Table S1. Description of articles included in review.

Author	Location	Sample Size and Age	Program and Length	Study Aim and Outcome Variable (OV)	Outcome	Study Quality
Barata, et al. (2017). [18]	Portugal	11-15 years 418 participants	SOS Climate Change and Biodiversity in Botanic Gardens (3 events over 4 months)	To test the effectiveness of an environmental education intervention among adolescents, and the effectiveness of commitment procedures on energy and water saving at home, comparing public/collective and private commitment. **OV**: Increased energy and water conservation.	• Intervention group indicated more energy saving at home compared to controls. • Public commitment more likely to save water. • No difference in saving electricity, only feelings of guilt in experimental group.	***
Becker-Leifhold et al. (2019). [49]	Germany	13-16 years 10 participants (female)	Fashion Libraries (1 month)	To explore if students' attitudes would change over time in response to distinct interventions and project-based learning (towards sustainable fashion options). **OV**: Change in attitude towards sustainable fashion options	• Post intervention student increase in knowledge of social and environmental consequences resulting in buying less. • Knowledge on unethical garment processes led to critical and reflective thinking and informing peers.	***
Bekker, et al. (2017) [47]	Netherlands	17-28 years 386 participants	Cultured Meat experiment	To investigate the influence of information provision on the explicit and implicit attitude toward cultured meat **OV**: Attitude change towards cultured meat	• Explicit attitude towards cultured meat influenced by information on sustainability and information about positive perceived sustainable product • Providing participants with positive information about cultured meat or solar panels resulted in positive attitude change toward cultured meat	****
Birmingham, et al. (2014). [55]	USA	10-13 years Six participants	Green Carnival through GET city program	Capture educated actions by youth (female students of colour) from low socio-economic status working through complex socio-scientific issues. **OV**: To understand how the carnival acts as a space for educated action.	• Place-based and science expertise provided a tool for youth to take educated action for community. • Participants reported being able to talk about environmental and global warming issues candidly based on their place-based and core science education.	*****
Bissinger, et al. (2018). [19]	Germany	15 years 283 participants	3.5hr Botanical garden intervention to increase environmental literacy	Explore if intervention promoted knowledge acquisition, strengthened participant's Inclusion of Nature in One's Self concept, and assessed participants' attitudes and pro-environmental behaviour intentions **OV**: Increased Nature in One's Self, increased knowledge and intention.	• Increased knowledge post program (6 weeks), demonstrating hands on approach to be effective. Systems knowledge also increased initially but dropped. Action related knowledge increased. • Nature in self only significant short term. Perceived freedom to interact with nature increased their connectedness to nature. Increased in pro-environmental behaviour based on self-report.	***
Blyth, & Harre (2020) [45]	New Zealand	12-18 years 9 participants	Make a Difference (MAD) – 3 day residential camp named hui	Evaluation study aimed to offer insight into MAD and the value of its configuration for encouraging transformative learning and action competence. **OV**: Developmental (knowledge, attitudes and values) action-related (roles and activities)	• Results suggested MAD enables high levels of engagement with new ideas and people, equips participants with tools for sustainability leadership and a supportive community. Encourages intentional action (core of action competence). Students reported joining environmental groups, initiating projects and taking leadership roles.	**
Brigham & Imbertson (2020). [29]	USA	76 17-25 years*	The University of Minnesota Grand	Demonstrate an approach to educating for systemic change facilitated by experiential and art-based forms of learning.	• Students reported increased knowledge of energy grid, increase in	**

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			Challenge Curriculum (GCC) – university semester course		systems thinking and increased need to spread knowledge to others.	
Ceaser (2012). [56]	USA	16-21 50-100 participants approx..	Our School at Blair Grocery – Urban Farming School (average stay few weeks)	Examines critical urban farming school in New Orleans' Lower Ninth Ward for how student action is addressed. **OV**: Environmental student action	• Students reported feeling empowered and determined to make the world a better place, both ecologically and socially • increased pro-environmental behaviour.	****
Cheng, et al. (2021) [30]	Malaysia	16-23 years 100 participants 29 interviewed (FGDs)	Edcraft Gamified Learning (EGL) - 2 day activity	To understand how effective online gamified recycling game is on youth's intention and factors of research framework **OV**: Recycling intention	• Recycling intention did not increase.	**
Cornelius, et al. (2014). [44]	USA	15-16 years 134 participants	5 classroom lessons (50 min) on energy saving intervention	Increasing GHG energy saving and behaviour relating to other sub-categories of energy saving using theory-based, school-based intervention. **OV**: Increased GHG saving behaviour.	• Compared to control group, students in intervention group significantly improved energy saving behaviour. • Significant increase in self efficacy and knowledge towards switching off appliances, consumption, and driving.	***
Dann & Schroeder (2015). [46]	USA	13-15 years 700 participants	Michigan 4-H Great Lakes and Natural Resources Camp Nonformal Science (one week)	To understand the impact of camps as contexts for informal learning. **OV**: Nonformal learning as a mechanism for environmental stewardship.	• Camp had positive impact on Great Lakes literacy, place attachment and stewardship intentions. Significant increase, post camp, in their capacity to influence issues by acting with others. • Knowledge and confidence also significantly increased.	****
de Vreede, et al. (2014) [50]	Canada	15-16 years 23 participants	Mindshift club, youth led peer education program	Investigates whether a peer education approach can facilitate youth taking sustainability actions. **OV**: Peer education influencing sustainability action	• Peer leaders reported significant. Personal growth and learning. • Every leader reported an average of 5 different pro-environmental behaviour changes. • Sense of empowerment, skill development and interpersonal relationships significantly increased	****
Ernst, et al. (2017). [20]	USA	13-18 98 participants	Student Climate and Conservation Congress (SC3) (1 week)	To explore the role of environmental attitudes, locus of control, sense of personal responsibility and behavioural intention on environmental action and intention towards future involvement in environmental action in student environmental leaders. **OV**: Environmental action and leaders.	• Pre-program levels of environmental attitudes was the only significant predictor of environmental action • Program did not have significant effect on those who did not have an already positive attitude towards the environment. Intention to act pro-environmentally in the future 8 months post was not sig.	****
Flora, et al. (2014). [21]	USA	12-18 years 1241 participants	Alliance for Climate Education (ACE) (1 x interactive assembly)	Understand influence of 1-h ACE program on attendees' climate knowledge, attitudes, and behavioural intentions, and whether this influence varied by Six Americas audience segment. **OV**: Increased climate knowledge, attitudes, and behavioural intentions.	• Increased level of knowledge and discussion with parents and friends post assembly. • Increased home pro-environmental behaviour. • Those who were considered disengaged, doubtful, or dismissive did not improve. • Increase self-efficacy for talking about CC or starting project.	*****

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Gallay, et al. (2022) [61]	USA	12-18 years 486 participants	Southeast Michigan Stewardship Coalition (SEMIS) project - one semester or school year	Explore student's learning and dispositions associated with participation in civic science projects in marginalised communities **OV**: Increased participation in civic projects	• Increased awareness of negative human impacts on environment, increased agency and efficacy, learning and leadership, systems thinking and discussions with family through collective action	*****
Griffin, et al. (2016). [31]	USA	98 participants Those who were adolescent between 1995-2014	Texas Chapter of The Wildlife Society's Wildlife Conservation Camp (WCC) (one week)	Identify long-term effects of the WCC on past participants as they transition into adulthood and begin their careers. **OV**: Increased wildlife and conservation efforts later in life	• Survey reported 2/3 of respondents were in conservation related career, with majority reporting WCC influenced career choice. • 75% participants reported increase in eco and land use knowledge post WCC. • 85% continued to participate in camp activities with family and friends.	****
Hehir, et al. (2020) [32]	Canada	14-30 years 217	Students On Ice – 2-3 week polar expedition to Antarctic and the Arctic for adolescents	Explore impact of youth polar expeditions on participants' pro-environmental behaviour, up to 18 years after their polar voyage. **OV**: Increased pro-environmental behaviour due to increased social identity, inclusion of nature in self	• Results found increased levels of confidence and speaking up, increased PEB (flying, diet, transportation), volunteering and public speaking • Inclusion of nature in self and social identity increased PEB, increased social identity increased nature in self	***
Hooi Ting, & Chin Cheng (2017). [43]	Malaysia	20-22 years 100 participants	Eco-Tourism educational study trip within university	Aims to examine the pro-environmental behaviour (PEB) outcome and change through student participation and guided learning in an ecotourism-education-based study setting. **OV**: Increased PEB measure post trip.	• Significant increase from weak PEB to stronger intention towards PEB post study trip due to increased scores of feeling responsibility towards the environment.	*****
Kuthe, et al. (2020). [33]	Austria & Germany	13-16 years 392 participants	k.i.d.Z.21-Austria: Education project in school	Project aimed at raising climate change literacy among teenagers. Study aimed at identifying weaknesses in adolescent climate change awareness. **OV**: Increased climate change literacy and identifying weaknesses.	• Increase in climate change knowledge except for those in disengaged group. • The teenagers belonging to the charitable group had a low level of personal concern. • The concerned activists had higher scores than the other teenagers.	**
Leitão, et al. (2022) [51]	Portugal & USA	11-14 years 98 participants	Ocean Literacy mobile app recycling game	Examine relationship between learning outcomes and game elements (points, badges, leader board) **OV**: Increased learning based on game elements	• PBL triad increased learning outcomes by 30% compared to control group (points, badges, leader board). Portuguese students performed better in knowledge element than UK.	****
Liao & Li (2019). [64]	China	12-19 years 562 participants	MSW Community Campaign (since 2000)	Study aimed to understand Chinese high school students' intention toward the separation of solid waste on campus (SSWC) **OV**: Reduced waste on campus	• environmental knowledge and education strongest indicators of attitude and intention towards solid waste reduction	***
Lim, et al. (2021) [40]	USA	18-26 years 159 participants	Text-message intervention to encourage plant based diet - 8 weeks (2-3	Identify effect of 8 week intervention on diet predictors, intentions, and intake in addition to exploring roles of values on intention and behaviour	• Decrease in intention of consuming animal-based protein and intention to consume fruit and vegetables sig.	*****

Author	Location	Sample Size and Age	Program and Length	Study Aim and Outcome Variable (OV)	Outcome	Study Quality
			texts a week) based on meal times	**OV**: Increased intention or behaviour to consuming plant-based food	• Increase in intention for plant-based proteins not sig. • Actual intake only increased for eggs	
Lindemann-Matthies et al. (2021) [41]	Germany	14-19 years 9 interviewed	Collective public commitment project: Weekly workshops over 5 weeks to establish goals (18 youth involved)	Investigate participation in teenagers in collective public commitment and workshop will strengthen ability and willingness to take action **OV**: Behaviour change on pro-environmental behaviour 3 years later	• Youth maintained pro-environmental behaviour and attitudes 3 year post workshops and commitment. Most participants had become ambassadors for sustainable lifestyles within their social environment	****
Mackay, et al. (2020). [34]	Canada	15-16 years 14 participants	Indigenous Youth at COP24 – an extension of Youth Knowledge Fair	To understand if participation in climate change action activities lead to the development of youth leadership skills. **OV**: Leadership skills	• Expanding social networks, combined learning opportunities, and leadership skills were developed	****
Marques, et al. (2020). [25]	Portugal	12-15 years 361 participants	The WaterCircle Project – 3 workshops.	Include students in the process of identification and discussion of environmental problems and solutions, foster students' role as active agents in their local community. **OV**: Increased environmental awareness	• Students were able to identify and show concern for environmental problems in the community and identify solutions. • No sig. statistical difference between environmental concern between control and experimental group. • Environmental self-efficacy improved significantly in exp. Group. Reported increase in agency, self-awareness and systems thinking.	***
Molderez (2021). [62]	Belgium	17-25 years* 22 University students	Student Swap Stuff Project (one university semester)	Analysing how transformative learning nurtures ecological thinking via project **OV**: Increased ecological thinking	• Project was helpful in allowing students to rethink the traditional economic system and understanding their own levels of consumption	*****
Ngo, et al. (2020) [22]	Vietnam	13-15 years 348 Participants	Addressing psychological distance on climate change risk with message framing (One day experiment)	To investigate how perceptions of climate change risk and efficacy affects behavioural change. **OV**: To predict behaviour change: perceived responsibility and mitigation intention	• Concrete and action-oriented or abstract and information oriented messages led to: Changing adolescents' perceptions on climate change severity and susceptibility; and higher sense of self-response efficacy, increased willingness perform climate change mitigation behaviours. • Higher perception of risk (severity, susceptibility) and efficacy (self- and response efficacy) led to: Higher levels of assumed responsibility and behavioural intentions towards climate change mitigation	*****
Oe, et al. (2022) [57]	Japan	Undergraduate students 46 participants	University student-led projects that aim to raise environmental awareness in local communities	Understand potential prospects for community-based learning opportunities for environmental awareness and healthy behaviour change **OV**: Influence communities' environmental conscious attitudes and behaviour"	• Social education facilities, fostering ESD, can be a catalyst for participants' learning outcomes and a foundation for enviro friendly behaviour change and healthy citizenship in a social education facility rather than school facilities. A combination of knowledge acquisition and emotional drive fosters climate friendly behaviour	*****
Ouariachi, et al. (2018). [35]	Netherlands	21-33 years 15 participants	We Energy Game – Interactive web game	Analyse communicational and educational aspects of game.	• Students reported being more aware of challenges of affordable renewable energy.	***

Author	Location	Sample Size and Age	Program and Length	Study Aim and Outcome Variable (OV)	Outcome	Study Quality
			(1hr 40 min session)	**OV**: Willingness to change own energy saving behaviours.	• Prefer the game as a pedagogical method to learn about sustainability and energy transition compared to a traditional classroom. • Game does not have an effect on willingness to change attitudes and behaviours in energy saving	
Pickering, et al. (2021) [65]	Canada	13-28 years n/a	EnRiCH Youth Research Team - youth led community based DRR program - monthly 1.5 hour meetings after school hours	Understanding elements of the EnRICH Youth Research Team **OV**: Outline implementation and outcomes to date of program	• Youth experienced improved knowledge of risks, enhanced adaptive capacity, increased sense of social worth by being given opportunities lead knowledge dissemination projects, educate community and connect with academics and PH practitioners. Program created modules, knowledge activities, children's book, youth participation video	****
Riemer, et al. (2016). [66]	Uganda, Germany, Canada, United States, Bangladesh, India	16-26 years 365 participants	Youth Leading Environmental Change Project (6 months)	Describes the results of a longitudinal mixed-method study investigating the short-term and intermediate impacts of YLEC on university students in six countries. **OV**: Increased environmental action.	• Action-orientated, informal and participatory workshop effective for critical thinking, fostering empowerment and collective efficacy. • Exp. Group initial behaviour change (environmental action), returned to baseline at 12 months.	****
Rudd, et al. (2020) [58]	United Kingdom	9-18 years 180 participants	You and Co2 program (3 workshops) – pilot study	program designed to encourage students to reflect on their personal impact on the environment, while also appreciating their place within society to bring positive social change. **OV**: Develop critical thinking concerning CC through arts-based approach	• Program associated with small but significant attitude change towards reducing carbon footprint • Films produced by students highlighted low carbon modes of travel, plastic waste and pollution and food choices.	**
Ruppert-Stroescu, et al. (2015). [60]	USA	17-30 years 97 participants	Fashion Detox – 10 week blogging study within university semester	Examine the experiences of individuals who are more aware of the fashion apparel industry and likely to be actively engaged in the apparel consumption process. **OV**: Creativity associated with "detoxing".	• Changes in attitudes and behaviour toward fashion apparel prompted expressions of creativity (style change, altering garment, borrowing) to fill the void of buying.	*****
Sayal, et al. (2016). [36]	Bangladesh, Canada, India	18-22	Youth Leading Environmental Change Project.	Examine the impact of systems thinking on youth environmental engagement.	• Systems thinking assisted in motivating participants cognitively and emotionally and promoted understanding the complex issue of environmental solutions. Systems thinking increased motivating engagement towards environmental action.	*****
Selby, et al. (2020) [52]	Costa Rica	15-19 years 22 participants	Stanford Environmental Leadership and Language program (SELAL) (2 week intensive program)	Investigate how pedagogically-positioned social relationships mediate students' knowledge, perceptions, and leadership **OV**: Changes in ecological and ecotourism knowledge, perception of social relationships, perception as leaders or mentors	• EE is effective when incorporating social and ecological elements, and social nature of learning. • Students as environmental leaders tied to social relationships	****
Senbel, et al. (2014). [27]	USA	17-25*	My Everyday Earth (MEE) – competition	To gauge the short- and medium-term energy consumption outcomes of the energy reduction competition.	• Individuals' energy conserving actions more influenced by their peers and context of conservation than own	****

Author	Location	Sample Size and Age	Program and Length	Study Aim and Outcome Variable (OV)	Outcome	Study Quality
			tracked via social media and app – 6 months	**OV**: Reduced energy consumption	awareness of the impact of their actions. • Energy conservation efforts reported by majority one year post competition.	
Spangenberger, et al. (2020). [23]	Germany	12-14 years 82 participants	Serena Supergreen and Broken Blade interactive game for renewable energy (addresses SDG 5 and 7)	Introduce the game Serena Supergreen and the Broken Blade as an interactive game based on building knowledge on renewable energy at a secondary school. **OV**: Increased knowledge on renewable energy.	• Knowledge acquisition tests showed majority of students remembered quests in game 11 months post intervention. • Positive experience enabled longer memory retention.	***
Stapleton (2015). [59]	USA	15-17 years 13 participants	NGO 4-week overseas trip (South East Asia), plus home country projects	Explore how practice, action, and recognition can facilitate environmental identity development. **OV**: Development of environmental identity	• Student reports acceptation into trip led to increased pro-environmental behaviour. • Autonomous environmental projects increased environmental identity.	***
Stevenson, et al. (2018) [28]	USA	11-15 years 1043 participants	Developing a model of climate change behaviour among adolescents program	To understand if increased climate change knowledge led to increased climate change concern and hope **OV**: Increased climate change concern and hope	• Study found to be non-significant in behaviour change and concern or fostering hope. Knowledge did significantly increase.	****
Tayne, et al. (2020). [53]	USA	14-18 years 43 participants	Lens on Climate Change (LOCC) – (one week)	Explores how students, mentors, and their co-produced films framed climate change action, assessing how discourse on action across scales was connected to hope, agency, justice, and neoliberalism. **OV**: How climate change action is framed.	• Individual behaviour change appeared to provide an accessible tool for youth to envision tackling climate change issues. • Students see action as a collective.	****
Townrow, et al. (2016) [37]	New Zealand	13-14 years 275 student surveys, 14 interviews staff and students	The Maui's Dolphin Challenge (3 weeks)	Study aimed to understand how intervention would reduce litter in schools by students. **OV**: Reduce school litter	• Challenge reduced amount of litter at school by 50%. • The dolphin enabled a moral dimension to litter reduction. • Peer norms had both negative and positive impact.	***
Trujillo, et al. (2021) [48]	Colombia	130 undergraduate students	Norm and norm-related emotions experiment on pro-environmental behaviour	Using "choice architecture techniques" to make personal or social norms salient on short term behaviour based on emotions and nudging **OV**: Short-term pro-environmental behaviour on actual or willingness to purchase enviro-friendly notebook	• Activation of personal norms was more effective than social norms salient in the purchasing of notebook where correct behaviour was pointed out and product assortment. • Guilt and pride most sig linked to choice	****
Vantamay (2019). [24]	Thailand	18-22 years 80 participants	The 3s project: saving, selecting and sharing – pilot intervention.	Evaluate a community based social marketing (CBSM)campaign for promoting sustainable consumption behaviour (SCB) amongst Thai youth ("3S Project"). **OV**: Increased perceived behavioural control, changes in subjective norms and changes in attitude (short term).	• Increase overall attitude towards SCB compared to control. • Influenced by subjective norm(friends), the perceived behavioural control, the intention to perform SCB.	***
Walsh & Cordero (2019). [54]	USA	11-14 years 835 participants	The Green Ninja Film Academy	Development project examining efficacy of combining climate science concepts and practices with digital storytelling for middle school youth.	• Increased scores on science content and practices.	*****

Author	Location	Sample Size and Age	Program and Length	Study Aim and Outcome Variable (OV)	Outcome	Study Quality
			(GENIE) (4-8 weeks)	**OV**: Increased identity and agency, science and knowledge practice.	• Students reported feeling more able to take action in their personal lives and their community.	
Whitehair, et al. (2013). [42]	USA	17-25 years 540 participants	Written Messages to improve edible waste (4 weeks)	Assess whether two forms of printed message materials influenced food waste beliefs and behaviours in college students participating in an on-campus meal plan. **OV**: Reduced edible waste in cafeteria.	• Students had high levels of belief, but insignificant conviction toward environmental sustainability or food waste. • No difference between neutral and personal message. • Overall 15% reduction in waste.	****
Williams & Chawla (2016). [38]	USA	10 -18 years approx.. 18 participants	Thorne Nature Experience, Wild Bear Mountain Ecology Centre, and the CUSD	Explores experiences that remained salient in the memories of former participants in three nature-based programs in Colorado, five to forty years after childhood involvement. **OV**: social and environmental identity.	• Hands-on learning increased awareness. • Giving responsibility to campers gave them to opportunity to look out for "well-being" of natural environment. • 83% influenced their environmental identity. • 50% influenced their career or academic choice.	*****
Young, et al. (2020). [39]	USA	16-18 15 participants (female)	Girls on Ice program: 8 days on a mountaineering expedition in a wilderness setting dominated by glaciers	Understand how program influenced young women to construct their post-program worlds in terms of pro-environmental behaviour. **OV**: systems thinking influence PEB	• Findings found sense of relatedness to nature builds when there is increased knowledge on ecosystem linkages, and • witnessing the scale of glacier loss made climate change increasing pro-environmental behaviour. • One year post program almost all participants reported in undertaking pro-environmental behaviours.	*****
Zhang & Gibson (2021) [63]	USA	20-33 years 31 participants	Field-based study abroad programs in Australia, New Zealand and Fiji (10 days - 4 weeks) by university	Examine potential to educate on sustainability through study abroad programs **OV**: sustainability related attitudes and behaviour years after program	• Students report "sustainability mind frame" years after participation. • Increase in everyday pro-environmental behaviour and sustainability focussed careers. • Increased interest in local cultures and communities.	*****

Note: Where an * occurs next to participants' ages it is indicating the authors did not explicitly state an age, but rather a grade level.