola (2006)    | Outreach School Garden Project                                                            | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Waliczek (2001)| Project GREEN school garden program                                                       | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |
| Wells (2014)    | Healthy Gardens, Healthy Youth                                                            | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  | ✓  |

Note: some studies did not report sufficient details about the intervention, so no tick may mean not applicable or not reported.
cluster RCT (elementary school based) reported physical activity measures derived from both a questionnaire and accelerometer [23] (Table 11). While children who participated in school gardening (intervention group) reported being ‘usually’ less sedentary ($p = 0.001$) and spent more time engaged in ‘moderate’ physical activity ($p = 0.010$) compared to the control group, there was no increase in ‘light’ physical activity or reduction in sedentary behaviour when measured objectively using accelerometers. Note however that the accelerometer analysis was based on a selected subsample of students.

**Well-being**

Four studies reported children’s well-being using a variety of measures, only some of which used valid and reliable scales, including quality of life, life skills and interpersonal relationships [17, 24, 30, 39] (Table 12). Two of the four studies did not find a significant difference between intervention and control groups using their selected measures at follow up [24, 30]. The other two studies did not report their child wellbeing outcomes adequately [17, 39]. Overall, quantitative evidence for the impacts of school gardens is limited with some suggestion of improvements in knowledge, attitudes and preferences towards fruit and vegetables, but little objective evidence of changes in eating habits or physical health benefits.

**Qualitative evidence for the health and well-being impacts of school gardening**

Qualitative evidence was synthesised narratively and is described below in relation to the health, wellbeing and educational impacts described by children, teachers and parents, and those factors thought to be associated with the success and sustainability of school gardens. Tables 13 and 14 show the subthemes which make up each of these broad themes and which studies contributed to each.

**Health impacts**

Most studies described perceived nutritional benefits for children involved in school gardening, including greater knowledge and awareness, improved attitudes towards food such as willingness to try new foods, and healthier eating habits [13, 25, 40, 44, 45, 47–52] (Table 13).
When I grow them [vegetables] I feel like I should always try it. And when I’ve grown them I like them better than the shop ones. – Child, primary school [50].

This quote illustrates how participation in school gardening created a sense of connection to the food grown, which encouraged children to be more adventurous and led to increased preference for vegetables. Staff and volunteers observed these changes in children’s attitudes and behaviour and some, like this administrator, became optimistic about the potential of school gardens to generate major shifts in food culture in the long term.

We’ve got to start with these kids now, so that when they become the grandparents, they’re modelling correctly for the kids. We’re probably not going to change the values of today’s elderly and today’s parents, but if we begin with the kids we’re going to have a chance over time to change the health and wellness of the population. – Administrator [40]

These kinds of aspirations may be idealistic, but they contributed to enthusiasm and motivation to support the school gardens, the importance of which will be explored later in this review. The quote also illustrates the perception expressed in three studies [40, 50, 51] that starting at an “early” age (not defined) could be an important factor in the success of school gardening interventions for encouraging the development of a healthy lifestyle.

Other studies described school gardening as an opportunity for physical activity for both children and adults [13, 40, 50–52]. Primary school teachers appreciated the

Table 6 Quality appraisal of included qualitative studies (n = 16)

| First author (year) | Wallace criteria | Total # Yes ratings | Overall rating |
|---------------------|------------------|---------------------|----------------|
| Ahmed (2011) [40]   | Y N CT Y Y N Y Y Y Y Y Y Y  | 10               | Moderate       |
| Alexander (1995) [41] | Y Y N P Y Y Y N N CT  | 8               | Moderate       |
| Anderson (2011) [42] | Y Y CT Y Y CT P P N N P P  | 5               | Weak           |
| Block (2012) [24]  | Y Y Y Y P Y Y Y Y NA Y    | 11              | Strong         |
| Block (2009) [25]  | Y Y Y Y P Y Y Y Y NA Y    | 11              | Strong         |
| Gibbs (2013) [26]  | Y Y Y Y P Y Y Y Y NA Y    | 11              | Strong         |
| Townsend (2014) [43] | Y Y Y Y Y P Y Y Y Y P  | 10              | Moderate       |
| Bowker (2007) [44] | Y Y Y Y Y P Y Y Y Y Y P  | 10              | Moderate       |
| Chawla (2014) [41] | Y Y Y Y P Y Y Y Y P Y Y  | 11              | Strong         |
| Chiumento (2012) [12] | Y P CT Y Y P P P Y Y N NA P  | 5               | Weak           |
| Cutter-Mackenzie (2009) [45] | Y N CT Y Y P Y P P N Y Y Y P  | 7               | Moderate       |
| Hazzard (2011) [46] | Y N CT Y P P P Y P N N P  | 3               | Weak           |
| Henryks (2011) [47] | Y Y Y Y Y N Y P Y Y P NA P  | 8               | Moderate       |
| Lakin (2008) [48]  | Y N CT Y Y Y Y CT N P N Y N  | 5               | Weak           |
| Miller (2007) [49] | Y N CT Y Y CT Y Y P P N N N  | 5               | Weak           |
| Ming Wei (2012) [13] | Y Y CT Y Y P Y Y Y Y NA Y  | 10              | Moderate       |
| Passy (2010) [50]  | Y N CT Y Y Y Y CT N Y N Y P  | 7               | Moderate       |
| Somerset (2005) [51] | Y N CT Y N CT N P P Y N N CT  | 3               | Weak           |
| Viola (2006) [52]  | Y Y Y Y Y Y P P P Y Y Y  | 9               | Moderate       |

Where multiple publications reported qualitative data from the same study, they were appraised as one study

Y yes, P partial, N no, CT can’t tell, NA not applicable
Overall quality rating: strong (11–12 ratings Y); moderate (6–10 ratings Y); weak (1–5 ratings Y)
Legend for Table 6: Wallace criteria (Wallace et al. [18])
1. Is the research question clear?
2. Is the theoretical or ideological perspective of the author (or funder) explicit?
2b. Has this influenced the study design, methods or research findings?
3. Is the study design appropriate to answer the question?
4. Is the context or setting adequately described?
5. Is the sample adequate to explore the range of subjects and settings, and has it been drawn from an appropriate population?
6. Was the data collection adequately described?
7. Was data collection rigorously conducted to ensure confidence in the findings?
8. Was there evidence that the data analysis was rigorously conducted to ensure confidence in the findings?
9. Are the findings substantiated by the data?
10. Has consideration been given to any limitations of the methods or data that may have affected the results?
11. Do any claims to generalisability follow logically and theoretically from the data?
12. Have ethical issues been addressed and confidentiality respected?

The scoring system used above was adapted for the purposes of this review
physical aspect of gardening for certain groups of students in particular: “the boys that you want to keep physically busy” and those “children who cannot concentrate in class” [51]. In a rural Hawaiian elementary school, parents saw it as an opportunity “to teach work ethics, to become physically strong and healthy, and to raise awareness of how other people labour to make our lives better and easier” [13]. School gardens are positioned as part of a social, even moral, education.

Well-being impacts
Most qualitative studies reported well-being impacts of school gardening for children and/or adult participants [11–13, 25, 40, 41, 44, 45, 47–52] (Table 13). We further categorised these into personal and social well-being impacts. The personal well-being impacts included enjoyment and feelings of achievement, satisfaction and pride from nurturing the plants, seeing them grow and eventually harvested the crops [11–13, 25, 40, 41, 44, 45, 47–52].

*It makes me feel good inside, all fresh, good... I enjoy touching the soil, the plants. You can feel them...I feel part of them...Yes, it makes me feel that I can care more about things... Being more gentle, caring more, the plants are like people.* – Student, age 17 [11].

These emotions are visceral and again there is the sense of connection to nature, which is very different to the classroom experience and brings different lessons – based on empathy and care – to the children in terms of how they interact with people.

Most studies described how children gained confidence and self-esteem through school gardening [11–13, 25, 41, 44, 47–52]. Developing and maintaining the gardens gave children the opportunity to demonstrate ownership and responsibility [12, 13, 24, 40, 48–50], which may have contributed to these feelings of confidence.

*A child who struggled and had learning disabilities ... and just her confidence and her ability to outshine other kids, who have strengths in other areas was just amazing and she was just really comfortable, in her element. She knew exactly what she was doing, she was in control, she was starring while she was organising the other kids. The building of confidence was just amazing.* – Teacher, primary school [25].

This quote echoes those above and suggests particular benefits of mastery and empowerment for children who do not excel in the usual academic setting, such as those with learning or behavioural difficulties. The school gardens allowed them to shine in different ways and to experience success.

In some studies, children and adolescents described school gardens as peaceful places (using words like ‘refuge’ or ‘sanctuary’) where they could slow down and let go of any stresses [11–13, 24, 45]. Students who reported these kinds of benefits included some with mental health disorders like Attention Deficit Hyperactivity Disorder (ADHD) and depression [11], behavioural and emotional difficulties [12] and minority ethnic groups including recent migrants [45]. Teenage gardeners articulated reasons why they found the garden so relaxing [11]. For some, it was about being outdoors and the connection with nature, which gave them a sense of perspective. For others, the contrast of physical work allowed the brain some quiet time for reflection and this enabled them to process stress.

*It’s almost like meditation, like my body is present but my mind just kind of drifts off and goes someplace else, and thinks about things...It’s brainless tasks most of...*
| First author (year) | Sample (n) | Outcome measures | Outcomes | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|---------------------|------------|------------------|----------|-------------------|-----------------|--------------|--------------------------------------------|
|                     |            |                  |          | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) |                                      |                          |
| Brouwer (2013) [21] | n = 12     | Structured dietary assessment method for pre-school children (whilst in care) | V served (servings/day) | 1.42 (0.67) | 1.24 (0.57) | NA | NA | 1.13 (0.31) | 0.75 (0.21) | NR |                                      |                          |
|                     |            |                  | V consumed (servings/day) | 0.90 (0.68) | 1.05 (0.67) | 0.80 (0.38) | 1.23 (0.38) | 0.80 (0.38) | 1.23 (0.38) | 0.80 (0.38) | 1.23 (0.38) |                                      |                          |
|                     |            |                  | F served (servings/day) | 1.55 (0.99) | 0.92 (0.56) | 0.92 (0.56) | 0.92 (0.56) | 0.92 (0.56) | 0.92 (0.56) | 0.92 (0.56) | 0.92 (0.56) |                                      |                          |
|                     |            |                  | F consumed (servings/day) | 1.00 (0.89) | 0.67 (0.22) | 0.67 (0.22) | 0.67 (0.22) | 0.67 (0.22) | 0.67 (0.22) | 0.67 (0.22) | 0.67 (0.22) |                                      |                          |
|                     |            |                  | Serving size = one cup FV; half cup dried fruit; FV juices not included (source: USDA MyPlate) | | | | | | | | |                                      |                          |
| Christian (2014) (1) [9] Trial 1; n = 1256 | | CADET (115 items) | F intake (g/day) | 201 (9.3) | 168 (11.8) | 214 (9.5) | 208 (11.5) | NA | NA | 193 (8.2) | 181 (17.1) | MD = −22 (24.3); p = 0.3 |                                      |                          |
|                     |            |                  | V intake (g/day) | 87 (4.4) | 89 (9.0) | 102 (4.3) | 118 (8.6) | 111 (10.2) | 95 (3.8) | 100 (4.7) | 122 (9.9) | MD = −7 (14.2); p = 0.6 |                                      |                          |
|                     |            |                  | FV intake (g/day) | 269 (10.7) | 237 (14.5) | 300 (10.5) | 308 (14.0) | 328 (23.0) | 299 (8.9) | 305 (22.4) | 296 (9.6) | MD = −43 (22.8); p = 0.06 |                                      |                          |
| Christian (2014) (2) [10] Trial 2; n = 1391 | | CADET (115 items) | F intake (g/day) | 206 (7.9) | 219 (17.6) | NA | NA | 193 (8.2) | 181 (17.1) | MD = −22 (24.3); p = 0.3 |                                      |                          |
|                     |            |                  | V intake (g/day) | 95 (3.8) | 111 (10.2) | 100 (4.7) | 122 (9.9) | 111 (10.2) | 100 (4.7) | 122 (9.9) | 111 (10.2) |                                      |                          |
|                     |            |                  | FV intake (g/day) | 299 (8.9) | 328 (23.0) | 305 (22.4) | 305 (22.4) | 305 (22.4) | 305 (22.4) | 305 (22.4) | 305 (22.4) |                                      |                          |
| Cotugna (2012) [27] | n = 359    | Lunchtime observations | Students who chose salad for lunch (%) | 17.4 | 24.0 | 22.2 | 22.1 | NR due to scheduling issues | 20.3 | NR |                                      |                          |
| Davis (2011) [28]   | n = 104    | Block Food Screener (41 items) | F intake (servings/day) | 4.0 (0.7) | 3.9 (0.8) | NA | NA | 4.1 (0.9) | 4.2 (0.8) | p = 0.83 | p = 0.83 | p = 0.08 |                                           |                          |
|                     |            |                  | V intake (servings/day) | 1.6 (1.0) | 1.6 (1.0) | 1.9 (1.3) | 1.3 (1.0) | 1.9 (1.3) | 1.3 (1.0) | p = 0.11 | p = 0.11 |                                        |                          |
| Gibbs (2013) [26]   | n = 764    | Parent questionnaire | F ≥ 2 servings/day (%) | 84.2 | 79.8 | 74.6 | 72.5 | 9.5 | 7.7 | 7.3 | 5.9 | 9.5 | OR = 1.68 (0.90 to 3.14); p = 0.11 | OR = 0.87 (0.54 to 1.42); p = 0.59 |                          |
|                     |            |                  | V ≥ 5 servings/day (%) | 7.7 | 7.3 | 5.9 | 9.5 | 7.7 | 7.3 | 5.9 | 9.5 | OR = 1.68 (0.90 to 3.14); p = 0.11 | OR = 0.87 (0.54 to 1.42); p = 0.59 |                          |
|                     |            |                  | Serving size = one apple or orange, two kiwi or apricots, one cup dried fruit | | | | | | | | |                                      |                          |
| Jaenke (2012) [15]  | n = 127    | 24 h recall x 2 | F intake (servings/day) | 1.2 (1.0) | 1.5 (1.0) | 1.0 (0.9) | 2.1 (2.2) | 2.0 (1.7) | 1.9 (1.3) | Between group mean differences only | p = 0.76 | p = 0.06 | F = 10.98; p < 0.001 | F = 15.00; p < 0.001 |                          |
| Morgan (2010) [30]  | n = 127 (some differences) | 24 h recall x 3 (workbook) | F intake (servings/day) | 0.8 (0.8) | 0.3 (0.5) | 0.7 (0.6) | 0.6 (0.7) | 0.8 (0.8) | 0.3 (0.5) | Between group mean differences only | p = 0.76 | p = 0.06 | F = 10.98; p < 0.001 | F = 15.00; p < 0.001 |                          |
|                     |            |                  | V intake (servings/day) | 1.2 (0.6) | 1.8 (1.1) | 1.7 (0.7) | 1.4 (0.7) | 1.2 (0.6) | 1.8 (1.1) | Between group mean differences only | p = 0.76 | p = 0.06 | F = 10.98; p < 0.001 | F = 15.00; p < 0.001 |                          |
| McAlaeese (2007) [16] | n = 122 | 24 h recall x 3 (workbook) | F intake (servings/day) | 2.8 (0.8) | 2.5 (0.79) | 2.9 (0.78) | 2.6 (0.86) | 2.8 (0.8) | 2.5 (0.79) | 2.9 (0.78) | 2.6 (0.86) | NR |                                      |                          |
|                     |            |                  | V intake (servings/day) | 2.5 (0.79) | 2.7 (0.93) | 2.6 (0.86) | 2.6 (0.86) | 2.7 (0.93) | 2.6 (0.86) | 2.6 (0.86) | 2.6 (0.86) | NR |                                      |                          |
| Meinen (2012) [31]  | n = 404    | Parent survey | Child ate F yesterday († times) | 2.8 (0.8) | 2.5 (0.79) | NA | NA | 2.8 (0.78) | 2.9 (0.78) | NR |                                      |                          |
|                     |            |                  | Child ate V yesterday († times) | 2.5 (0.79) | 2.7 (0.93) | NA | NA | 2.6 (0.79) | 2.6 (0.86) | NR |                                      |                          |
| Parmer (2009) [37]  | n = 115    | Lunchroom observations | V consumption (0 = not eaten; 1 = eaten) | 0.70 (0.4) | 0.64 (0.5) | 0.64 (0.5) | 0.83 (0.3) | 0.50 (0.5) | 0.64 (0.5) | 0.83 (0.3) | 0.50 (0.5) | NR |                                      |                          |
| Parmer (2007) [36]  | n = 115    |                  |                  | | | | | | | | |                                      |                          |
| First author (year)       | Sample (n) | Outcome measures | Outcomes                                                                 | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|---------------------------|------------|------------------|--------------------------------------------------------------------------|--------------------|------------------|---------------|---------------------------------------------|
| Ratcliffe (2011)          | n = 320    | Garden Vegetables Frequency Questionnaire (22 items) Taste Test       | V consumed more than once a month (# varieties) V consumed at school V consumed at home | NR                 | NA               | NR            | Change values only reported p = 0.001       |
|                           |            |                  |                                                                          | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) |                                                                                     |

F fruits, V vegetables, FV fruits and vegetables, SD standard deviation (or standard error where a); MD mean difference, OR odds ratio, F = F statistic from ANOVA

*see results text for explanation of how differences in duplicate data reporting were handled

†same study but different sample sizes reported

No meta-analysis due to heterogeneity of outcomes (e.g. inconsistent definitions and reporting of FV serving size) and study designs (e.g. different comparison groups; lack of follow-up means; different data collection methods)
Table 8 Results of included quantitative studies: child’s nutrient intakes (and other dietary outcomes)

| First author (year) | Sample (n) | Outcome measures | Outcomes | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|---------------------|------------|------------------|----------|--------------------|------------------|--------------|---------------------------------------------|
|                     |            |                  | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) |                                             |
| Christian (2014)    | 1138\dagger| CADET            | 2034 (39.4) \*  | 1520 (178.2) \*  | 1993 (34.1) \*  | 1567 (168.4) \*  | NA                           | NA                           | MD = –46; p = 0.6                     |
|                     |            |                  | 75 (1.8) \*     | 58 (7.1) \*       | 73 (1.5) \*     | 64 (6.7) \*       | NA                           | NA                           | MD = –6; p = 0.2                      |
|                     |            |                  | 265 (4.4) \*    | 186 (21.5) \*     | 267 (4.3) \*    | 193 (20.6) \*     | NA                           | NA                           | MD = –7; p = 0.5                      |
|                     |            |                  | 13 (0.3) \*     | 10 (1.3) \*       | 13 (0.3) \*     | 11 (1.3) \*       | NA                           | NA                           | MD = –1; p = 0.1                      |
|                     |            |                  | 82 (2.3) \*     | 65 (8.2) \*       | 78 (1.7) \*     | 64 (7.7) \*       | NA                           | NA                           | MD = –8; p = 0.1                      |
|                     |            |                  | 132 (2.9) \*    | 90 (10.5) \*      | 134 (2.6) \*    | 99 (10.6) \*      | NA                           | NA                           | MD = –7; p = 0.5                      |
|                     |            |                  | 11 (0.2) \*     | 8 (1.0) \*        | 11 (0.2) \*     | 8 (0.9) \*        | NA                           | NA                           | MD = –4; p = 0.5                      |
|                     |            |                  | 2632 (76.3) \*  | 2272 (286) \*     | 2572 (57.6) \*  | 2257 (267.7) \*   | NA                           | NA                           | MD = 16; p = 0.9                      |
|                     |            |                  | 227 (5.3) \*    | 169 (19.7) \*     | 224 (4.5) \*    | 180 (18.6) \*     | NA                           | NA                           | MD = –11; p = 0.3                     |
|                     |            |                  | 1956 (98.8) \*  | 1995 (864) \*     | 2352 (101.7) \* | 2164 (878) \*     | NA                           | NA                           | MD = 168; p = 0.5                     |
|                     |            |                  | 108 (3.7) \*    | 113 (31.7) \*     | 105 (3.5) \*    | 125 (31) \*       | NA                           | NA                           | MD = 13; p = 0.02                     |
| Christian (2014)    | 1391\dagger| CADET            | 2039 (32.7)     | 1845 (172)        | NA               | NA             | 1932 (32.8) | 1836 (170) | MD = 9; p = 0.9                     |
|                     |            |                  | 82 (18.0)       | 76 (7.9)          | NA               | NA             | 78 (2.0)   | 77 (7.9)  | MD = –1; p = 0.8                      |
|                     |            |                  | 2742 (58.4)     | 2621 (259)        | NA               | NA             | 2575 (64.2) | 2656 (257) | MD = –34; p = 0.8                     |
|                     |            |                  | 135 (2.3)       | 108 (11.4)        | NA               | NA             | 127 (2.4)  | 107 (11.3) | MD = 1; p = 0.8                       |
|                     |            |                  | 2024 (74.9)     | 1841 (299)        | NA               | NA             | 2089 (83.9) | 2168 (329) | MD = –327; p = 0.2                     |
|                     |            |                  | 118 (3.2)       | 75 (30.2)         | NA               | NA             | 118 (3.2)  | 73 (30)   | MD = 2; p = 0.7                       |
|                     |            |                  | 11 (0.2)        | 10 (0.9)          | NA               | NA             | 11 (0.2)   | 10 (0.9)  | MD = 0.1; p = 0.8                      |
|                     |            |                  | 13 (0.3)        | 12 (1.2)          | NA               | NA             | 12 (0.2)   | 11 (1.2)  | MD = 0.3; p = 0.6                      |
|                     |            |                  | 267 (4.0)       | 227 (21.7)        | NA               | NA             | 254 (3.6)  | 225 (21.6) | MD = 2; p = 0.8                       |
|                     |            |                  | 235 (4.5)       | 192 (18.9)        | NA               | NA             | 220 (4.3)  | 188 (18.8) | MD = 4; p = 0.6                       |
|                     |            |                  | 75 (1.4)        | 70 (6.5)          | NA               | NA             | 69 (1.4)   | 68 (6.4)  | MD = 2; p = 0.6                       |
| Cotter (2013)       | 155\dagger| 24 h urine samples; flame photometry | 7.5 (2.4) | 6.4 (2.2) | 8.1 (3.0) | 7.5 (3.0) | 7.7 (2.0) | 7.4 (3.0) | NR |
| Davis (2011)        | 104\dagger| Block Food Screener (41 items) | 2011.0 (1410.4) | 1639.5 (1046.5) | NA               | NA           | 1961.0 (1077.5) | 1535.2 (902.9) | p = 0.85 |
|                     |            |                  | 85.4 (67.7)     | 65.1 (43.0)       | NA               | NA           | 81.6 (49.0) | 58.3 (38.3) | p = 0.59 |
|                     |            |                  | 79.9 (26.6)     | 62.6 (49.6)       | NA               | NA           | 73.3 (52.4) | 57.8 (41.4) | p = 0.92 |
|                     |            |                  | 2442 (145.7)    | 2113 (122.3)      | NA               | NA           | 2522.2 (1196) | 2028.8 (109.1) | p = 0.94 |
|                     |            |                  | 11.8 (10.2)     | 9.9 (9.4)         | NA               | NA           | 11.5 (7.6)  | 11.2 (9.7) | p = 0.15 |
|                     |            |                  | 16.1 (11.5)     | 16.1 (8.6)        | NA               | NA           | 18.7 (10.3) | 13.3 (7.5) | p = 0.01 |
|                     |            |                  | 2.1 (2.4)       | 2.8 (2.5)         | NA               | NA           | 2.6 (1.7)   | 2.1 (1.3)  | p = 0.97 |
|                     |            |                  | 0.8 (0.9)       | 0.9 (0.7)         | NA               | NA           | 0.7 (0.7)   | 0.6 (0.6)  | p = 0.13 |
| Gibbs (2013)        | 764\dagger| Parent questionnaire | 74.1 (75.6) | 762 (68.1) | 68.1 | NA | NA | OR = 1.33 (0.70 to 2.5); p = 0.38 |
| McAleese (2007)     | 112\dagger| 24 h recall x 3 (workbook) | 430.4 (244.1) | 612.4 (359.6) | 428.5 (247.9) | 358.8 (273.3) | 621.4 (294.1) | 549.5 (248.9) | F = 5.86; p = 0.004 |

SD: standard deviation; MD: mean difference, OR: odds ratio, F: F statistic from ANOVA
\dagger: same study but different sample sizes reported

No meta-analysis for due to baseline differences in vitamin C intake (McAleese, [16]; Christian, [10]) and lack of accounting for possible clustering effects (McAleese, [16])
Table 9 Results of included quantitative studies: child’s food preferences (including willingness to taste and taste ratings)

| First author (year) | Sample (n) | Outcome measures | Outcomes | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|---------------------|------------|------------------|----------|--------------------|------------------|--------------|------------------------------------------|
| Block (2009) [25]   | n = 770    | SAKG child questionnaire (four point scale) | Always willing to try new foods if… | NA | NA | 35 | 23 | NR |
|                     |            |                  | Never tried it before (%) | 26 | 39 | 35 | 23 | NA |
|                     |            |                  | Cooked it (%) | 32 | 51 | 39 | 34 | NA |
|                     |            |                  | Grown it in the garden (%) | 26 | 39 | 35 | 23 | NA |
| Gibbs (2013) [26]   | n = 764    | SAKG parent questionnaire | Child always willing to try new foods (%) | 27 | 33 | 24 | 27 | NA |
| Gatto (2012) [29]   | n = 107    | Motivation for Healthy Eating (17 items) | Preference for fruits | NA | NA | 4.8 | 2.2 | NS |
|                     |            |                  | Preference for vegetables | NA | NA | 4.2 | 2.3 | p < 0.05 |
|                     |            |                  | Combination of measures (13 items; seven point scale) | 4.4 (2.5) | 5.8 (1.8) | 4.9 (2.4) | 6.2 (1.4) | p = 0.9 |
|                     |            |                  | Vegetable from the garden taste better than vegetables from the store (%) | 0.11 | 0.06 | 0.29 | 0.61 | p = 0.06 |
| Jaenke (2012) [15]  | n = 127    | Food preference assessment tool | Overall willingness to taste (6) | 4.54 (1.50) | 4.03 (1.94) | 3.93 (2.04) | 4.91 (1.78) | p < 0.001 |
|                     |            |                  | Overall taste rating (30) | 18.5 (7.4) | 18.1 (9.0) | 15.5 (8.8) | 18.1 (7.9) | p < 0.001 |
|                     |            |                  | Taste rating carrot (5) | 3.7 (1.6) | 3.7 (1.6) | 3.5 (1.8) | 3.7 (1.6) | p = 0.071 |
|                     |            |                  | Taste rating pea (5) | 2.9 (1.8) | 2.8 (1.8) | 2.0 (1.9) | 2.9 (1.8) | p < 0.001 |
|                     |            |                  | Taste rating tomato (5) | 2.9 (2.3) | 2.4 (2.3) | 2.5 (2.4) | 2.9 (1.8) | p < 0.001 |
|                     |            |                  | Taste rating broccoli (5) | 2.6 (1.8) | 2.8 (2.0) | 2.1 (2.1) | 2.6 (1.8) | p = 0.03 |
|                     |            |                  | Taste rating capsicum (5) | 2.4 (2.1) | 3.0 (2.1) | 2.1 (2.1) | 2.4 (2.1) | p < 0.001 |
|                     |            |                  | Taste rating lettuce (5) | 4.1 (1.5) | 3.7 (1.9) | 3.3 (1.9) | 4.1 (1.5) | p = 0.02 |
| Morgan (2010) [30]  | n = 127    |                  | Reported in Morgan paper only: | | | | | |
|                     |            |                  | Willingness to taste: | | | | | |
|                     |            |                  | Lettuce (proportion) | 0.94 | 0.97 | 0.83 | 0.85 | 0.77 | 0.61 | 0.24 |
|                     |            |                  | Carrot (proportion) | 0.89 | 0.92 | 0.89 | 0.88 | 0.82 | 0.70 | 0.14 |
|                     |            |                  | Capsicum (proportion) | 0.60 | 0.74 | 0.77 | 0.64 | 0.51 | 0.35 | 0.04 |
|                     |            |                  | Broccoli (proportion) | 0.71 | 0.93 | 0.74 | 0.61 | 0.58 | 0.36 | 0.01 |
|                     |            |                  | Tomato (proportion) | 0.60 | 0.76 | 0.56 | 0.48 | 0.60 | 0.40 | <0.001 |
|                     |            |                  | Pea (proportion) | 0.69 | 0.77 | 0.74 | 0.76 | 0.65 | 0.41 | 0.02 |
|                     |            |                  | Would you eat this food as a snack? | | | | | |
|                     |            |                  | Lettuce (proportion) | 0.60 | 0.68 | 0.54 | 0.69 | 0.39 | 0.30 | 0.15 |
|                     |            |                  | Carrot (proportion) | 0.67 | 0.60 | 0.64 | 0.60 | 0.63 | 0.61 | 0.09 |
|                     |            |                  | Capsicum (proportion) | 0.22 | 0.43 | 0.25 | 0.29 | 0.23 | 0.29 | 0.39 |
|                     |            |                  | Broccoli (proportion) | 0.06 | 0.40 | 0.18 | 0.18 | 0.19 | 0.06 | <0.001 |
|                     |            |                  | Tomato (proportion) | 0.46 | 0.48 | 0.48 | 0.32 | 0.42 | 0.34 | 0.31 |
|                     |            |                  | Pea (proportion) | 0.21 | 0.61 | 0.24 | 0.32 | 0.25 | 0.11 | 0.001 |
| Meinen (2012) [31]  | n = 404    | Student survey (three point scale) | Willingness to try fruits and vegetables: | | | | | |
|                     |            |                  | If given a new kind of fruit at home (/3) | 2.5 (0.60) | 2.6 (0.59) | 2.6 (0.58) | 2.5 (0.65) | NR |
|                     |            |                  | If given a new kind of fruit at school (/3) | 2.2 (0.72) | 2.3 (0.72) | 2.3 (0.69) | 2.2 (0.69) | NR |
|                     |            |                  | If given a new kind of vegetable at home (/3) | 2.2 (0.70) | 2.3 (0.70) | 2.3 (0.69) | 2.2 (0.71) | NR |
|                     |            |                  | If given a new kind of vegetable at school (/3) | 2.1 (0.73) | 2.1 (0.78) | 2.0 (0.71) | 2.0 (0.75) | NR |
|                     |            |                  | Would you choose fruit as a snack? (/3) | 2.4 (0.68) | 2.5 (0.63) | 2.5 (0.66) | 2.5 (0.64) | NR |
|                     |            |                  | Would you choose vegetables as a snack? (/3) | 1.8 (0.74) | 2.0 (0.73) | 1.9 (0.78) | 2.0 (0.75) | NR |
| First author (year) Sample (n) | Outcome measures | Outcomes | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|-------------------------------|------------------|----------|--------------------|------------------|--------------|--------------------------------------------|
|                               |                  |          | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) | F = 4.840; p < 0.01 |
| Parent survey (10 items; four point scale) | Like/dislike of fruits and vegetables: | | | | | | | | | | |
| Apples (/4) | 3.8 (0.45) | 3.7 (0.57) | 3.8 (0.46) | 3.8 (0.52) | | | | | | |
| Watermelon (/4) | 3.7 (0.58) | 3.6 (0.68) | 3.6 (0.74) | 3.6 (0.75) | | | | | | |
| Broccoli (/4) | 2.8 (1.05) | 2.9 (1.06) | 2.9 (1.02) | 2.8 (1.07) | | | | | | |
| Tomatoes (/4) | 2.3 (1.12) | 2.5 (1.15) | 2.4 (1.13) | 2.5 (1.16) | | | | | | |
| Spinach (/4) | 2.2 (0.99) | 2.4 (1.14) | 2.2 (1.06) | 2.1 (1.02) | | | | | | |
| Swiss chard (/4) | 1.6 (0.82) | 2.0 (0.95) | 1.7 (0.96) | 1.7 (0.78) | | | | | | |
| Zucchinis (/4) | 2.3 (0.99) | 2.4 (0.95) | 2.3 (1.11) | 2.3 (1.01) | | | | | | |
| Cucumbers (/4) | 3.0 (0.99) | 3.0 (1.05) | 2.9 (1.13) | 3.1 (1.01) | | | | | | |
| Green beans (/4) | 3.3 (0.89) | 3.4 (0.90) | 3.3 (0.95) | 3.4 (0.85) | | | | | | |
| Peppers (/4) | 2.4 (1.13) | 2.6 (1.12) | 2.3 (1.17) | 2.3 (1.09) | | | | | | |
| Student questionnaire (six items; five point scale) | Mean total tasting score indicating willingness to taste (/5) | | | | | | | | | | |
| Vegetables tasted: spinach, carrots, peas, broccoli, zucchini and red bell pepper. | 4.07 (0.31)* | 4.83 (0.23)* | NA | NA | 3.90 (0.30)* | 3.90 (0.29)* | p < 0.005 | | | | |
| Vegetable preference survey (six items; five point scale) | Vegetable preference score at post-test: | | | | | | | | | | |
| Broccoli (/5) | 3.8 (0.1)* | 3.8 (0.1)* | 3.2 (0.2)* | | | | | | | |
| Carrots (/5) | 4.7 (0.1)* | 4.7 (0.1)* | 4.4 (0.1)* | | | | | | | |
| Jicama (/5) | 3.9 (0.2)* | 3.8 (0.2)* | 3.6 (0.2)* | | | | | | | |
| Snow peas (/5) | 3.8 (0.2)* | 3.1 (0.2)* | 2.9 (0.2)* | | | | | | | |
| Spinach (/5) | 3.0 (0.2)* | 3.2 (0.2)* | 3.1 (0.2)* | | | | | | | |
| Zucchini (/5) | 4.0 (0.2)* | 3.2 (0.1)* | 3.1 (0.2)* | | | | | | | |
| Vegetable preference score at 6 m follow up: | | | | | | | | | | | |
| Broccoli (/5) | 4.0 (0.1)* | 3.7 (0.1)* | 3.5 (0.2)* | | | | | | | |
| Carrots (/5) | 4.6 (0.1)* | 4.7 (0.1)* | 4.4 (0.1)* | | | | | | | |
| Jicama (/5) | 3.8 (0.2)* | 3.4 (0.2)* | 3.2 (0.2)* | | | | | | | |
| Snow peas (/5) | 3.7 (0.2)* | 3.0 (0.2)* | 3.0 (0.2)* | | | | | | | |
| Spinach (/5) | 3.4 (0.1)* | 3.2 (0.1)* | 3.3 (0.2)* | | | | | | | |
| Zucchini (/5) | 4.0 (0.1)* | 3.4 (0.1)* | 3.2 (0.2)* | | | | | | | |
| Vegetable preferences at post-test: Do you eat this food at home? (/6) | | | | | | | | | | | |
| Broccoli (/5) | | | | | | | | | | | |
| Carrots (/5) | | | | | | | | | | | |
| Jicama (/5) | | | | | | | | | | | |
| Snow peas (/5) | | | | | | | | | | | |
| Spinach (/5) | | | | | | | | | | | |
| Zucchini (/5) | | | | | | | | | | | |
| Vegetable preferences at 6 m follow up: | | | | | | | | | | | |
| Broccoli (/5) | | | | | | | | | | | |
| Carrots (/5) | | | | | | | | | | | |
| Jicama (/5) | | | | | | | | | | | |
| Snow peas (/5) | | | | | | | | | | | |
| Spinach (/5) | | | | | | | | | | | |
| Zucchini (/5) | | | | | | | | | | | |
| Would you eat this food as a snack? (/6) | | | | | | | | | | | |
| Broccoli (/5) | | | | | | | | | | | |
| Carrots (/5) | | | | | | | | | | | |
| Jicama (/5) | | | | | | | | | | | |
| Snow peas (/5) | | | | | | | | | | | |
| Spinach (/5) | | | | | | | | | | | |
| Zucchini (/5) | | | | | | | | | | | |
| Would you eat this food as a snack? (/6) | | | | | | | | | | | |
| Broccoli (/5) | | | | | | | | | | | |
| Carrots (/5) | | | | | | | | | | | |
| Jicama (/5) | | | | | | | | | | | |
| Snow peas (/5) | | | | | | | | | | | |
| Spinach (/5) | | | | | | | | | | | |
| Zucchini (/5) | | | | | | | | | | | |
Table 9 Results of included quantitative studies: child’s food preferences (including willingness to taste and taste ratings) (Continued)

| First author (year) Sample (n) | Outcome measures | Outcomes | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|--------------------------------|------------------|----------|--------------------|------------------|--------------|---------------------------------------------|
|                                |                  |          | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) | Baseline Mean (SD) | Follow-up Mean (SD) |          |                                    |
| O’Brien (2006) [35] n = 38    | FV preference assessment (four point scale) | Total fruit preference (/8) | 7.18 (0.31)* | 10.94 (0.92)* | NA          | NA | 6.05 (0.33)* | 8.81 (0.91)* | 9.05 (0.97)* | NR          |                                    |
|                               |                  | Total vegetable preference (/16) | 11.24 (0.92)* |                |              |                |              |                |              |                                    |
|                               |                  | Fruits and vegetables tasted unknown | |                |              |                |              |                |              |                                    |
| Parmer (2009) [37] n = 115    | FV preference questionnaire (six items; five point scale) | Willingness to taste (/6) | 4.82 (1.6) | 3.45 (0.9) | 5.11 (1.1) | 3.85 (0.8) | 5.33 (1.2) | 4.15 (0.6) | 3.84 (2.1) | 3.99 (0.7) | 3.82 (0.5) | F = 0.878; p = 0.42 F = 14.45; p < 0.001 |
|                               |                  | Ratings of tasted fruits and vegetables (/5) | 3.50 (1.0) | 4.38 (0.5) | 4.15 (1.2) | 3.85 (0.8) | 4.15 (0.6) | 3.85 (0.8) | 4.15 (1.2) | 3.85 (0.8) | 4.15 (0.6) |                                    |
|                               |                  | Fruits and vegetables tasted: carrots, broccoli, spinach, zucchini, cabbage and blueberries | | | | | | | | |                                    |
| Parmer (2007) [36] n = 115    | FV preference survey (15 items; three point scale) | Fruit preference (/3) | 2.59 (0.4) | 2.08 (0.5) | 2.70 (0.3) | 2.20 (0.6) | 2.73 (0.3) | 2.14 (0.6) | 2.59 (0.4) | 2.57 (0.3) | NR                                      |
|                               |                  | Vegetable preference (/3) | 2.60 (0.3) | 2.03 (0.5) | 2.70 (0.3) | 2.20 (0.6) | 2.73 (0.3) | 2.14 (0.6) | 2.59 (0.4) | 2.57 (0.3) | NR                                      |
| Ratcliffe (2011) [38] n = 320  | Taste test (five items; five point scale) | Willingness to taste vegetables (/5) | NR | | Change values only reported | NA | NA | Change values only reported | 0.286 | 0.279 |                                    |
|                               |                  | Preference for vegetables (/5) | | | | | | | | |                                    |
|                               |                  | Vegetables tasted: carrots, string beans, snow peas, broccoli and Swiss chard | | | | | | | | |                                    |
|                               | Garden Vegetables Frequency Questionnaire (22 items plus two added) | Preference for vegetables: all (24 items) | | | | | | | | |                                    |
|                               |                  | grown in school garden (11 items) | | | | | | | | |                                    |
|                               |                  | not grown in school garden (13 items) | | | | | | | | |                                    |
|                               |                  | Willingness to taste vegetables: all (24 items) | | | | | | | | |                                    |
|                               |                  | grown in school garden (11 items) | | | | | | | | |                                    |
|                               |                  | not grown in school garden (13 items) | | | | | | | | |                                    |

F fruits, V vegetables, FV fruits and vegetables, SD standard deviation (or standard error where*); OR odds ratio, F F statistic from ANOVA
*see results text for explanation of how differences in duplicate data reporting were handled
No meta-analysis due to heterogeneity of outcome measures
Table 10 Results of included quantitative studies: child’s knowledge and attitudes towards food (including self-efficacy)

| First author (year) | Sample (n) | Outcome measures | Outcomes (data are means and SD unless otherwise stated) | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|---------------------|------------|------------------|----------------------------------------------------------|-------------------|----------------|-------------|-------------------------------------------------|
| Christian (2014) [10] | Trial 1; n = 1138 | Child questionnaire: FV knowledge | % of children who agreed: | % agreed | % agreed | % agreed | % agreed | NA | NA | Odds ratio (95 % CI) |
|                     |            | Attitudes towards FV | I enjoy eating fruit | 94.5 | 91.8 | 96.4 | 96.2 | OR = 0.4 (0.1 to 1.0) |
|                     |            |                     | I like trying new fruits | 78.0 | 76.3 | 83.3 | 86.6 | OR = 0.2 (0.02 to 0.9) |
|                     |            |                     | I try to eat lots of fruit | 83.0 | 81.3 | 86.7 | 90.1 | OR = 0.4 (0.2 to 0.9) |
|                     |            |                     | I enjoy eating vegetables | 65.6 | 64.7 | 66.9 | 65.9 | OR = 0.6 (0.4 to 1.0) |
|                     |            |                     | I like trying new vegetables | 58.9 | 58.0 | 61.0 | 60.0 | OR = 1.0 (0.7 to 1.5) |
|                     |            |                     | I try to eat lots of vegetables | 64.6 | 70.9 | 66.7 | 69.6 | OR = 1.1 (0.7 to 1.7) |
|                     |            |                     | Eating FV every day keeps me healthy | 93.5 | 94.1 | 94.1 | 97.2 | OR = 0.6 (0.2 to 1.6) |
|                     |            |                     | There is usually lots of FV to eat at home | 89.2 | 89.8 | 87.6 | 94.1 | OR = 0.4 (0.2 to 0.9) |
|                     |            |                     | I’m good at preparing FV | 71.8 | 74.7 | 81.3 | 83.6 | OR = 0.6 (0.3 to 1.1) |
|                     |            |                     | My family encourages me to eat FV | 87.1 | 90.7 | 88.3 | 93.7 | OR = 0.7 (0.3 to 1.5) |
|                     |            |                     | % who knew that 5 FV per day are needed to stay healthy | 76.2 | 79.0 | 72.7 | 79.0 | OR = 0.9 (0.4 to 1.6) |
|                     |            |                     | % who had tasted their own FV at follow-up | 62.3 | 62.1 | 52.4 | 67.8 | OR = 0.8 (0.5 to 1.4) |
| Christian (2014) [10] | Trial 2; n = 1391 | Child questionnaire: FV knowledge | % of children who agreed: | % agreed | % agreed | NA | NA | % agreed | % agreed | Odds ratio (95 % CI) |
|                     |            | Attitudes towards FV | I enjoy eating fruit (% who agreed) | 96.7 | 96.0 | NA | NA | 96.8 | 97.0 | OR = 1.1 (0.4 to 2.9) |
|                     |            |                     | I like trying new fruits | 86.0 | 84.0 | NA | NA | 84.5 | 80.4 | OR = 1.2 (0.7 to 1.9) |
|                     |            |                     | I try to eat lots of fruit | 87.2 | 88.2 | NA | NA | 82.7 | 85.8 | OR = 1.0 (0.6 to 1.6) |
|                     |            |                     | I enjoy eating vegetables | 68.8 | 69.5 | NA | NA | 64.2 | 61.7 | OR = 1.2 (0.9 to 1.6) |
|                     |            |                     | I like trying new vegetables | 62.8 | 59.5 | NA | NA | 605 | 56.9 | OR = 0.9 (0.7 to 1.2) |
|                     |            |                     | I try to eat lots of vegetables | 72.8 | 75.5 | NA | NA | 66.7 | 68.6 | OR = 1.2 (0.8 to 1.8) |
|                     |            |                     | Eating FV every day keeps me healthy | 94.9 | 97.0 | NA | NA | 96.2 | 96.4 | OR = 1.2 (0.5 to 2.8) |
|                     |            |                     | There is usually lots of FV to eat at home | 89.6 | 92.8 | NA | NA | 88.9 | 89.5 | OR = 1.5 (0.9 to 2.5) |
|                     |            |                     | I’m good at preparing FV | 79.3 | 78.1 | NA | NA | 77.9 | 79.3 | OR = 0.8 (0.6 to 1.1) |
|                     |            |                     | My family encourages me to eat FV | 89.9 | 92.8 | NA | NA | 87.7 | 91.9 | OR = 0.9 (0.5 to 1.6) |
|                     |            |                     | % who knew that 5 FV per day are needed to stay healthy | 73.6 | 79.1 | NA | NA | 67.3 | 67.5 | OR = 1.7 (1.1 to 2.5) |
|                     |            |                     | % who had tasted their own FV at follow-up | 60.1 | 66.4 | NA | NA | 56.0 | 58.1 | OR = 1.4 (0.8 to 2.4) |
| Meinen (2012) [31] | n = 404 | Knowledge of fruits and vegetables | Knowledge of recommended daily servings of FV (%) | 33 | 35 | 36 | 42 | NR |
| Morgan (2010) [30] | n = 127 | Gimme 5 questionnaire (eight multiple choice questions) | FV knowledge (/8) | 5.4 (1.4) | Between group mean differences only | 5.1 (1.3) | Between group mean differences only | 6.1 (1.8) | Between group mean differences only | p = 0.02† |
|                     |            | Food preference assessment tool | Ability to identify vegetables (/1) | 0.9 (0.1) | 0.9 (0.1) | 0.9 (0.1) | p < 0.001† |
## Table 10 Results of included quantitative studies: child’s knowledge and attitudes towards food (including self-efficacy) (Continued)

| First author (year) | Sample (n) | Outcome measures | Outcomes (data are means and SD unless otherwise stated) | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|---------------------|------------|------------------|----------------------------------------------------------|-------------------|----------------|--------------|---------------------------------------------|
| Morris (2001) [32]  | n = 97     | Food identification questionnaire (food groups/recommendations) | Nutrition knowledge score (/5) | 1.9 (0.2)\(^a\) | 2.5 (0.2)\(^a\) | NA | NA | 2.4 (0.2)\(^a\) | 2.5 (0.2)\(^a\) | NR |
| Morris (2002) (1) [33] | n = 213 | Nutrition knowledge questionnaire (30 multiple choice questions) | Nutrition knowledge score at post-test (/30): | NR | 20.8 (0.4)\(^a\) | NR | 20.5 (0.4)\(^a\) | NR | 17.1 (0.4)\(^a\) | F = 24.238, p < 0.0005 |
| Morris (2002) (2) [34] | n = 215 | Vegetable preference survey (six items) | Ability to correctly name vegetables at post-test (/6) | NR | 3.3 (0.1)\(^a\) | NR | 3.0 (0.1)\(^a\) | NR | 2.6 (0.1)\(^a\) | F = 9.795, p < 0.0005 |
| O’Brien (2006) [35] | n = 38 | Nutrition knowledge questionnaire (derived from Family Nutrition Program evaluations) | Nutrition knowledge (/10) | 7.53 (0.34)\(^a\) | 7.18 (0.30)\(^a\) | NR | NR | 7.05 (0.29)\(^a\) | 7.38 (0.33)\(^a\) | NR |
| Parmer (2009) [37]  | n = 115   | Fruit and vegetable survey (adapted Struempler & Raby) | Food groups | 3.69 (1.8) | 5.20 (1.2) | 4.08 (1.7) | 4.75 (1.9) | 4.03 (1.8) | 4.46 (1.3) | NS |
| Parmer (2007) [36]  | n = 115   | Nutrient-food associations | 1.46 (1.1) | 3.56 (1.6) | 1.67 (1.5) | 3.70 (1.8) | 1.82 (1.4) | 1.92 (1.3) |
| Ratcliffe (2011) [38] | n = 320 | Taste test | Ability to identify vegetables | NR | Change values only reported | NA | NA | NR | Change values only reported | p = 0.002 |

\(FV = \) fruits and vegetables, SD standard deviation (or standard error where\(^a\)); OR odds ratio

\(^a\)Note: the p values reported for these outcomes relate to subgroup analysis (n = 109) of students with lower baseline scores (Morgan et al. 2010)

No meta-analysis due to heterogeneity of outcomes and different comparison groups (Christian, [10] Trials 1 and 2)
the time, so it's also like zenful, so you get to listen to things...I think about stuff, so I don't have to go home and think about it right before bed, so instead I can just go to sleep and stuff. I just feel happier in a way, and more at peace. – Student, age 15 [11].

This is another example of the sensory, visceral nature of gardening activities, which may have stress-reducing or restorative effects similar to those described in Ulrich's psycho-evolutionary theory [53].

Children experienced positive and negative emotions in the school gardens and participants described how they were able to express themselves and manage their emotions more effectively in that environment [11, 13, 25, 41, 49–51]. For example, following the vandalising of the school garden, a teacher said:

It really offended them that these students had done this damage to their garden...So then we talk about it and say, well, it made them feel very angry that these children had destroyed part of their garden...it was a positive experience that the children learn that doing what to those children must have been a fun thing to do to go tear up our garden, didn't make us feel good. They were on the receiving end of it and so even though it was a negative experience you can make it a positive one. – Teacher [41].

In this example, the teacher had her own views about how the negative experience has been turned into a constructive learning experience, but this was not articulated by the children themselves.

The social well-being impacts of school gardening were mainly about building relationships [11–13, 25, 41, 44, 47, 49–52]. Children enjoyed interacting with their friends, teachers, gardening specialists, parents and volunteers – some of whom were people they would not normally come into contact with.

You have to work together...It's not about individualism which is promoted in the school structure in some ways, but really communication, cooperation and ownership of something. – Garden staff [40].
| First author (year)            | Sample (n) | Outcome measures                             | Outcomes                                           | Intervention group | Comparison group | Control group | Group x time results (adjusted, if reported) |
|--------------------------------|------------|----------------------------------------------|--------------------------------------------------|-------------------|-----------------|--------------|---------------------------------------------|
| Block (2012) [24]              | n = 764    | KIDSCREEN-10 Child quality of life score     | Child quality of life score                      | 48.9 (8.4)        | NA              | 48.2 (7.9)  | Adjusted statistic = 1.23 (0.7); p = 0.09   |
|                               |            | Teacher strongly agrees that:                | Student social behaviour is good (%)            | 41.9              | 41.9            | 41.9         |                                             |
|                               |            |                                               | Students cooperate well with other students (%) | 48.8              | 53.8            | 57.8         |                                             |
| Morgan (2010) [30]             | n = 127    | Quality of school life instrument (40 items) | Quality of school life                          | 3.2 (0.2)         | 3.2 (0.3)       | 3.0 (0.4)    | Adjusted statistic = 0.51; p = 0.3          |
|                               |            |                                               | Means by age and gender only                    | NA                | NA              | Means by age and gender only                |                                             |
| Robinson (2005) [39]           | n = 281    | Youth Life Skills Inventory (32 questions; three point scale) | Overall life skills score (/96)                 | 83.02 (7.95)      | 84.51 (7.88)   | 85.8 (6.14)  |                                             |
|                               |            |                                               | Working with groups                             | (7.95)            | (7.81)          | (6.14)       |                                             |
|                               |            |                                               | Self-understanding Leadership                   | (1.74)            | (1.41)          | NR           |                                             |
|                               |            |                                               | Leadership                                      | (1.74)            | (1.41)          | NR           |                                             |
|                               |            |                                               | Decision making                                 | (1.96)            | (1.76)          | NR           |                                             |
|                               |            |                                               | Communication                                   | (2.05)            | (1.85)          | NR           |                                             |
|                               |            |                                               | Volunteerism                                    | (1.71)            | (1.85)          | NR           |                                             |
| Waliczek (2001) [17]           | n = 589    | Self-Report of Personality Scale for children and adolescents | Interpersonal relationships                      | Means by age and gender only | NA              | Means by age and gender only                |                                             |
|                               |            |                                               | Means by age and gender only                    | NA                | NA              | Means by age and gender only                |                                             |

SD standard deviation
No meta-analysis due to heterogeneity of outcome measures
| First author (year) | Quality | Health impacts | Well-being impacts |
|---------------------|---------|----------------|-------------------|
| Food/nutrition knowledge | Attitudes towards food | Healthier eating habits | Physical activity | Enjoyment | Achievement, satisfaction, pride | Confidence, self-esteem, ownership, responsibility | Relaxation, stress release | Express/manage emotions | Building relationships, belonging | Cultural awareness, cohesion |
| Ahmed (2011) [40]     | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Alexander (1995) [41] | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Anderson (2011) [42]  | Weak    | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Block (2009, 2012) [24,25] | Strong | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Gibbs (2013) [26]     | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Townsend (2014) [43]  | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Bowker (2007) [44]    | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Chawla (2014) [11]    | Strong  | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Chiumento (2012) [12] | Weak    | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Cutter-Mackenzie      | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| (2009) [45]          |         |    |    |    |    |    |    |    |    |
| Hazzard (2011) [46]   | Weak    | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Henryks (2011) [47]   | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Lakin (2008) [48]     | Weak    | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Miller (2007) [49]    | Weak    | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ming Wei (2012) [13]  | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Passy (2010) [50]     | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Somerset (2005) [51]  | Weak    | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Viola (2006) [52]     | Moderate | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| First author (year) | Educational impacts | Factors influencing success and sustainability |
|---------------------|----------------------|-----------------------------------------------|
|                     | Academic improvements | Experiential learning style, curriculum integration | Supportive environment, inclusive, equal | Cultural relevance | Support from staff, volunteers | Pressure on staff, timetable | Fundraising, resources |
| Ahmed (2011) [40]   | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Alexander (1995) [41]| ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Anderson (2011) [42]| ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Block (2009, 2012) [24;25] | ✓  | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Gibbs (2013) [26]   | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Townsend (2014) [43]| ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Bowker (2007) [44]  | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Chawla (2014) [45]  | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Chiumento (2012) [12]| ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Cutter-Mackenzie (2009) [45]| ✓  | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Hazzard (2011) [46] | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Henryks (2011) [47]| ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Lakin (2008) [48]   | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Miller (2007) [49]  | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Ming Wei (2012) [50]| ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Passy (2010) [51]   | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Somerset (2005) [51]| ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
| Viola (2006) [52]   | ✓                    | ✓                              | ✓                            | ✓          | ✓        | ✓        | ✓ |
Gardening was seen as promoting teamwork and cooperation, working together towards common goals, which may help to break down some of the social boundaries and elitism associated with traditional academic structures.

Teachers, parents and volunteers also enjoyed the opportunity to interact with children in the garden setting and described how it improved teacher-student and inter-generational relationships [25, 47, 51]. Volunteers described feeling valued and ‘belonging’ in the school gardens [43, 47]. This gave them a sense of purpose because they felt they were doing something worthwhile – contributing to the children’s education and giving back to the community. In this respect, the personal and social well-being impacts of school gardening are interrelated and this combination of factors creates the motivation for volunteering.

Finally, participants described how school gardening contributed to improved cultural awareness and cohesion [12, 25, 40, 45, 50]. Parents from non-English-speaking backgrounds who might not contribute to other school activities felt comfortable in the garden [24]. In multi-cultural communities, the combination of gardening and cooking activities provided an opportunity for children to learn about each other’s cultures [45]. It was also a successful medium for developing English language skills as children relaxed and engaged in “everyday conversations” [45].

Qualitative evidence for educational impacts of school gardening

The most common outcomes reported alongside health and well-being impacts were related to potential educational impacts of school gardening [11–13, 25, 40–42, 44, 45, 47–51] (Table 14). As we have included only studies also reporting health and well-being impacts, we can only present evidence for the educational impacts of school gardening from these studies, and so this is not a comprehensive synthesis of the qualitative evidence for the educational impacts of school gardening. Six studies which focussed on educational aspects were excluded during full text screening because they did not match our primary review focus on health and well-being outcomes (see Fig. 1).

Whilst none of the included studies reported academic attainment outcomes (quantitative), two qualitative studies reported children’s beliefs that school gardening was having a positive impact on their school work [11, 44] and these beliefs were echoed by teachers and volunteers in four more studies [13, 25, 50, 51].

I’m able to complete my homework faster, because I’m in a better place to do other things, because I just spent an hour not worrying about my homework and my grades and my timing for anything, because there’s no deadline here. – High School Student with ADHD, age 17 [11]

This quote provides further evidence that it might be children with special educational needs that stand to benefit the most from school gardening. It also suggests that well-being impacts such as stress reduction may lead to academic impacts for some students, echoing the proposed mechanisms of Attention Restoration Theory, which suggests that contact with nature can restore depleted ability to concentrate [54].

Increased levels of engagement and motivation among children who participated in school gardening was noted in some studies, although it was not always clear if this was referring generally to time spent in the garden, to garden activities intended to promote academic learning, or also to classroom-based learning [12, 13, 24, 41, 50]. In one study, teachers described how they harnessed this potential by tailoring gardening activities to the needs of individual children and creating opportunities for them to demonstrate their skills and knowledge [24]. In our view this has obvious links to the well-being impacts of confidence and self-esteem. However, some children did not work well in the gardens and teachers found them difficult to ‘contain’ in open spaces [25]. Suggested reasons for this were that some tasks were repetitive and the rewards of gardening were not immediate, resulting in loss of engagement [25].

Some children developed a greater awareness of the environment through school gardening [11, 25, 41, 44, 45, 48–50]. This varied from awareness of the immediate garden environment, such as water conservation, seasonality, composting techniques and local wildlife [25, 44] to consideration of global environmental issues, such as the food supply chain (“ground to plate”), sustainability, recycling and the importance of protecting the environment [44, 45, 48]. Gardening was seen as a positive environmental behaviour and reinforced the sense of connection with nature [11, 45, 48].

There were also ‘educational’ impacts for adult staff and volunteers in terms of learning new skills in the school gardens and related activities like cooking [25, 47, 50]. In some schools there were formal opportunities for volunteers to attend short courses and gain certificates, which helped to keep volunteers motivated [43].

Qualitative evidence for factors influencing the success and sustainability of school gardening programmes

Most qualitative studies discussed one or more aspects of school gardening programmes that had contributed to their success and/or challenges they had to overcome, evidence which will be useful for schools considering, implementing or managing a gardening programme [12, 13, 25, 40, 41, 44–52] (Table 14).

The ‘experiential’ or hands-on learning style was described as an effective way to teach children academic...
subjects in a more applied and holistic way [25, 40, 44–46, 48, 50–52].

*We’ve done a lot of graphs, a lot of growth measurement. Planted seedlings, measured them and predicted at sixteen weeks, forecasting what size they will be. They are graphed and monitored every fortnight… And we’ve talked about sustainability, compost and everything just ties in… We’ve used maths, perimeter, and volume in the garden… Cubic metres… That would have been a really good one for the [grade] five/sixes, if they had actually bought the soil, found out the costing. A lot of things like that you think of in retrospect… There’s still more scope to have time in the regular curriculum and a more consistent approach, to have more of a strategic approach.* – Teacher [25].

This example from the Stephanie Alexander Kitchen Garden Program illustrates the potential for schools to integrate core curriculum subjects with fun gardening activities, and suggests a strong mechanism underpinning the potential well-being and educational impacts of school gardens. However, not all the interventions studies in this review integrated garden and curriculum activities in this way (Table 4).

Some qualitative studies indicated that some form of cooking or food preparation was integrated with the school gardening intervention, or encouragement to become involved in cooking or food preparation at school or at home, for some or all of their participants (but this was not necessarily a key component of the integration – see Table 4) [13, 24, 42, 45, 47, 48, 50, 52].

*Doin’ the cook-up with Miss… was fun. We put a recipe book together for the tuckshop as well. We did this every week so that the tuckshop would have healthy food.* – Student [52].

Cooking facilitated enjoyment and a sense of achievement. Passy also suggests that the sense of celebration created by sharing cooked garden produce was also important in encouraging students to taste the food [50].

*We have a whole bunch of young adults who know how to go to the shop or the market and pick up some vegetables and make themselves something delicious out of it… imagine uni students nourished on seasonal vegetables instead of two-minute noodles.* – Volunteer [47].

This example, from the Stephanie Alexander Kitchen Garden Program, illustrates how combining experience of gardening and cooking also gave children some of the life skills needed to live healthily [47]. It also supports the earlier quote from Ahmed et al. (2011) which proposes the potential long term impacts of changing attitudes to food through gardening.

School gardens were also described by teachers, parents and volunteers as being supportive and inclusive environments; a ‘level playing field’ where all children could participate equally [12, 13, 24, 47, 50]. This characteristic may help to explain well-being benefits if children felt comfortable to be themselves and participate without any sense of pressure or competitiveness. One study described how achievements in the garden were celebrated in school newsletters or assemblies, which contributed to feelings of pride, confidence and motivation among children who were previously unruly [50].

Considering the socio-demographic and cultural characteristics of the school community in the design of school gardening programmes could ensure that they effectively engage both children and the wider community [12, 25, 40, 45, 52]. This connection with cultural heritage and local foods was particularly important in multi-ethnic or native/indigenous communities.

In eleven studies and across many different types of schools, support from stakeholders – including staff, volunteers and the wider community – was considered one of the most important factors influencing the success and sustainabilty of school gardens [13, 25, 41, 45–52].

*I bring in a variety of people throughout the year to help with various facets of our garden… Last week we had someone come in and show us how to prune our fruit trees and so they get all different kinds of role models… some people are perhaps more patient, some people are less patient… they realize that not all men are the same, not all women are the same, and they get to see people who are not teachers.* – Teacher.

This quote relates to gardening specialists, but support from volunteers (including parents, grandparents and other members of the community) and local organisations/businesses was also valued by teachers for similar reasons – increasing capacity, diversity of skills, materials and resources. However, some schools experienced difficulty recruiting enough volunteers [25, 46, 50].

*The four of us especially have all realized they need some support for this kitchen garden program, being that our funding runs out at the end of this year. So we ran this bloody fair and that was six months of my life and that’s what I gave up to ensure that my children still have this program in their school.* – Parent volunteer [43].
This is clearly an example of overdependence on volunteers, which became a source of resentment and threatened the sustainability of the garden. This suggests that schools need to consider the balance between making use of volunteers and keeping them motivated. The same applies to teachers (and other school staff) and two studies highlighted concerns about increased pressure on workloads and fitting school gardening into an already overcrowded timetable [25, 50]. One innovative way of motivating teachers was to offer continuing professional development (CPD) opportunities, benchmarks to work towards and cash prizes [50]. A study of the California Instructional School Garden Program found that when schools formed a garden committee (including administrators, teachers, parent/community volunteers and garden coordinators) it helped to define roles, share responsibilities and reduce the risk of overburdening any one person [46].

Finally, some schools experienced financial challenges, such as securing ongoing funding and resources for the school gardens [13, 25, 46, 50, 51]. Schools had found various solutions included fundraising events, donations from local businesses and grant applications [25].

There is a lot of sharing that goes on within the gardening community, and I think it’s important to reach out beyond the school gardens and contact people in community gardens and local gardening clubs. I have also contacted all of the retailers in this area – all the big box stores, the local nursery stores if they have damaged goods – if they have goods that are unsalable in any way, if they’re just old seeds, I’ll take them. – Member of staff [46].

This example demonstrates the importance of developing links with the wider community to increase the visibility and sustainability of the school garden.

**Discussion**

In this mixed methods review, we have systematically and transparently identified, selected, appraised and synthesised the best available evidence on the health and well-being impacts of school gardens. We have used the highest quality international evidence available, although much of this, particularly the quantitative evidence, was judged to be weak in our quality appraisal (Tables 5 and 6).

We found some quantitative evidence for nutritional impacts of school gardening, such as increased preference for, and consumption of, fruits and vegetables. However, many of the included studies relied upon self-reported outcomes, likely to be affected by social desirability bias, especially in children in school settings. It is notoriously difficult to measure food consumption accurately, with different measures having different challenges – the CADET tool, for example, has been found to overestimate fruit intake and underestimate vegetable intake [55]. It was not possible to conduct meta-analyses due to study design and data limitations. Measurement scales, or methods of applying the same measures, were too heterogeneous to allow outcomes to be pooled. In addition, interventions ranged in length from 10 weeks to 18 months.

We also found substantial qualitative evidence on a wide range of health and well-being impacts but these were rarely supported by the quantitative evidence, either because these outcomes were not measured, or because few studies identified significant impacts. It is not clear why these perceptions in the qualitative evidence synthesis are supported by few findings in the quantitative evidence base; whether this should be treated as evidence of no effect or whether, especially due to limitations in the quantitative study designs, it should be seen as no evidence of effect. It should also be noted that only three studies used mixed methods to evaluate impacts, and the quantitative and qualitative evidence comes largely from different school gardening interventions.

Our qualitative synthesis provides contextual information about which aspects of school gardening may be important, how health and well-being impacts may be related to educational impacts, and what factors are important for the success and sustainability of school gardening programmes. This qualitative evidence provides plausible suggestions for how school gardens could lead to health and well-being improvements which may help to influence better study design and the elements of school gardens that have the potential to be beneficial.

Based on the qualitative synthesis, we have developed a conceptual model (Fig. 3) to visually represent some of the possible mechanisms and pathways through which gardening could lead to health and well-being impacts. These are our interpretations of the evidence we have synthesised and, to some extent, the model has been left open to further interpretations, without the use of lines joining up specific pathways. It should be read from left to right to consider how the physical and social aspects of school gardening, coupled with factors influencing success and sustainability, might lead to health and well-being (and other) outcomes. The bottom arrow suggests a feedback loop mediated by feelings of enjoyment, engagement and motivation. This model builds on the ‘social-ecological conceptual model’ presented in a previous review, which depicted potential short-term (proximal) and long-term (distal) effects of school gardens and the interconnections between individual, family, school and community-level effects [3]. Our model also suggests the potential for broader intermediate and long term impacts, although we have focused on more
immediate, individual-level health and wellbeing effects as determined by our original review questions. Such long term effects are supported in the broader literature, particularly those suggested that understanding and appreciation of the natural world in childhood may lead to environmental responsibility in adulthood as well as support broader perceptions of wellbeing and quality of life [56, 57].

Although much of the evidence from individual qualitative studies is context specific, we have observed several cross-cutting themes that we believe to be transferable between studies. Firstly, school gardening can be integrated with the wider curriculum to maximise opportunities for learning: from nutrition education, to practical growing and food preparation skills, to core curriculum subjects taught in fun ways. To achieve this it is important for teachers to be involved in developing and delivering school gardening activities, with support from other stakeholders in the school and community. Secondly, school gardens appear to have particular benefits for children who have complex needs (behavioural, emotional, or educational) and do not thrive in an academic environment. The evidence suggests that these children may be able to express themselves better in the garden, leading to feelings of calmness, self-esteem and success. Gardening may therefore be described as physical, social and visceral; distinct and complementary to the individual and cerebral nature of classroom education. Thirdly, we noticed a two-way flow whereby the perceived benefits associated with school gardening meant that children were motivated to continue gardening and adults (teachers, parents and volunteers) were motivated to continue to support the school gardening programmes. This feedback loop contributes to the ongoing success and sustainability of school gardening programmes, as indicated in our conceptual model (Fig. 3).

**Strengths and limitations of the review**

By combining quantitative and qualitative synthesis methods, this review has highlighted the divergence between these research methods and the need for greater synergy. The qualitative research suggests that health and well-being impacts may be felt by those children who struggle in a classroom setting, but quantitative studies did not examine this subgroup. It is possible that

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**Fig. 3** Conceptual model showing the potential health and well-being impacts of school gardening

| Physical and social aspects of school gardening | Factors influencing success and sustainability | Intermediate to long term final outcomes |
|------------------------------------------------|---------------------------------------------|----------------------------------------|
| Growing and nurturing crops to produce food    | Connection with cultural heritage and local foods | Knowledge and awareness of where food comes from |
| Connection to nature and the environment       | Environmental awareness                      | Improved attitudes towards food e.g., willingness to try |
| Physical activity and working hard in the garden | Fundraising and resources                     | Healthier eating habits including more FV |
| Communication, cooperation, teamwork           | Supportive and inclusive environment          | Academic and behavioural improvements |
| Social interactions and meeting new people     | Building relationships and social networks    | Improved feelings of well-being         |
| Support from staff, volunteers, community      |                                            |                                        |

**Intermediate to long term final outcomes**

| Improved attitudes towards food e.g., willingness to try | Healthier eating habits including more FV | Academic and behavioural improvements |
|--------------------------------------------------------|---------------------------------------------|----------------------------------------|
| Feeling valued, belonging                              | Improved feelings of well-being             |                                        |
| Sense of purpose                                       |                                            |                                        |
| Social and cultural cohesion                           |                                            |                                        |

**Fig. 3** Conceptual model showing the potential health and well-being impacts of school gardening

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average population outcomes obscure impact among these children, or that the outcomes are less relevant to them. Although improvements in eating habits and physical activity were reported in the qualitative research, these were poorly supported by the quantitative studies. Again, it is unclear whether this is due to lack of effect, or deficiencies in the study designs. The qualitative research suggests holistic effects that may be difficult to quantify, as well as suggesting that impacts may be felt in the medium to long term, whereas included studies report only short term follow up.

Whilst the qualitative studies provided the greatest insights, we recognise that by combining multiple studies set in different contexts, some of the meaning and depth of findings from individual studies will have been lost. Whilst we added our own interpretations to those of the authors, we were limited by the original study designs and implicit biases. For example, the primary studies did not consider the perspectives of children who did not participate in school gardening and reasons for this.

School gardens can be seen as operating in line with the WHO Health Promoting School’s Framework which aims to take a holistic approach to health promotion in schools [58]. Our focus was health and well-being impacts and we did not include studies that focused only on educational impacts of school gardens. Future reviews could consider this broader remit which may be important for school policy makers.

We had hoped to comment on whether there were different impacts of school gardening interventions on health and wellbeing for different age groups. However, the majority of studies focus on younger children, in pre-school [21] or primary/elementary school [9, 15–17, 24–31, 33, 35, 37, 39] with only a small number of participants of middle school [22, 38] or junior high age [17] (Table 2). We therefore conclude that there is insufficient evidence to answer this question.

We restricted this review to OECD countries because developing countries have very different baseline health (and nutrition) characteristics and needs. Most of the evidence comes from the UK, Australia and the USA and it is unclear how transferable the findings are beyond these locations.

Implications and recommendations for future research
The quality appraisal of both quantitative and qualitative studies included in this review highlighted weaknesses in study design and reporting, despite using strict criteria to exclude the weakest study designs. We would recommend that future studies apply the quality criteria used in systematic reviews at the design stage to improve the robustness of the findings and facilitate meta-analysis. More convincing quantitative evidence is needed to promote school gardening programmes as public health interventions. Greater use of objective measures would provide more robust evidence and consistency in measures used across studies would allow meta-analysis in future reviews.

Our findings have some resonance with theories identified in a recent systematic review of how the school environment impacts on student health [59]. For example, the ‘theory of human functioning and school organisation’ suggests that the ways in which schools implement formal and informal modes of teaching, and develop relationships between staff and students, influence students’ commitment and engagement to learning [60]. The ‘social development model’ suggests that pro-social activities can increase students’ commitment to school [61]. Activities that support social and emotional learning have the potential to reduce stress and improve behaviour, both of which may ultimately improve school performance [62]. Although gardening was not one of the mainstream activities tested in the meta-analysis by Durlak et al., it has the potential to be. Considering in more detail how school gardens are anticipated to impact on the school experience, student health and well-being and school outcomes, including through the development of logic models or theories of change, garden programmes’ impact could be enhanced.

A set of theories in the broader literature suggest that school gardening may have longer term impacts than those addressed in the studies included in this review. Positive and repeated contact with elements of the natural world in childhood has been suggested to relate to pro-environmental behaviours and beliefs in adulthood [57]. Pro-environmental behaviours and ‘connectedness to nature’ have been found to be related to dimension of wellbeing [63]. Furthermore the type and frequency of childhood exposure to natural environments is thought to influence adult use of such spaces [64]. There is a growing body of evidence which has shown robust associations between use of natural environments (for leisure, physical activity and so on) and a range of positive health outcomes [65]. There is therefore interest in identifying ways in which children can be provided with regular and meaningful opportunities to experience the natural environment.

Future studies on school gardening could usefully make use of theory-led methods, such as realist synthesis or evaluation [66, 67], to develop evidence-based causal explanations of how and why school gardens work, for which groups of students, in which types of schools.

Conclusions
Despite their popularity, there is currently limited quantitative evidence that school gardens can have health and well-being benefits for students, and the evidence that does exist is based on self-reported outcome measures.
The qualitative evidence suggests that participants in school gardening programmes (including children and adults) may experience and perceive a range health and well-being impacts. Further high quality evidence is needed to facilitate subgroup analysis of health benefits and the extent of well-being benefits.

School gardens are complex interventions, yet few studies articulated a logic model to show how it was believed that school gardens might have an impact on health and wellbeing. More appropriate study design, and more consistency in the way food intake is measured, is required.

Competing interests
The authors declare that they have no competing interests.

Authors’ contributions
All authors contributed to the design of this review, critically revised the manuscript and approved the final versions. HO contributed to all stages of the systematic review (searching, screening, data extraction, quality appraisal and synthesis) and drafted the manuscript. SG and RW contributed to double searching, double data extraction, quality appraisal and synthesis. AB devised the search strategy, ran the literature searches and carried out citation searching. BL read and commented on the paper and situated findings in the broader literature. RG conceived the idea for the review and is the guarantor.

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